CHAMBERS'S

INFORMATION FOR THE PEOPLE.

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EDITED BY

WILLIAM AND ROBERT CHAMBERS

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PREFACE.

Six years have now elapsed since the completion of 'THE INFORMATION FOR THE PEOPLE' in its second and improved form. Owing to the rapid advance of almost every branch of science and art, this is a long period in the history of a work of the nature of an encyclopædia. It has therefore appeared proper that these volumes should be recast, so as to adapt them as nearly as possible to the present state of human knowledge.

Designed in an especial manner for the People, though adapted for all classes, the work will be found to comprise those subjects on which information is of the most importance; such as the more interesting branches of science—physical, mathematical, and moral; natural history, political history, geography, and literature; together with a few miscellaneous papers, which seemed to be called for by peculiar circumstances affecting the British people. Thus everything is given that is requisite for a *generally well-informed man* in the less highly-educated portions of society, and nothing omitted appertaining to intellectual cultivation, excepting subjects of professional or local interest. It will be understood, then, that the 'INFORMATION FOR THE PEOPLE' is not an encyclopædia in the comprehensive meaning of the word, but rather one embracing only the more important departments of general knowledge. The ruling object, indeed, has been to afford the means of *self-education*, and to introduce into the mind, thus liberated and expanded, a craving after still farther advancement.

The improvements of the present edition will be found very considerable. All the scientific treatises have been carefully remodelled, with due attention to recent discoveries. Subjects, the interest of which is past, have been omitted or greatly condensed, and others of a more enduring and important nature have taken their place. So much new information has been introduced, that the work is more encyclopædic than it has hitherto been. In the Index to each volume will be found an explanation of, or reference to, almost every subject necessary in ordinary circumstances to be known.

It is proper to mention that, in the preparation of this edition, great assistance has been rendered throughout by Mr DAVID PAGE, to whose varied talents we have on other occasions been in no small degree indebted.

W. AND R. C.

Edinburgh, November 1, 1848.

CONTENTS.

INFORMATION FOR THE PEOPLE.

ASTRONOMY.

Astronomy (from the Greek, *astron*, a star, and *nomos*, a law) is, comprehensively, that science which explains the nature and motions of the bodies filling infinite space, including our own globe in its character of a planet or member of the solar system. The science may be divided into two departments—1. *Descriptive Astronomy*, or an account of the systems of bodies occupying space; 2. *Mechanical Astronomy*, or an explanation of the physical laws which seem to have produced, and which sustain, the arrangements of the heavenly bodies, and of all the various results of the arrangement and relations of these bodies. *Uranography* is a subordinate department of the science, presenting an account of the methods which have been adopted by astronomers for delineating the starry heavens, and working the many mathematical problems of which they are the subject.

I. DESCRIPTIVE ASTRONOMY.

The early ideas of mankind respecting the objects described by astronomy, proceeded upon appearances which the uninstructed eye placed before them, and were far from being true. It was supposed that the earth was, as it seems, a fixed plain, or, at the most, a fixed sphere, with an outer sphere, forming the heavens, revolving around it once in the twenty-four hours. Even philosophers deemed the earth the central and most important object in the system, and regarded the heavenly bodies—the sun, moon, planets, and stars—as comparatively small objects, fixed in different crystal spheres, each of which observed its own laws of revolution, according to the apparent motions of the bodies fixed in it. It was not till after much study and investigation that even the most enlightened minds arrived at a knowledge of the truth; nor was it for some time longer that the idea of the earth not being in the centre of the system, or anything but a small and subordinate part of it, was generally admitted. There is no room here to trace all the steps by which the truth was ascertained, or to argue the uninstructed mind out of all its first and erroneous impressions. But it may be hoped that when the actual constitution of the heavens has been described, it will be possible to form some notion how the celestial objects in their real character and real arrangements happen to appear as they do to our eyes.

The field contemplated by the astronomer is no less than infinite space. So, at least, he may well presume space to be, seeing that every fresh power which he adds to his telescope allows him to penetrate into remoter regions of it, and still there is no end. In this space, systems, consisting of suns and revolving planets, and other systems again, consisting of a numberless series of such lesser systems, are suspended by the influence of gravitation, operating from one to another, yet each body at such a distance from another, as, though the mind of man can in some instances measure, it can in none conceive. We begin with what is usually called the Solar System—that is, the particular solar system to which our earth belongs, and of which the *Sun* is the centre.

THE SOLAR SYSTEM.

The solar system, so named from *sol* (Latin), the sun, consists of the sun in the centre, upwards of thirty ascertained planets, and an unknown number of bodies named comets. We say *ascertained* planets, because, from the recent discoveries of Leverrier and others, there seems a likelihood that we shall yet discover more bodies of this nature. The word planet is from the Greek, *planao*, I wander, because the few such bodies known to the ancients were chiefly remarkable in their eyes on account of their constantly shifting their places with reference to the other luminaries of the sky. Comets are so named from *coma* (Latin), a head of hair, because they consist of a long brush of luminous matter streaming from a point.

Planets.—Of the planets, there are eight which may be said to rank in the first class, in as far as they move in orbits considerably removed from each other, and are in this respect comparatively independent; while a group of small bodies, at least five in number, may be said to have but one orbitual part in the series, and thus to be only co-ordinate with one of the rest. These thirteen are called *primary* planets, to distinguish them from others which move round certain of the primaries, and which are called *secondaries*, or satellites, from *satelles* (Latin), originally signifying a life-guardsman, but, by a wider application, one who follows and serves another.

The primary planets are—Mercury, Venus, the Earth, Mars, Vesta, Ceres, Pallas, Juno, Astræa, Jupiter, Saturn, Uranus, and Neptune. Most of these names are derived from the fabulous divinities of ancient Greece. The Earth has one satellite, the Moon; Jupiter has four; Saturn, seven; Uranus is supposed to have six; and Neptune has one.

The planets move round the sun on nearly one level or plane, corresponding with the centre of his body, and in one direction, from west to east. The secondary planets, in like manner, move in planes round the centres of their primaries, and in the same direction, from west to east. These are denominated revolutionary motions; and it is to be observed that they are double in the case of the satellites, which have at once a revolution round the primary, and a revolution, in company with the primary, round the sun. The path described by a planet in its revolution is called its *orbit*. Besides this motion of revolution, each planet, secondary as well as primary, and the sun also, has a motion in its own body, like that of a bobbin upon a spindle. An imaginary line, forming, as it were, the spindle of the sun or planet, is denominated the *axis*; and the two extremities of the axis are called the *poles*. The axes of the sun and planets are all nearly at a right angle with the plane of the revolutionary movements. The motion on the axis is called the rotatory motion, from *rota*, the Latin for a wheel. The sun, the primary planets, and the satellites, with the doubtful exception of those attending on Uranus, and overlooking that of Neptune, as yet unascertained, move on their axes in the same direction as the revolutionary movements, from west to east.

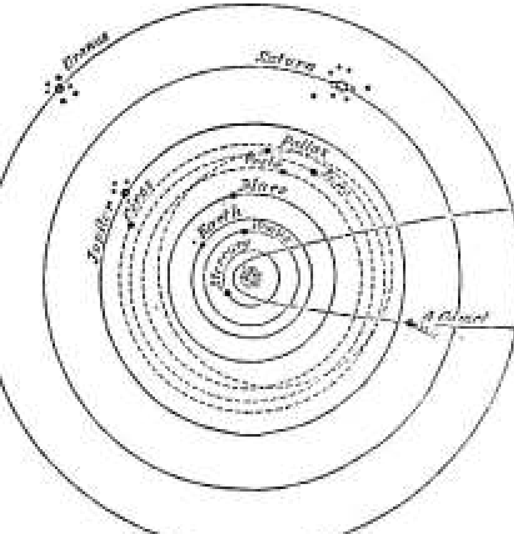
The Sun is a sphere or globe, of 882,000 miles in diameter, or 1,384,472 times the bulk of the earth, moving round its axis in 25 days. When viewed through a telescope, the surface appears intensely bright and luminous, as if giving out both heat and light to the surrounding planets. But on this surface there occasionally appear dark spots, generally surrounded with a border of less dark appearance; some of which spots have been calculated to be no less than 45,000 miles in breadth, or nearly twice as much as the circumference of the earth. The region of the sun's body on which the spots appear, is confined to a broad space engirdling his centre. They are sometimes observed to come into sight at his western limb, to pass across his body in the course of twelve or thirteen days, and then disappear. At other times they are observed to contract with great rapidity, and disappear like something melted and absorbed into a boiling fluid. Upon the bright parts of the sun's body there are also sometimes observed streaks of unusual brightness, as if produced by the ridges of an agitated and luminous fluid. It has been surmised that the sun is a dark body, enveloped in an atmosphere adapted for giving out heat and light, and that the spots are produced by slight breaks or openings in that atmosphere, showing the dark mass within. Though so much larger than the earth, the matter of the sun is of only about a fourth of the density or compactness of that of our planet, or little more than the density of water.

Diameters of Planets in English Miles.

The Sun,	882,000
Mercury,	3,140
Venus,	7,800
Earth,	7,912
Mars,	4,189
The Asteroids,	*
Jupiter,	89,170
Saturn,	79,042
Uranus,	35,112
Neptune,	36,000

Densities of Planets, that of the Earth being considered as 1.

The Sun,	0·25
Mercury,	2·93
Venus,	0·92
Earth,	1·
Mars,	0·73
The Asteroids,	*
Jupiter,	0·23
Saturn,	0·11
Uranus,	0·25
Neptune,	—



The Solar System, to the orbit of Uranus.

Distances of Planets from the Sun.

Mercury,	37,000,000
Venus,	68,000,000
Earth,	95,000,000
Mars,	144,000,000
The Asteroids,	*
Jupiter,	490,000,000
Saturn,	900,000,000
Uranus,	1,821,000,000
Neptune,	2,850,000,000

Periods of Revolution round the Sun.

Mercury,	88 days.
Venus,	225 ...
Earth,	365¼ ...
Mars,	687 ...
The Asteroids,	* ...
Jupiter,	4,332½ ...
Saturn,	10,746½ ...
Uranus,	30,686 ...
Neptune,	60,126 ...

The sun is surrounded to a great distance by a faint light, or luminous matter of extreme thinness, shaped like a lens or magnifying-glass, the body of the sun being in the centre, and the luminous matter extending in the plane of the planetary revolutions, till it terminates in a point. At particular seasons, and in favourable states of the atmosphere, it may be observed, before sunrise or after sunset, in the form of a cone pointing obliquely above the place where the sun is either about to appear, or which he has just left. It is termed the *Zodiacal Light*.

Mercury, the nearest planet to the sun, is a globe of about 3140 miles in diameter, rotating on its axis in 24 hours and 5½ minutes, and revolving round the central luminary, at a distance of 37,000,000 of miles, in 88 days. From the earth it can only be seen occasionally in the morning or evening, as it never rises before, or sets after the sun, at a greater distance of time than 1 hour and 50 minutes. It appears to the naked eye as a small and brilliant star, but when observed through a telescope, is horned like the moon, because we only see a part of the surface which the sun is illuminating. Mountains of great height have been observed on the surface of this planet, particularly in its lower or southern hemisphere. One has been calculated at 10¾ miles in height, being about eight times higher, in proportion to the bulk of the planet, than the loftiest mountains upon the earth. The matter of Mercury is of much greater density than that of the earth, equalling lead in weight.

Venus is a globe of about 7000 miles in diameter, or nearly the size of the earth, rotating on its axis in 23 hours 21 minutes and 19 seconds, and revolving round the sun, at the distance of 68,000,000 of miles, in 225 days. Like Mercury, it is visible to an observer on the earth only in the morning and evening, but for a greater space of time before sunrise and after sunset. It appears to us the most brilliant and beautiful of all the planetary and stellar bodies, occasionally giving so much light, as to produce a sensible shadow. Observed through a telescope, it appears horned, on account of our seeing only a part of its luminous surface. The illuminated part of Venus occasionally presents slight spots. It has been ascertained that its surface is very unequal, the greatest mountains being in the southern hemisphere, as in the case of both Mercury and the earth. The higher mountains in Venus have been estimated by some to range between 10 and 22 miles in altitude. The planet is also enveloped in an atmosphere like that of the earth; hence the probability that its surface supports a kindred vegetable and animal existence. Mercury and Venus have been termed the Inferior Planets, as being placed within the orbit of the earth.

The *Earth*, the third planet in order, and one of the smaller size, though not the smallest, is important to us, as the theatre on which our race have been placed to "live, move, and have their being." It is 7912 miles in mean diameter, rotating on its axis in 24 hours, at a mean distance of 95,000,000 of miles from the sun, round which it revolves in 365 days 5 hours 48 minutes and 49 seconds. As viewed from another of the planets, suppose the moon, "the earth would present a pretty, variegated, and sometimes a mottled appearance. The distinction between its seas, oceans, continents, and islands would be clearly marked; they would appear like brighter and darker spots upon its disk. The continents would appear bright, and the ocean of a darker hue, because water absorbs the greater part of the solar light that falls upon it. The level plains (excepting, perhaps, such regions as the Arabian deserts of sand) would appear of a somewhat darker colour than the more elevated and mountainous regions, as we find to be the case on the surface of the moon. The islands would appear like small bright specks on the darker surface of the ocean; and the lakes and mediterranean seas like darker spots or broad streaks intersecting the bright parts, or the land. By its revolution round its axis, successive portions of the surface would be brought into view, and present a different aspect from the parts which preceded."—*Dick's Celestial Scenery*, p. 135.

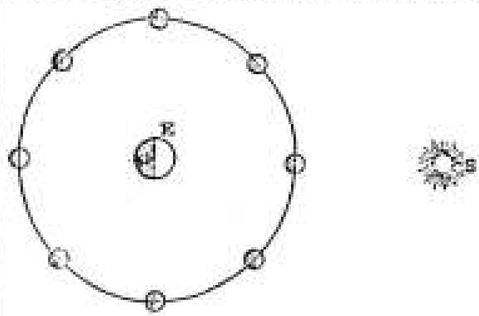
The form of the earth, and probably that of every other planet, is not strictly spherical, but oblately spheroidal; that is, flattened a little at the poles, or extremities of the axis. The diameter of the earth at the axis is 26 miles less than in the cross direction. This peculiarity of the form is a consequence of the rotatory motion, as will be afterwards explained.

The earth is attended by one satellite, the *Moon*, which is a globe of 2160 miles in diameter, and consequently about a 49th part of the bulk of the earth, revolving round its primary in 27 days 7 hours 43 minutes and 11 seconds, at the distance of 237,000 miles. The moon is 400 times nearer the earth than

Telescopic appearance of the Moon.

the sun is; but its diameter being at the same time 400 times less than that of the sun, it appears to us of about the same size. The moon rotates on her axis in exactly the same time as she revolves round the earth. She consequently presents at all times the same part of her surface towards the earth. Inspected through a telescope, her surface appears of unequal brightness, and extremely rugged. The dark parts, however, are not seas, as has been supposed, but more like the beds of seas, or great alluvial plains. No appearance of water, or of clouds, or of an atmosphere, has been detected. The surface presents numerous mountains, some of them about a mile and three-quarters in height, as has been ascertained by measurement of the shadows which they cast on the neighbouring surface. The tops of the mountains of the moon are generally shaped like a cup or basin, with a small eminence rising from the centre, like many volcanic hills on the earth. It has hence been surmised that the moon is in a *volcanic state*, as the earth appears to have been for many ages before the creation of man, and that it is perhaps undergoing processes calculated to make it a fit scene for animal and vegetable existence.

The moon, turning on its axis once in a little more than 27 days, presents every part of its surface in succession to the sun in that time, as the earth does in 24 hours. The *day* of the moon is consequently nearly a fortnight long, and its *night* of the same duration. The light of the sun, falling upon the moon, is partly absorbed into its body; but a small portion is reflected or thrown back, and becomes what we call *moonlight*. The illuminated part, from which we derive moonlight, is at all times increasing or diminishing to our eyes, as the moon proceeds in her revolution round our globe. When the satellite is at the greatest distance from the



Phases of the Moon.

sun, we, being between the two, see the whole of the illuminated surface, which we accordingly term *full moon*. As the moon advances in her course, the luminous side is gradually averted from us, and the moon is said to wane. At length, when the satellite has got between the earth and the sun, the luminous side is entirely lost sight of. The moon is then said to *change*. Proceeding in her revolution, she soon turns a bright edge towards us, which we call the *new moon*. This gradually increases in breadth, till a moiety of the circle is quite filled up; it is then said to be *half moon*. The luminary, when on the increase from *new* to *half*, is termed a crescent, from *crescens*, Latin for increasing; and this word has been applied to other objects of the same shape—for instance, to a curved line of buildings.

In the early days of the new moon, we usually see the dark part of the body faintly illuminated, an appearance termed the *old moon in the new moon's arms*. This faint illumination is produced by the reflection of the sun's light from the earth, or what the inhabitants of the moon, if there were any, might be supposed to consider as moonlight. The earth, which occupies one invariable place in the sky of the moon, with a surface thirteen times larger than the apparent size of the moon in our eyes, is then *at the full*, shining with great lustre on the sunless side of its satellite, and receiving back a small portion of its own reflected light. The light, then, which makes the dark part of the moon visible to us, may be said to perform three journeys—first from the sun to the earth, then from the earth to the moon, and finally from the moon back to the earth—before our eyes are enabled to perceive this object.

Mars, the fourth of the primary planets, is a globe of 4189 miles in diameter, or little more than a half of that of the earth; consequently, the bulk of this planet is only about a fifth of that of our globe. It performs a rotation on its axis in 24 hours 39 minutes and 21⅔ seconds, and revolves round the sun, at a distance of 144,000,000 of miles, in 686 days 22 hours and 18 seconds. Mars appears to the naked eye of a red colour; from which circumstance it was, probably, that the ancients bestowed upon it the name of the god of war. Inspected through a telescope, it is found to be occasionally marked by large spots and dull streaks, of various forms, and by an unusual brightness at the poles. As the bright polar parts sometimes project from the circular outline of the planet, it has been conjectured that these are masses of snow, similar to those which surround the poles of the earth.

Vesta, Ceres, Pallas, Juno, and *Astræa*, are five small globes, revolving between the orbits of Mars and Jupiter, in paths near and crossing each other, and which are not only much more elliptical than the paths of the other planets, but also rise and sink much farther from the plane of the general planetary revolutions. *Vesta* is of a bulk only 1-24,000th part of the bulk of the earth, with a surface not exceeding that of the kingdom of France. It revolves round the sun in 3 years 66 days and 4 hours, at a mean distance of 225,500,000 of miles. Though the smallest of all the planets, it gives a very brilliant light, insomuch that it can be seen by the naked eye. *Juno* is 1425 miles in diameter, and presents, when inspected through the telescope, a white and well-defined appearance. Its orbit is the most eccentric of all the planetary orbits, being 253,000,000 of miles from the sun at the greatest, and only 126,000,000, or less than one-half, at the least distance. In the half of the course nearest to the sun, the motion of the planet is, by virtue of a natural law afterwards to be explained, more than twice as rapid as in the other part. *Ceres* has been variously represented as of 1624 and 160 miles in diameter. The astronomer who calculated its diameter at 1624 miles, at the same time believed himself to have ascertained that it has a dense atmosphere, extending 675 miles from its surface. It is of a reddish colour, and appears about the size of a star of the eighth magnitude. Ceres revolves round the sun, at a distance of 260,000,000 of miles, in 4 years 7 months and 10 days. *Pallas* has been represented as of 2099 miles in diameter, with an atmosphere extending 468 miles above its surface. Another astronomer has allowed it a diameter of only 80 miles. It revolves round the sun, at a mean distance of 266,000,000 of miles, in 4 years 7 months and 11 days. However unimportant it may appear beside the larger planets, it has a peculiar interest in the eyes of astronomers, on account of its orbit having a greater inclination to the plane of the ecliptic than those of all the larger planets put together. *Astræa* revolves round the sun at a mean distance of 247,000,000 of miles in 1521 days. It is evident that these small planets are not distinct and independent in the same degree with Mercury, Venus, and the other primaries. Cosmogonists presume that the matter which in other cases has gone to form one planet of the first rank, has in their case been separated into several parts, assuming various but connected orbits.

These five planets, which are sometimes called *asteroids*, have only recently become known to mankind. Ceres was discovered at Palermo, in Sicily, on the 1st of January 1801, by M. Piazzi, who gave it this name in honour of the tutelary goddess of his native country. Pallas was discovered at Bremen, in Lower Saxony, on the 28th of March 1802, by Dr Olbers. Juno was discovered by Mr Harding, at the observatory of Lilienthal, near Bremen, on the 1st of September 1804. Vesta was discovered on the 29th of March 1807, by the same astronomer who had discovered Pallas. Astræa was not discovered till 1845. Even while we write (August 1847), other two have been announced as an addition to the group, under the names of *Hebe* and *Iris*.

Jupiter is the largest of all the planets. Its diameter is nearly eleven times that of the earth, or 89,170 miles, and its volume or mass is consequently 1281 times that of our globe. The density of Jupiter is only a fourth of that of the earth, or about the lightness of water. It performs a rotation on its axis in 9 hours 55 minutes and 33 seconds, or about two-fifths of our day. It revolves round the sun, at a distance of 490,000,000 of miles, in 4330 days 14 hours and 39 minutes, or nearly twelve of our years. Viewed through a telescope, Jupiter appears traversed by dark lines, or belts, which occasionally shift, melt into each other, or separate, but sometimes are observed with little variation for several months. These belts are generally near the equator of the planet, and of a broad and straight form; but they have been observed over his whole surface, and of a lighter, narrower, and more streaky and wavy appearance. It is supposed that the dark parts are lines of the body of the planet, seen through openings in a bright cloudy atmosphere.

Jupiter is attended by four satellites, which revolve round it, in the same manner as the moon round our globe, keeping, like it, one face invariably presented to their primary. They are of about the same size, or a little larger diameter than our moon; the first having a diameter of 2508, the second of 2068, the third of 3377, and the fourth of 2890 miles. The first revolves round the primary planet in 1 day 18 hours 28 minutes; the second in 3 days 13 hours 14 minutes; the third in 7 days 3 hours 43 minutes; and the fourth in 16 days 16 hours 32 minutes. These satellites frequently eclipse the sun to Jupiter; they are also eclipsed by the primary planet, but never all at the same time, so that his dark side is never altogether without moonlight.

The satellites of Jupiter were discovered by Galileo, being among the first results of the invention of the telescope. They have been of great use in several astronomical calculations of importance, particularly in suggesting the theory of the gradual propagation of light. It having been observed that their eclipses always took place sooner than was to be expected when the earth was near Jupiter, and later when it was at the greatest distance, an astronomer solved the difficulty by supposing that light required some time to travel—a conjecture which was afterwards confirmed by other observations.

Saturn, seen through a telescope, is the most remarkable of all the planets, being surrounded by a ring, and attended by seven satellites. In bulk, this is the second of the planets, being 79,042 miles in diameter, or about 995 times the volume of the earth. Its surface appears slightly marked by belts like those of Jupiter. It performs a rotation on its axis in 10 hours 16 minutes, and revolves round the sun, at a distance of 906,000,000 of miles, in 10,759 days 19 hours 16 minutes, or about 29½ of our years. At such a distance from the sun, that luminary must be diminished to one-ninetieth of the size he bears in our eyes, and the heat and light in the same proportion. The matter of Saturn is one-ninth of the density of our earth.

The ring of Saturn surrounds the body of the planet in the plane of its equator. It is thin, like the rim of a spinning-wheel, and is always seen with its edge presented more or less directly towards us. It is luminous with the sun's light, and casts a shadow on the surface of the planet, the shadow of which is also sometimes seen falling on part of the ring. The distance of the inner edge from the planet is calculated at about 19,000 miles; its entire breadth from the inner to the outer edge is 28,536; the thickness is not more than 100. In certain positions of the planet, we can see its surface at a considerable angle, and the openings or loops which it forms at the sides of the planet. At other times we see its dark side, or only its edge. From observations made upon it in favourable circumstances, it is found to be apparently divided near the outer edge by a dark line of nearly 1800 miles in breadth, as if it were divided into two concentric rings. From other appearances, it has been surmised to have other divisions, or to be a collection of several concentric rings. It is also occasionally marked by small spots. The ring of Saturn rotates on its own plane in 10 hours 32 minutes 15 seconds and a part of a second, being about the same time with the rotation of the planet.

The seven satellites of Saturn revolve around it, on the exterior of the ring, and almost all of them in nearly the same plane. They are so small, as not to be visible without a powerful telescope. The two inner ones are very near to the outer edge of the ring, and can only be discerned when that object is presented so exactly edgeways as to be almost invisible. They have then been seen passing, like two small bright beads, along the minute thread of light formed by the edge of the ring. The three next satellites are also very small; the sixth is larger, and placed at a great interval from the rest. The seventh is the largest; it is about the size of the planet Mars, and is situated at nearly thrice the distance of the sixth, or about 2,300,000 miles from the body of Saturn. The revolutions of these satellites range from 1 to 79 days; and it has been ascertained of some of them that, according to the usual law of secondary planets, their rotations on their axes and their revolutions round their primary are performed in the same time, so that, like our moon, they always present the same face to the centre of their system. The orbit of the seventh satellite is much inclined to the plane of Saturn's equator.

Uranus, or Herschel, is a globe of 35,112 miles in diameter, rotating on its axis in 7 hours, and performing a revolution round the sun, at the distance of 1,823,000,000 of miles, in 84 of our years. It was discovered, on the 13th of March 1781, by Sir William Herschel, at Bath. The sun to this remote planet must appear only a 400th part of the size which he bears in our eyes. Two satellites are known, and other four are suspected, to attend upon Uranus. The two which have been observed circulate round their primary in orbits almost perpendicular to the ecliptic, and are further supposed to move in a direction contrary to that of all the other planetary motions—namely, from east to west.

The existence of *Neptune* was ascertained by calculation by M. Leverrier of Paris, in September 1846, and the planet was consequently detected at the first search for it by M. Galle of Berlin. Having a diameter of 50,000 miles, it ranks as the third planet of our system in point of magnitude; it is nearly 2,900,000,000 of miles distant from the sun, from which it receives only a nine-hundredth part of the light which falls on our sphere. Its year is 167 of ours, or 60,986 days, and it has already been ascertained to be attended by at least one satellite, and to be surrounded by a ring like that of Saturn.

Some idea may be obtained of the comparative size of the principal objects of the solar system, by supposing a globe of two feet diameter, placed in the centre of a level plain, to represent the sun; a grain of mustard-seed, placed on the circumference of a circle 164 feet in diameter, for Mercury; a pea, on a circle of 284 feet, for Venus; another pea, on a circle of 430 feet, for the Earth; a large pin's head, on a circle of 654 feet, for Mars; four minute grains of sand, in circles of from 1000 to 1200 feet, for Vesta, Ceres, Pallas, Juno, and Astræa; a moderate-sized orange, on a circle of nearly half a mile in diameter, for Jupiter; a small orange, on a circle four-fifths of a mile in diameter, for Saturn; a small plum, on a circle of a mile and a-half in diameter, for Uranus; and an ordinary plum, on a circle of two miles and a-half, for Neptune. It is calculated that the united mass of the whole of the planets is not above a 600th part of the mass of the sun.

COMETS.

Comets are light vapoury bodies, which move round the sun in orbits much less circular than those of the planets. Their orbits, in other words, are very long ellipses or ovals, having the sun near one of the ends. Comets usually have two parts—a body or nucleus, and a tail; but some have no tail, while others have no apparent body. The nucleus of some appears opaque and brilliant; in others it is vaporiform, and so thin, that the stars have been seen through it. The tail is a

still lighter luminous vapour, surrounding the body, and streaming far out from it in the direction contrary to its forward motion. A vacant space has been observed between the body and the enveloping matter of the tail; and it is equally remarkable that the tail has in some instances appeared less bright along the middle, immediately behind the nucleus, as if it were a stream which that nucleus had in some measure parted into two.

In ignorant ages, the sudden appearance of a comet in the sky never failed to occasion great alarm, both on account of its threatening appearance, and because it was considered as a sign that war, pestilence, or famine was about to afflict mankind. Knowledge has dispelled all such superstitious alarms; but yet we are not well acquainted with the nature of comets, either as regards their revolutions, or the properties of their physical constitutions.

Out of the great multitude—certainly not less than 1000—which are supposed to exist, about 150 have been made the subject of scientific observation. Instead of revolving, like the planets, nearly on the plane of the sun's equator, it is found that they approach his body from all parts of surrounding space. At first, they are seen slowly advancing, with a comparatively faint appearance. As they approach the sun, the motion becomes quicker, and at length they pass round him with very great rapidity, and at a comparatively small distance from his body. The comet of 1680 approached within one-sixth of his diameter. After passing, they are seen to emerge from his rays, with an immense increase to their former brilliancy, and to the length of their tails. Their motion then becomes gradually slower, and their brilliancy diminishes, and at length they are lost in distance. It has been ascertained that their movement round the sun is in accordance with the same law which regulates the planetary movements, being always the quicker the nearer to his body, and the slower the more distant. In the remote parts of space their motions must be extremely slow.

Three comets have been observed to return, and their periods of revolution have been calculated. The most remarkable of these is one usually denominated Halley's Comet, from the astronomer who first calculated its period. It revolves round the sun in about seventy-five years, its last appearance being at the close of 1834. Another, called Encke's Comet, from Professor Encke of Berlin, has been found to revolve once in 1207 days, or $3\frac{1}{3}$ years; but in this case the revolving body is found, at each successive approach to the sun, to be a little earlier than on the previous occasion, as if, from some retarding cause, its orbit were gradually lessening, and as if the comet might consequently in time fall into the sun. The third, named Biela's Comet, from M. Biela of Josephstadt, revolves round the sun in $6\frac{3}{4}$ years. It is very small, and has no tail. In 1832, this comet passed through the earth's path about a month before the arrival of our planet at the same point. If the earth had been a month earlier at that point, or the comet a month later in crossing it, the two bodies would have been brought together, and the earth, in all probability, would have instantly become unfit for the existence of the human family. Comets are often affected in their motions by the attraction of the planets. Jupiter, in particular, has been described by an astronomer as a perpetual stumblingblock in their way. In 1770, a comet got entangled amidst the satellites of that planet, and was thereby thrown out of its usual course, while the motions of the satellites were not in the least affected by its proximity.

Comets often pass unobserved, in consequence of the part of the heavens in which they move being then under daylight. During a total eclipse of the sun, which happened sixty years before Christ, a large comet, not formerly seen, became visible, near the body of the obscured luminary. On many occasions their smallness and distance render them visible only by the aid of the telescope; on other occasions they are of vast size. The comet now called Halley's, at its appearance in 1456, covered a sixth part of the visible extent of the heavens, and was likened to a Turkish scimitar. That of 1680, which was observed by Sir Isaac Newton, had a tail calculated to be 160,000,000 of miles in length, a space greater than the distance of the earth from the sun. There was a comet in 1744, which had six tails, spread out like a fan across a large space in the heavens. The tails of comets usually stretch in the direction opposite to the sun, both in advancing and retiring.

THE STARS.

The idea at which astronomers have arrived respecting the stars, is, that they are all of them suns, resembling our own, but diminished to the appearance of mere specks of light by the great distance at which they are placed. As a necessary consequence to this supposition, it may be presumed that they are centres of light and heat to systems of revolving planets, each of which may be further presumed to be the theatre of a vital existence.

The stars seen by the naked eye on a clear night are not above a thousand in number. This, allowing a like number for the half of the sky not seen, gives about two thousand in all of visible stars. These are of different degrees of brilliancy, probably in the main in proportion to their respective distances from our system, but also perhaps in some measure in proportion to their respective actual sizes. Astronomers class the stars under different *magnitudes*, not with regard to apparent size, for none of them present a measurable disk, but with a regard to the various quantities of light flowing from them: thus there are stars of the first magnitude, the second magnitude, and so on. Only six or seven varieties of magnitude are within our natural vision; but with the telescope, vast numbers of more distant stars are brought into view; and the magnitudes are now extended by astronomers to at least sixteen.

The stars are at a distance from our system so very great, that the mind can form no idea of it. The brilliant one called Sirius, or the Dog-star, which was supposed to be the nearest, but merely because it is the most luminous, has been reckoned by tolerably clear calculation to give only 1-20,000,000th part of the light of the sun: hence, supposing it to be of the same size, and every other way alike, it should be distant from our earth not less than 1,900,000,000,000,000,000 miles. An attempt has been made to calculate the distance of Sirius by a trigonometrical problem. It may be readily supposed that the position of a spectator upon the earth with respect to celestial objects must vary considerably at different parts of the year: for instance, on the 21st of June, he must be in exactly the opposite part of the orbit from what he was on the 21st of December—indeed no less than 190,000,000 miles from it. The apparent change of position of celestial objects in consequence of this movement is called *parallax*. Now, it has been found that Sirius is so distant, that an angle formed between it and the two extremities of the earth's orbit is too small to be appreciated. Were it so much as one second, or the 3600th part of a degree, it could be appreciated by the nice instruments we now possess; but it is not even this. It is hence concluded that Sirius must be at least 19,200,000,000,000 miles distant, however much more! Supposing this to be its distance, its light would take several years to reach us, though travelling, as it does, at the rate of 192,000 miles in a second of time!

It is ascertained, beyond doubt, that some stars, at one time visible, and registered by ancient astronomers, are not now to be seen; while many instances are on record of stars which have come into sight for a time, and then gradually vanished. A large star suddenly became visible 125 years before Christ, and attracted the attention of Hipparchus, who was thereby induced to draw up a catalogue of stars, the first ever made. In the year 389, a star blazed forth in the constellation Aquila,* and after remaining for three weeks as bright as the planet Venus, disappeared. A star appeared in the region of the heavens between Cepheus and Cassiopeia in the years 945, 1264, and 1572, and is supposed to be one which comes within our sight once every three hundred and nineteen years, or thereby. At its last appearance, it was very attentively observed by the celebrated Danish astronomer Tycho Brahé, who published a volume respecting it. Its appearance was so sudden, that, in returning from his laboratory to his dwelling-house, he found a group of country people gazing at it, and was satisfied it had not been in that quarter of the sky half an hour before. It was then as bright as Sirius, and continued till it surpassed Jupiter when brightest, and was visible at mid-day. It disappeared entirely about eighteen months after being first observed. Another bright star appeared, in the constellation Serpentarius, in October 1604, and remained for a year. It is mentioned by contemporary writers, that at the birth of Charles II., in 1630, a large star, never before observed, appeared in the daytime, as if to mark something extraordinary in the fortunes of the child that day ushered into existence. Other instances have been noticed in still more recent times; but, upon the whole, this is a point in which astronomical observation is defective. It seems, however, to be clearly ascertained that some, if not all of the stars, have periodical motions throughout space, some more rapid than others. In several of the instances where the period is short, there is no want of positive knowledge. It has been ascertained, for instance, that the star Omicron, in Cetus, has a periodical movement occupying 334 days. It is seen as bright as a star of the second magnitude for about a fortnight; then gradually diminishes for three months, till it becomes invisible, in which state it remains for five months, when it again becomes visible, and gradually increases till it regains its former brightness, more or less—for it does not always reach the same degree of lustre. The star Algol, in the constellation Perseus, continues visible during a period of sixty-two hours, when it suddenly loses its splendour, and from a star of the second magnitude, is reduced, in three hours and a-half, to the fourth; after which it begins to increase, and in three hours and a-half resumes its former size. There are eleven other stars which exhibit analogous phenomena, some of them at intervals of five hundred years, to which we may look forward without any danger of mistake. Astronomers have long been of opinion that our solar system might have a motion through space. From recent observations, it is now believed to have such a motion; nay, the whole of the stars of our cluster appear as moving round a fixed point. The situation of this point has been determined by Dr Mädler of Dorpat as in the small group of stars called the Pleiades. The distance of our sun from that point is calculated at 34,000,000 of times that of the earth from the sun. Dr Mädler considers that the stars are crowded immediately round the centre; then a belt of comparatively vacant space; then again a crowded belt; and so on alternately to the extremity. Our sun is supposed to

* It may be stated here, in anticipation of more particular explanations to be given afterwards, that the starry heavens are by astronomers mapped out into a series of constellations, or assemblages of stars, each of which bears the name of some figure or other object—as *Aquila* the Eagle, *Cetus* the Whale, *Castor* and *Pollux*, twin demigods of the Greek mythology, &c. Each particular star in a constellation, in the order of its magnitude, is distinguished by a letter of the Greek alphabet, and when those are exhausted, with a number.

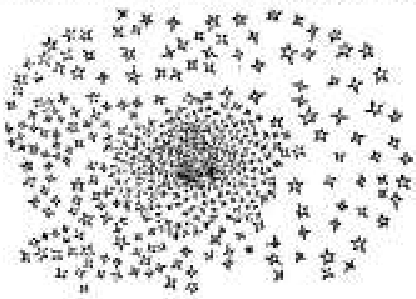
revolve round a central sun, at the rate of 2,200 miles a minute; yet the whole revolution requires 18,200,000 of our years!

Another variety in the nature of these luminaries is their being in some instances not *single* stars, as they appear to the naked eye, but a group of two or more, evidently, from their motions, forming one system. The star Castor, in one of the Twins, is found, when much magnified, to consist of two stars, of between the third and fourth magnitude, within five seconds (a very small space) of each other. Sir William Herschel made observations upon more than 500 stars of this kind, where the distance is not more than half a minute (also a very small space); and to this list a foreign astronomer has added five times that number. Nor is there reason to suppose that, in *all* these instances, one of the stars is at a great distance behind the other, and that they are only brought together by the accident of our position. Many of the double stars, no doubt, are thus accidentally brought together; but of a great number, it has been fully ascertained that they are each a system, with a reciprocal relation to each other. They are therefore called *Binary Stars*. It is generally observed that they move round each other within a certain time, and in elliptical orbits; the revolution of Castor, for instance, is supposed to be accomplished in 252 years; of ξ of Ursa Major, in 58¼ years; of 70 Ophiuchi, in 73 years. In fact, there is the same variety in this branch of the starry system as in its other departments, and the revolutions of the few binary stars that have been accurately surveyed range from 43 to 1200 years. Several of these duplicate stars have made a revolution since they were first observed, and are now advancing in their second period. One, ζ *Herculis*, was seen double, in 1782, by Sir William Herschel; in 1795, it was hardly distinguishable to be double; in 1802, it was double no longer, the one being eclipsed by the other, though a small part of one was still jutting out at the side of the other: astronomers are now watching to observe them once more become separate. Whether one of these stars serves to the other as a sun, or whether both are suns, or whether the organized life with which they are probably stored be of a kind which can endure a perpetual light and heat thrown from the one to the other—or in what other manner these immense worlds are put to use—it would be vain to inquire. One remarkable peculiarity in them is, the variety of tints apparent in the light emitted by a considerable number of them; but no accurate account has yet been given of the reason of this wonderful difference of colour in the stars.

Perhaps the most magnificent of all the starry phenomena is the *Milky Way*. This, as is generally known, is a broad belt, of whitish lustre, which stretches round the whole sky, being parted into two streaks for a large part of the circuit. The ancients formed the mean idea of this light, that it was the milk spilt by the nurse of Mercury, one of the deities; hence its name. When examined by a telescope, it is found to consist entirely of stars, "scattered by millions," as Sir John Herschel beautifully describes them, "like glittering dust on the black ground of the general heavens." The average magnitude of these stars is about the tenth or the eleventh, and hence their invisibility to the naked eye. It is a very remarkable circumstance, that, though the stars of the larger magnitudes are scattered with considerable equality over the whole heavens, there is a notable clustering of the smaller ones towards the body of this ring. Sir William Herschel, by gauging, as it were, the depth of our starry system in this and other parts, arrived at what he believed to be an approximation to the figure of the system itself—namely, an elongated cake-shaped mass, parting flatwise into two at one particular part of the exterior (where the Milky Way is double), and in which our solar system was placed somewhat nearer the one extremity than the other. Where the distance between two stars is so great as we have seen—and we can suppose the distance between all the rest to be no less—what must be the entire extent of this star-system, composed as it is of millions of millions of distinct bodies!

REMOTE STAR-SYSTEMS—NEBULÆ.

Our own star-system, inconceivably vast as it is, is but an item of the heavenly inventory. Far beyond its bounds, the telescope of Herschel has descried similar systems in great numbers, each hanging in some tolerably defined shape in the vast empyrean, and each capable of being resolved, not exactly into stars, though these are in some instances visible, but into what has been expressively called *star-dust*, a collection of small brilliant particles, each of which would probably appear a distinct sun under a stronger power of artificial vision. Observations have been made upon these star-systems chiefly in the direction of the thinner parts of our own system, where the sky is clearest of our own stars, and where of course they are most distinct from other and nearer objects. But even in those limited fields of the sky, very great numbers have been seen—between 1000 and 2000 in the northern hemisphere alone—a number, we must recollect, exceeding that of all the ordinarily visible stars in the same section of the heavens.



Remote Star-System.

They are of various forms, but in general, as has been said, tolerably well-defined. Many appear as spherical clusters, with a crowding of the star-dust towards the centre: of this kind there is a brilliant example in the constellation Hercules. It has been remarked, that in the worlds about the centre of such clusters, the visible heavens must be inconceivably brilliant, though they will have no appearances resembling our Milky Way. There is another spherical class, in which the external parts are the most brilliant: in these cases, the visible heavens of a world near the centre will probably be almost entirely composed of milky way. From our earth these annular clusters are presented in various points of view, some so nearly edgewise, that we can barely see the long line of thin matter in the centre. Several exhibit to Lord Rosse's telescope most remarkable and even startling forms; one being somewhat like an anchor, another like a crab, and so forth. Surprising to relate, there are more than one bearing a strong resemblance to the form which has been presumed as that of our own star-system—namely, a flattened mass, with a brilliant annular exterior, parting flatwise into two at one part! In the *Magellanic clouds*, a nebulous object in the southern hemisphere, there is one remote star-system (30 Doradûs), described by Sir John Herschel as "consisting of a number of loops united in a kind of nuclear centre or knot, *like a bunch of ribbons disposed in what is called a true-lover's-knot!*" "We are," says an astronomer who possesses eloquence worthy of his noble science, "lost in mute astonishment at these endless diversities of character and form. But in the apparent aim of things near and around us, we may perhaps discern some purpose which such variety will also serve. It seems the object or result of known material arrangements, to evoke every variety of creature, the condition of whose being can be made productive of a degree of durability; and perhaps it is one end of this wonderful evolution of firmaments of all orders, that there, too, the law of variety may prevail, and room be found for unfolding the whole riches of the Almighty." The vast general distance of these clusters, their distinctness from our own system, and their relative distances, have been determined by the comparative powers of the telescopes employed in observing them. Some of them are distant from us many thousands of times the distance of Sirius, the nearest of our own stars.

Astronomers have long had under their observation a set of peculiar objects, apparently within the limits of our star-system, and called *Nebulæ*, from their filmy cloud-like appearance. There is one of magnificent appearance in the girdle of the constellation Andromeda, and another still more splendid in the sword-hilt of Orion, both visible to the naked eye. Some of these objects are of irregular form, stretching like a fragment of semi-pellucid membrane over the sky, with patches of brighter matter scattered irregularly throughout their extent. In others, the bright patches are of greater intensity, so as to have the decided appearance of *gatherings* of the matter towards a particular point. Others there are, in which these bright parts seem nearly disengaged from the surrounding thin matter, or only bedded on a slight background composed of it. In a fourth class, we see detached masses, approaching more or less to a spherical form, and with various measures of comparative brightness towards the centre, until they resemble a star with only a slight *bur* around it. When telescopes of high powers were applied to these bodies, many of them were resolved into dense clusters of stars; but others could not thus be resolved, and had such a peculiar appearance, that it was surmised that they were not starry masses, but patches of diffused matter in the course of being condensed to stars and systems—belated portions, so to speak, of the same soft and diffused material, which, countless ages ago, was condensed into the defined bodies forming the remainder of our star-system! This surmise was readily supported by many, on the belief that such uncondensed suns were likely to exist, and that the hypothesis furnished a ready basis whereon to found the history and connection of the solar system. But in 1846, the powerful telescope of Lord Rosse showed that one of the most marked of these nebulæ (that in Orion) did really consist of an immense irregular mass of stars, undiscernible before, from its being situated so remotely in the depth of the starry spaces. It has consequently been pronounced as extremely doubtful if there are any masses of diffused, or, properly speaking, nebulous matter, in the regions of space.

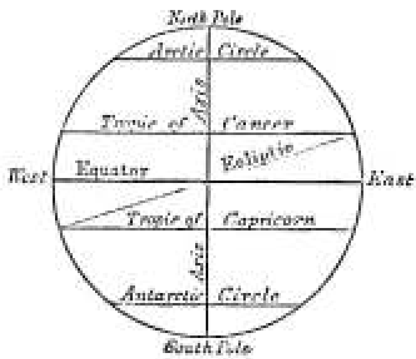
The discovery, however it may affect theories, infinitely exalts our conceptions of the magnitude and extent of the material universe. It teaches us to regard the farthest and filmiest speck which the most powerful telescope can descry, as a mass of worlds melted, by distance, into a dim light, but comprising individualities as perfect, and at the same time as progressive in their natures, as our own. "What mean, for instance," says Professor Nichol in a recent work, "those dim spots, which, unknown before, loom in greater and greater numbers on the horizon of every new instrument, unless they are gleams it is obtaining, on its own frontier, of a mighty infinitude beyond, also studded with glories, and infolding what is seen as a minute and subservient part? Yes; even the six-feet mirror, after its powers of distinct vision are exhausted, becomes in its turn simply as the child gazing on these mysterious lights with awful and hopeless wonder. I shrink below the conception that here—even at this threshold of the attainable—bursts forth on my mind! Look at a cloudy speck in Orion, visible, without aid, to the well-trained eye; *that* is a stellar universe of majesty altogether transcendant, lying at the verge of what is known. Well, if any of these lights from afar, on which the six-feet mirror is now casting its longing eye, resemble in character that spot, the systems from which they come are situated so deep in space, that no ray from them could reach our earth until after travelling through the intervening abysses during centuries whose number stuns the imagination. There must be some regarding which that faint illumination informs us, not of their present existence, but only that assuredly they were, and sent forth into the Infinite the rays at present reaching us, at an epoch farther back into the past than this momentary lifetime of man, by at least *thirty millions of years!*"

URANOGRAPHY.

Under this term (delineation of the heavens) may be comprehended all those arrangements which have been made by astronomers for artificial representation of the heavens, and for the working of the many mathematical problems of which the heavenly bodies are the subject.

The stars, as they appear in their places on the apparent concave sphere of the heavens, are represented in proper arrangement on the *celestial globe*, which is expressly designed as a miniature of that sphere, but bearing also the fanciful figures assigned to the constellations, and the lines necessary for the working of various problems. It is required that, in the first place, we give a brief description of the terrestrial globe, or similar miniature representation of the earth.

Astronomers, for the convenience of their science, have supposed certain lines to pass through and around the globe. One, passing through the centre, between north and south, is called the *axis* of the globe, from a Greek word signifying axle. The two extremities are called the *poles*, from the Greek word *polos*, signifying a pivot. A line girding the globe in the middle, or cutting it into two equal portions, is styled the *equator*; all to the north and south of which are respectively called the northern and southern hemispheres. The circuit of the earth, both in its girth between east and west, and between north and south, is divided into 360 parts, called *degrees*. At the distance of twenty-three and



a-half nearly of these degrees from the equator, in both directions, are two parallel lines called the *tropics*, and at the same distance from each pole is a parallel circle, styled in the one case the *arctic*, and in the other the *antarctic circle*. The space between the tropics is called the *torrid zone*, because the sun, being always vertical in some part of that space, produces a greater degree of heat than what is felt elsewhere. The spaces between the tropics and the arctic and antarctic circles are called the *temperate*, and the spaces within these latter circles the *frigid zones*. Lastly, a line which cuts the equator obliquely, touching upon opposite points of the tropics, is called the *ecliptic*. The ecliptic and equator are called greater circles, because they cut the earth at the thickest parts; the others are called lesser circles.

A series of lines drawn from pole to pole over the earth's surface (like the division lines of a peeled orange), and cutting the equator at right angles, are called *meridians* (from the Latin word *meridies*, mid-day), or lines of longitude. Every place upon the earth is supposed to have one of these passing through it, although only 24 are described upon the terrestrial globe. When any one of these is opposite the sun, it is then mid-day or twelve o'clock with all the places situated on that meridian, and consequently midnight with those on the opposite meridian on the other side of the earth. The exact situation of a place upon the earth's surface, or its latitude and longitude, is determined by means of those circles. They are all divided, as already hinted, into 360 parts, which parts are called *degrees;* these degrees again into 60 equal parts, called *minutes;* the minute into 60 others, called *seconds;* and so on. They are all indicated by certain signs placed behind the figure, and near the top of it—thus 8° 5′ 7″ is 8 degrees 5 minutes 7 seconds. A degree is 60 geographical miles, or about 69 English statute miles; a minute is the 60th part of that; and so on. The *latitude* of a place is its distance measured in that manner from the equator. If it lies north of that line, it is in north latitude; if south of it, in south latitude. There being only 360 degrees in the circumference of the earth, and the distance from the equator to either of the poles being only a fourth part of it, a place can never have more than 90 degrees of north or south latitude. The *longitude* of a place is the distance of its meridian from another, which is called the first meridian. The first meridian is quite arbitrary, and it is a matter of indifference through what point we draw it, provided it be settled and well known which one we adopt, so as to prevent mistakes. Foreigners fixed upon the principal observatories of their respective countries. In Germany, the island of Ferro is generally adopted; in France, the observatory of Paris; and in England, that of Greenwich. Longitude is reckoned either east or west of the first meridian; and 180 is therefore the utmost degree of longitude. Some geographers, however, reckon longitude all the way round the globe. From the shape of the earth, which is flat at the poles, the degrees of longitude decrease as we approach these in either direction. In order to measure latitude, each globe is furnished with a brass meridian circle, on which the degrees are marked. Longitude is measured by a similarly graduated circle, termed the *artificial horizon*, in which the globe is suspended.

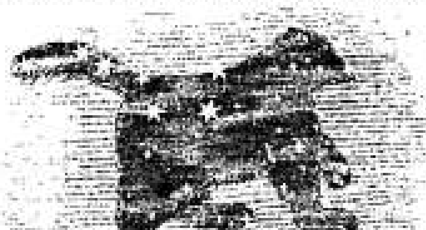
The other great circle, called the Ecliptic, is divided into twelve parts, called signs, which bear the name of the constellations through which this circle passes in the heavens, as shall be afterwards explained. There are other smaller circles which run round the earth parallel to the equator; these are called *parallels of latitude*, because, being everywhere at the same distance from the equator, the latitude of every point contained in any one of them is the same.

The celestial globe, representing that apparent outer sphere, the sky, in the centre of which the earth seems suspended, is marked by lines similar to those upon the terrestrial globe, each line upon the latter being supposed to have a corresponding line opposite to it in the heavens. Thus the celestial sphere is divided into the same number of degrees as the terrestrial. The celestial poles correspond to those parts of the heavens to which the terrestrial poles always point. The point of the heavens directly over our heads, or the very summit of our sky, is called the *zenith*, and is a sort of pole or middle point of the visible half of the heavens; the point which we would see directly beneath our feet, if the earth could be seen through, is called the *nadir*, and forms a pole to the nether half of the heavens. The celestial equator corresponds also to the terrestrial, and is, like it, everywhere 90 degrees distant from the poles. The equator of the earth thus lies directly under that of the heavens: the ecliptic does exactly the same, and cuts the former also at an angle of 23 degrees 28 minutes.

The place where the ecliptic cuts the equator at the vernal equinox is called the first point of Aries; and from this point the distance of all celestial bodies eastward and westward of it is measured. This is called their *right ascension*, and corresponds to the terrestrial longitude. Their latitude is determined by their distance from the equator, and is called their *declination*. The declination of the sun, or other heavenly body, is therefore called north or south declination, according to its proximity to the north or south pole of the heavens; hence it follows, that when the sun's declination is 10 degrees north, he is vertical at a place whose latitude is 10 degrees north. But the right ascensions do not so correspond with the longitudes, simply because the first point of the constellation Aries does not correspond to the first meridian (Greenwich); and because the longitudes are not measured quite round, as the right ascensions are.

The sun, which is always in the ecliptic, has of course no latitude, but he passes through all the degrees of longitude in a year. When any other celestial object has the same longitude as the sun, it is said to be in *conjunction* with him; and when the difference of longitude amounts to 180 degrees, half the circle of the heavens, it is said to be in *opposition* to him. Both these terms are comprehended in that of *syzygy*, which, when applied to any celestial object, means that it is either in conjunction or opposition to him. What is called an *equinoctial colure*, is a great circle supposed to be drawn through the pole of the ecliptic and the points where it intersects the equator. The *solstitial colure* is a similar circle, which passes through the solstitial points at right angles to it. The former colure is a secondary to the ecliptic, and the latter a secondary to both it and the equator. The equinoctial points are Aries and Libra, where the ecliptic cuts the equator. The solstitial points are Cancer and Capricorn; and when the sun is in either of them, he is at his farthest distance above or below the equator.

Allusion has already been made to the constellations or fanciful figures marked on celestial globes, to aid in distinguishing the position of the stars. The earliest astronomers seem to have adopted the idea of thus mapping out the starry heavens, being no doubt at first led to do so by the slight resemblances borne by various groups of stars to familiar terrestrial objects. Thus, a group in the northern part of the sky bears some resemblance to an ancient wain, or to a plough—as also to the hinder part of an animal, with its tail extended; hence it has been variously called *the Plough*, *Ursa Major*, or the Greater Bear, and *Charles's*



Constellation Ursa Major.

Wain—the last term being in honour of the illustrious French king Charlemagne. (In ordinary globes, Ursa Major is alone marked.) Another group, in the southern heavens, conveys the idea of a man's figure, and has been called Orion, from an early Greek semi-divine hero of that name. Some of the names of the constellations were conferred by Chaldean observers several hundred years before our era: others have been given within the last few ages. Particular stars of large magnitude also bear particular names, generally Arabic, having been affixed by Arabian astronomers—as Aldebaran, Dubhe, Alioth, &c. Arcturus and the group of small stars called the Pleiades, are alluded to in the book of Job, which is well known to be one of the earliest of the Scriptural compositions, and probably not less than 3000 years old.

Twelve of the constellations are placed in that part of the heavens which is opposite to the ecliptic in the terrestrial globe; that is to say, the plane of the planetary motions, if extended to the stars, would strike the part occupied by these constellations. This part of the celestial globe is called the *Zodiac*, and these are named the Zodiacal Constellations, or more commonly, the *Signs of the Zodiac*. The zodiac is a zone or belt, extending eight or ten degrees on each side of the ecliptic. It is divided into twelve parts, each of thirty degrees, called the signs of the zodiac. The names of the signs, and the days in which the sun enters them, are as follow:—*Spring signs*—Aries, the Ram, 21st of March; Taurus, the Bull, 19th of April; Gemini, the Twins, 20th of May. *Summer signs*—Cancer, the Crab, 21st of June; Leo, the Lion, 22d of July; Virgo, the Virgin, 22d of August. These are called Northern Signs, being north of the equator. *Autumnal signs*—Libra, the Balance, 23d of September; Scorpio, the Scorpion, 23d of October; Sagittarius, the Archer, 22d of November. *Winter signs*—Capricornus, the Goat, 21st of December; Aquarius, the Water-bearer, 20th of January; Pisces, the Fishes, 19th of February. These are called Southern Signs. Within the zodiac are performed the revolutions of all the principal planets.

II. MECHANICAL ASTRONOMY.

It is the province of Mechanical Astronomy to explain the physical laws which seem to have produced, and which sustain, the arrangements of the bodies occupying space, as well as all the various results of the arrangement and relations of those bodies.

It may, in the first place, be proper to explain what is meant by a *physical law*. In the operations of nature, certain results are invariably observed to take place as a consequence of certain circumstances. This has suggested to the mind of man that there is an *order* in all things, by virtue of which they are regulated to the best general purposes, the authorship of the *order* being no doubt the same as the authorship of matter itself—that is to say, referable to the Divine Being. Any particular regulation which we find imposed upon matter, we term a law of matter, or a physical law.

LAWS OF ATTRACTION AND MOTION.

We have first to consider the laws by virtue of which *particles and masses of matter attract each other*, as far as these are concerned in the province of Mechanical Astronomy.

Particles of matter, when brought close together, or within insensible distances, have a tendency to cohere, or stick together; and this operates in all cases, unless there be opposing influences of superior force. It is termed the *attraction of cohesion*.

Particles of matter have also a tendency to move or be drawn towards each other. This is called the *attraction of gravitation*, because it is what the weight or gravity of an object depends upon.

Under the influence of the attraction of cohesion, particles of fluid matter, when suspended at a proper distance from other objects, arrange themselves round a centre, and take a globular form. The dew-drop, suspended from the point of a thorn or blade of grass, is a familiar example of matter thus acting. If two such drops are brought close together, they will unite; a new and common centre will be instantly established for both, and they will resolve themselves into a new mass equally globular as before.

Under the influence of the law of gravitation, when any two masses of matter are brought within a certain distance from each other, they will, if there be no sufficient obstacle, rush together, and then remain in contact.

We may see this law operating if we take two fragments of cork, no matter how small, and set them afloat on the surface of a cup of water. If kept a considerable way apart, the impediments to their mutual attraction are too strong, and they therefore do not meet. But if brought within a short distance of each other, we shall observe them begin mutually to exercise an influence over each other, and immediately they will rush together, and so remain.

Material laws are equally ready to act on a large as on a small scale, and on a small as upon a large one. The same attraction of cohesion which causes the tear drawn from our eye by sympathetic feeling to be round, produced the spherical form of the vast orbs which people space. These, being originally fluid masses, gathered themselves round a centre, by the irresistible force of the law of the attraction of cohesion. So also are the planets restrained in their position regarding the central luminary, by the force of the same law of gravitation which causes an apple dropping from a tree to fall upon the ground, or two tea-stalks floating in our evening cup to go together, and range themselves as closely side by side as possible.

We have next to consider the laws which regulate the *motion* of masses of matter.

A mass of matter set in motion upon the surface of the earth, or within the compass of the atmosphere, invariably comes sooner or later to a stop. If we roll a ball along the surface, it goes briskly for a while, then slowly, and finally it stops, and remains at rest. What causes it to stop, is the resistance it meets with from the roughness of the ground, and the opposing fluid (atmosphere) in which it moves. It is precisely when as much force has acted in opposition to its motion, as was exerted in setting it agoing, that it comes to a pause. Were it not, however, for this opposing force, the ball, once set in motion, would travel on and on for ever.

Just so the orbs of space, once set in motion, go on and on perpetually, there being nothing whatever to oppose their progress. This applies as well to their spinning or rotatory motion on their axes, as to their progress along their orbits. If a top were set a-spinning on a smooth marble tablet, underneath the exhausted receiver of an air-pump, it would be found to keep in motion for a far longer space of time than in any ordinary circumstances, for then there would be comparatively little air to give resistance to its rotation, and the chief opposition would lie in its friction against the tablet. Could the air be entirely drawn away, and the top be made to spin in a state of suspension, it would be in precisely the same circumstances as an orb revolving on its axis in space, and in that case it would never stop as long as all the circumstances remained unaltered.

But the orbitual revolutions of planets are circular. Why should they be so? Because these orbs are under the influence of both the law of attraction and the laws of motion. Assuming the nebular hypothesis to be true, the impulse which they originally obtained tended to throw them off in a direct line into space, in the plane of the ecliptic. But the law of attraction prevented this result, and caused them to assume a circular course round the parent orb. They were propelled by the one cause (the centrifugal or centre-quitting force), but restrained by another (the centripetal or centre-seeking force, that is to say, attraction), and they therefore settled into paths where the two forces balanced each other.

To explain. If we take any circular body, say a common grinding-stone, and, having first put a few pieces of clay upon its rim, cause it to revolve quickly in a horizontal manner, it will be found that the pieces of clay, one after another, fly off in straight lines from the rim. The cause of this is, that each particular part of the rim of the grinding-stone, at every instant of its revolution, is describing a straightforward movement, and has itself, from the revolutionary motion, a tendency to go straight on, and is only kept in its place by being fixed to the rest of the stone. Every bit of clay that flies off, receives, at the instant of its parting, the force of the straightforward impulse which at that moment affected the part of the rim where it rested;

and hence its going off in a straight line. It is to be observed, however, that the earth immediately begins to act upon the flying piece of clay, and draws it downwards to itself in a bending line, its last movements being, in fact, a part of a circle. This is the power of attraction, which, in this case, is exercised in much greater force by the earth than by the grinding-stone; were the grinding-stone the sole mass of matter near by, and the opposing force of the atmosphere withdrawn, we should see the clay begin to fly round the stone in a circular course.

And this naturally brings us to consider the comparative powers of attraction exercised by different objects. A large mass has a much greater power of attraction than a small one. When two of unequal bulk are brought near each other, we shall only be sensible, perhaps, of the large one drawing the small one to it, and see no attractive power in the small one whatever. In reality, each mass, however small in comparison, exercises a certain degree of attractive power; and this power will depend expressly upon its relative bulk and density, according to fixed regulations of the nicest kind.

One great and important law presides over the attraction which one mass exercises over another. This relates to the *distance* between the two masses. We shall suppose two globes of unequal size. When the small one is removed to as great a distance from the large one as there is space between the surface of the large one and its centre (that is to say, the distance of a semi-diameter of the large one), the attractive force is diminished one-half. When it is removed to twice that distance, or two semi-diameters, the attraction is diminished to a fourth. When it is removed to the distance of three semi-diameters, the force is lessened to a ninth; to four semi-diameters, a sixteenth; to five, a twenty-fifth; and so on; the diminution being always as the squares of the amount of semi-diameters of distance, or these sums multiplied by themselves. The moon is distant from the earth sixty of the earth's semi-diameters; consequently, the attractive power exercised by the earth over the moon is only a 3600th part of what it would exercise at its surface.

In the revolution, then, of a planet round the sun, and of a satellite round a planet, there are various forces at work, all of them in the nicest proportion to each other, and to the mass of each body. There is first the amount of motion resulting from the original impulse; then the amount of attraction exercised by the central and larger over the smaller orb—the one pulling outwards, and the other pulling inwards, but both in union attended with the result of a circular or revolutionary motion.

Gravity has not the same force at all parts of the earth's surface. At the equator, the centrifugal force produced by the rotating motion is greatest; it declines in both directions towards the poles. In proportion as the centrifugal force is greater, the attractive power of the mass of the earth is less, for the first of these forces is directly counteractive of the other. There is of course least attractive power at the equator; and bodies are there drawn with less force towards the centre of the earth than would be found to be the case elsewhere. Yet this difference is not great, for even at the equator the attractive force is 288 times that of the centrifugal. Neither does the difference tell in the weighing of objects, for in that case two equivalents are used, and if a certain object is lighter, so also is the weight put into the opposite scale. The difference was first detected, in consequence of pendulum clocks being found to go slower as they were brought towards tropical latitudes. It was ascertained that the pendulum of a clock which went right at London, required to be one-eighth of an inch shorter (by which means its motion was accelerated) when it was placed upon the equator. This effect, however, is not altogether owing to the increase of centrifugal force, but partly also to the greater distance of the equator from the centre. And it was from a speculation as to the slower movements of pendulums at the equator, that Sir Isaac Newton first conceived the idea of the spheroidal form of the earth, which he ascertained to be of less diameter at the poles than at the equator, as 298 is to 299, or by twenty-six miles.

The orbits of the planets, it has been already seen, are not strictly circles, but rather ellipses, the sun being in each case placed in one of the *foci*—that is, the centre of one end of the ellipse. How should this circumstance affect the revolutionary motion? It might be supposed that, when the planet came to the part of its course where it is nearest to the sun, the attractive force would be greater, and that some derangement might take place. But this is not the case. At that part of the course the planet moves faster than elsewhere, and thus baffles the greater attractive force. This phenomenon is particularly apparent in comets, which have so eccentric an orbit. These bodies move with inconceivably greater speed when near the sun than in the remote parts of their orbits.

It was a discovery of the German astronomer Kepler, in the seventeenth century, that, notwithstanding the increased speed, a revolving orb goes over exactly the same amount of its circuit as when it moves more slowly. Suppose a multitude of lines radiating from the sun, at equal distances from each other, the orb would be found to cross from one to another of these, in exactly the same time, when it was *farthest* from the sun as when it was *nearest*. In scientific language, it describes equal areas in equal times.

Another discovery of Kepler established that there is a relation between the times respectively required by the planets for their revolutions, and their various distances from the sun. At a first glance, we are struck by the fact, that the periods of revolution increase more than in proportion to the distances. For example, the period of Mercury is about 88 days, and that of the Earth 365, being in proportion as 1 to 4.15 (or about 4 1-7th), while their distances, respectively 37,000,000 and 95,000,000 of miles, are in the less proportion of 1 to 2.56 (or a little more than $2\frac{1}{2}$); and a similar remark holds good in every instance. If we take the squares of the distances, we arrive at nothing satisfactory, for it considerably exceeds the proportion of the periods. If, however, we take the squares of the periods of two planets, we find they are in exactly the same proportion to each other as the *cubes* of the mean distances. Some may find a difficulty in understanding the nature of this calculation; but its ingenuity and its results form one of the highest boasts of astronomical science. "When we contemplate," says Sir John Herschel, "the constituents of the planetary system from the point of view which this relation affords us, it is no longer mere analogy which strikes us—no longer a general resemblance among them, as individuals independent of each other, and circulating about the sun, each according to its own peculiar nature, and connected with it by its own peculiar tie. The resemblance is now perceived to be a true *family* likeness; they are bound up in one chain—interwoven in one web of mutual relation and harmonious agreement—subjected to one pervading influence, which extends from the centre to the farthest limits of that great system, of which all of them, the earth included, must henceforth be regarded as members."

The solar system, though composed of many different masses distant from each other, is to be considered with respect to other masses as one mass, having a centre of gravity, by which its position with respect to other masses is regulated. The nearest stars no doubt exercise the force of gravitation upon it, so as to keep it in its position; and it also acts in the same way upon them. It is therefore not strictly correct to speak of the solar system, or any part of it, as *suspended* in space, for that term implies a hanging from a fixed point. It is, in reality, kept at its place by attractive influences exerted all round it by other masses. In like manner, we are to suppose our star-cluster as poised by the same forces in the midst of other clusters; and these, again, poised by others—an idea which leads us on and on through the fields of infinity, till the mind loses itself in an effort beyond its finite powers, and pauses contented to wonder and adore!

DIURNAL AND ANNUAL MOTION OF THE EARTH.

The earth is to be considered as a globe of nearly 8000 miles in diameter, performing a rotatory motion on its axis once every twenty-four hours. This motion is at the rate of 1036 miles an hour to places at the equator, but only 560 miles at London, and a gradually diminishing amount in places nearer to the poles.

From the situation of the earth with respect to the sun, it necessarily follows that only one-half of its surface should be exposed at a time to the light and heat diffused from that body. This is the case with all the planets. When any one part of the earth is presented to the sun, it is day at that part, and all the other heavenly objects are lost in the blaze of the great luminary. When, on the contrary, any part is averted from the sun, it is dark at that part, and the light of the stars is allowed to fall upon our organs. Each part is thus brought once every twenty-four hours towards the sun; in short, this is the cause of what we familiarly know as day and night.

There is a minute difference between the *civil* or *legal day* and what is called the *sidereal day*. The entire orb of the earth, in reality, revolves in 23 hours 56 minutes 4 seconds, or 3 minutes 56 seconds less than 24 hours. This is called a sidereal day, because the earth is then in the same relation to the stars as it was the day before. The fixed stars are so immensely distant from our earth, that its whole orbit is in respect to them but a point; so that no sensible difference is produced by its revolving round the sun. But the sun being much nearer us, any movement made by the earth can be appreciated. The time which elapses from the sun's being on the meridian of any place to its returning to the same spot next day, is exactly 24 hours, and is called an astronomical day. The natural day would always be the same as the sidereal day, if the earth had no other motion than that upon its axis. But in the same time that it has performed one of its daily revolutions eastward, it has also advanced about a degree westward, or in the opposite direction, which is the course it takes round the sun; so that, before the sun can shine exactly upon the same meridian, the earth must make up, as it were, its lee-way, and this it does in 3 minutes 56 seconds, the difference of time between a natural and a sidereal day. If the earth, then, had no other than its diurnal motion, we should have 366 days in the year.

When any spot on earth comes directly opposite to the sun, it is noon at that spot, and at every place in the same longitude. At the same moment, it is an hour before noon at the meridian of longitude fifteen degrees to the west of the same spot, and an hour earlier for every fifteen degrees farther to the west; because, as the earth moves from west to east, it requires so much time to bring those places to the same point—namely, opposite to the sun. In like manner, it is an hour after noon for every fifteen degrees to the eastward of the spot where it is noon, because at those places the sun has already been for so many hours past meridian. Thus the hour of the day varies in every part of the globe where the longitude or meridian line is different. When it is twelve o'clock noon with us in any particular part in Britain, it will be twelve o'clock at midnight in a corresponding point on the opposite side of the globe, near New South Wales; and the intermediate hours, sooner or later, will all lie in the countries between these two points, exactly according to their position or degrees of longitude.

The earth is at a mean distance of 95,000,000 of miles from the sun, and performs its revolution round him in a sidereal year, which is 365 days 6 hours 9 minutes 11 seconds mean solar time. The earth travels at the rate of 68,000 miles per hour. Its orbit is, as already stated, not a circle, but an ellipse, the sun being situated in one of the foci—that is, not in the centre, but near one of the ends of the oval-shaped figure. Neither does the earth go round the sun in an upright or perpendicular position; its axis is slanting or oblique. The degree of obliquity is 23 degrees 28 minutes. The points at which the ecliptic cuts the equator are called *nodes*: the period of time at which it does this, the *equinoxes* (a Latin term, signifying equal nights, for the days and nights are then of equal length all over the world). In consequence of this obliquity, during one part of the earth's course the north pole is turned towards the sun, and the south is dark; and during another part of its course, the south pole is turned to the sun, and the north is dark; and this is the cause of the difference of seasons, which will be better understood by referring to the subjoined figure.

THE SEASONS.

Let S represent the sun, and A B C D the earth at various places of its annual circuit; when the earth is at B or D, these are the periods of the equinox, when the line of the equator intersects or cuts through the line of the ecliptic. At this period, one-half of the globe is illuminated from pole to pole, or there is over all the earth an equal day and night of twelve hours. But

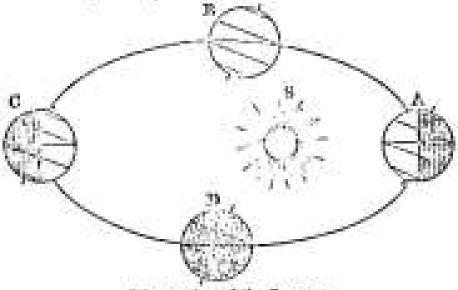


Illustration of the Seasons.

when the earth has proceeded to A, the pole or axis still keeping the same position, or pointing to one particular place in the starry heavens, it will be turned more directly from the sun; a greater proportion of his rays will shine on any particular spot of the southern half of the globe, and the period of day, or sunlight, will exceed that of darkness by the proportion of the light and shade parted in the circle of the earth. It will be observed also, that within the circle of the south pole, the sun will shine continually as the earth revolves on its axis, or, in short, to the inhabitants of that part of the globe the sun will never set for several months. When the earth has proceeded on to B, one-half of its annual course is finished, or this is the spring equinox, or equal day and night. At C, again, the earth has arrived at our longest day in summer, when the axis is turned to the sun, and the regions around the pole are in the light for a greater period, while darkness, or night, prevails for a less. It will be seen, too, that now the pole and circle around it revolve in perpetual light; or to the inhabitants of that region the sun never sets for some months, but they have one continued and uninterrupted day. At the other, or south pole, the same changes take place, only matters are reversed—there it is summer while we have winter, and the winter of the north pole is the summer of the south. In the middle regions of the earth, or around the equator, the sun's place does not suffer a very great change; and, accordingly, there the heat is nearly of the same intensity all the year through; and the length of their days and nights is nearly equal, or nearly the same as at the periods of the equinoxes. But the orbit in which the earth travels round the sun is not an exact circle; it is, as we have already mentioned, an ellipse, and the sun is placed near one end of it, as at the small circle and letter S. In consequence of this circumstance, the sun is much nearer us at one period of the year than another, and this happens in our winter; accordingly, the sun appears about one-thirtieth part larger in January than in June. But in proportion as the earth approaches in her orbit to the sun, her motion is quickened, and she passes over the winter half year in nearly eight days' less time than the summer. It is principally from this circumstance, as well as the shorter period of the day, that although the sun be nearer us in winter, and consequently his power of imparting heat greater, yet the actual quantity imparted is, on the whole, much less in the one season than the other. We have said that the north pole of the earth always points to a particular spot in the heavens; this is not, strictly speaking, correct; the pole or axis makes a circle round the centre of the axis of the ecliptic in a long period of years, and it is this motion that gives rise to the precession of the equinoxes, which will be afterwards described under that title.

ABERRATION OF LIGHT.

Although the most convincing proof of the earth's orbitual motion is not to be found in any circumstance of which the senses can take immediate cognisance, but is afforded by the full development of the planetary system, there is, however, one direct proof of it in a phenomenon discovered by Bradley, an illustrious astronomer. It is called the *aberration of light*, and is manifested by a small difference between the apparent and true places of a star, occasioned by the motion of light combined with that of the earth in its orbit. Vision, it is well known, arises from rays of light proceeding from any object, and entering the eye; and we see the object in the direction in which the rays have come. If both the body giving forth light, and that one which receives it, be at rest, the former will be seen in its true place, at least in so far as aberration is concerned; but let either of the bodies move, and this will not be the case. In order to render this plain, suppose a shower of hail to fall perpendicularly upon a number of tubes—say the pipes of an organ; if the organ remain stationary, the hailstones will descend sheer from the top to the bottom, without any deviation right or left; but move the organ in any direction, and they will strike the side opposite to the direction in which the motion is made. Now, it is just in this way that the eye misses the perpendicular ray, and, meeting an oblique one, receives an impression that the star lies in that direction. The object thus appears displaced, and the amount of displacement is *aberration*. The earth travels at the rate of about nineteen miles per second, and therefore is every instant changing its direction. Time is also occupied by light in traversing space, which it does at the amazing rate of 192,000 miles per second; so that also requires to be calculated for by astronomers. The effect of aberration is to make a star apparently describe a small ellipse in the heavens, in the centre of which it would be seen if the earth were motionless. The reader must carefully distinguish between aberration and refraction; their effects are the same—namely, to displace the ray-projecting object—but they proceed from very different causes. Besides these corrections which astronomers have to make in their calculations, there is another, resulting from what is called *parallax*, which may be as well introduced in this place.

PARALLAX.

The word *parallax*, in its general signification, denotes change of place; but in astronomical books it has a conventional meaning, and implies the difference of apparent positions of any heavenly luminary when viewed from the surface of the earth and from its centre. The centre of the earth is the general station to which all astronomical observations are referred; the situation of a heavenly body, observed from the surface of the earth, is called *the apparent place;* and that at which it would be seen from the imaginary place of observation at the centre of the earth, *the true or mean place*. Hence the altitudes of the heavenly bodies are depressed by parallax, which is greatest at the horizon, and decreases as the altitude of the object increases. This may be rendered very plain, by supposing that two persons placed individually at the end of a straight line, look at a candle removed at, say, 100 yards' distance from them. It is evident that the burning body will appear to be projected upon the wall of an apartment, or any other background, at very different positions to each of the spectators. The angle which this difference of position makes is similar to parallax. The farther they remove from the light, allowing them still to remain at the same distance from each other, the more obtuse the angle would become, and the less the parallax. Thus the fixed stars, being so far removed from us, when viewed from any two positions upon the earth's surface, are seen at the same place upon the celestial sphere, and hence have no perceptible parallax. It is different, however, with the luminaries belonging to our system; and by this means astronomers have been enabled to estimate the quantity of space which separates us from them. For a complete account of the means by which this is accomplished, we must refer the reader to more elaborate treatises than the present. A general and correct enough idea of it may be formed from the familiar example we have given. In the same manner, suppose two observers, one in the northern, the other in the southern hemisphere, at stations on the same meridian, observe on the same day the meridian altitudes of the sun's centre. "Having thence derived the apparent zenith distances," says Sir J. Herschel, "and cleared them of the effects of refraction, if the distance of the sun were equal to that of the fixed stars, the sum of the zenith distances thus found would be precisely equal to the sum of the latitudes north and south of the places of observation; for the sum in question would then be equal to the meridional distance of the stations across the equator. But the effect of the parallax being in both cases to increase the apparent zenith distances, their observed sum will be greater than the sum of the latitudes by the whole amount of the two parallaxes. This angle, then, is obtained by subducting the sum of the latitudes from that of the zenith distance; and this once determined, the horizontal parallax is easily found, by dividing the angle so determined by the sum of the sines of the two latitudes." It may be observed that the angles are determined by means of very nice instruments. The parallax thus obtained is called the *daily* or geocentric, in contradistinction to the annual or heliocentric, by which, in general, is understood the difference of place of a heavenly body, as seen from the earth and from the sun; in particular, however, it denotes the angle formed by two lines from the ends of the diameter of the earth's orbit to a fixed star, which, as we have already observed, from the immense distance of the latter, is inappreciable. Some idea of the importance of parallax may be obtained from the fact, that before the sun's was determined, the distance of that luminary from us was not estimated at within 13,000,000 of miles of its true amount. Its parallax is of course a very minute quantity, only 8″ 6.

OF SOLAR, SIDEREAL, AND ANOMALISTIC YEARS.

There are three different periods at which the sun may, in different senses, be said to return to the same position—when he returns to the same equinox at which he was before; when he returns to the same point in his orbit, or the ecliptic; and when, being in perigee (least distance from the earth), or apogee (farthest distance from the earth), he comes back to either again; or, which is the same thing, when, having been at a given distance from any of these points, he returns to the same point with respect to them. Each of these may be said to be a completion of the revolution of the sun (strictly speaking, it is a revolution of our own earth round him), and a revolution thus performed is called *a year*. The first and shortest is the equinoctial, solar, or tropical year; for his time of returning from tropic to tropic, they being situations holding the same relation to the equinox for the time being, is obviously the same as that from equinox to equinox. The value of this year is 365 days 5 hours 49 minutes nearly. But although the earth has thus returned to the same equinox, it has not made the entire circuit of its orbit, but must travel a little farther to arrive at the same point it was in a year before. This arises from a backward movement of the equinoctial point, as previously explained. The second is the sidereal year, which consists, as we said before, of 365 days 6 hours 9 minutes 9''.6, reckoned in mean solar time, or *a day more*, reckoned in sidereal time. Here, then, there is a remarkable difference between solar and sidereal time, which requires explanation. If the reader will recollect what was said with regard to a solar and sidereal *day*, the discrepancy between the times of the years will become apparent. In the course of twelve months, all the little daily deficiencies, as it were, amount to twenty-four hours, which constitutes the difference between the two years. The sun's apparent *annual* motion among the stars is performed contrary to the apparent *diurnal* motion of the sun and stars; hence the stars gain every day three minutes fifty-six seconds on the sun, which makes them rise that portion of time earlier every day. In the course of a year, the sun will fall behind the stars a whole circumference of the heavens, or one revolution, which deficiency he must make up to complete the number of days in a year. It is evident, then, that the sun apparently, or the earth really, turns 366 times round upon its axis; and had it no other motion, there would be as many days in a year. After the earth or sun has completed a sidereal year, before it can finish an anomalistic year, it must describe a farther arc of 11''.8 to arrive at its original position in perihelion, the latter having moved forward to that amount. In so doing, it occupies 4' 39''.7, which must be added to the sidereal period, making the anomalistic year 365 days 6 hours 13 minutes 49''.3 in length. All these periods have their uses in astronomy; but the one in which mankind are most particularly interested is the tropical year, or that on which the seasons depend, and which is a compound phenomenon, depending chiefly and directly on the annual revolution of the earth round the sun, but subordinately also, and indirectly, on its rotation round its own axis.

MEASUREMENT OF TIME.

Although the sidereal day, from its uniformity, is well adapted for astronomical purposes, yet it is scarcely sufficiently marked for the ordinary wants of life. No person but an astronomer ever attends to the culmination of a star; on this account, the diurnal return of the sun to the same meridian has been universally adopted as the measure of time; and this is called a *civil day*. Most nations reckon the beginning of their day from midnight, but astronomers count from noon to noon. The day thus determined is called the astronomical or solar day, and being regulated by the true motion of the sun, the time which is measured by it is called true or apparent time. Two causes conspire to render astronomical days unequal: first, the variable velocity of the sun in his orbit; and second, the obliquity of the ecliptic. A mean astronomical day, which is independent of any causes of inequality, has been obtained by astronomers introducing into the system two imaginary suns. These two fictitious bodies are supposed to move uniformly, the first in the ecliptic, the second in the equator; and as the circles are both equal, the actual motion of each of the bodies is equal. To those desirous of studying this part of the subject, we would recommend a perusal of the article *Astronomy* in the seventh edition of the Encyclopædia Britannica, page 778, where it is well illustrated. The correction or equation, by which apparent time is reduced to mean time, is technically called the *equation of time*. There are only four days in the year when the apparent and mean time are the same, and the equator of time nothing. In the interval between the first and second of these—that is, December 24th, and April 15th—and, again, in that between the third and fourth—that is, June 15th and September 1st—the apparent is always later than the mean time, or the clock is before the sun; in the other intervals which complete the year, the reverse is the case, and the clock is after the sun. The greatest difference between solar and true time amounts to between fifteen and sixteen minutes. Tables of equation are constructed for the purpose of correcting the differences. For further information on the Measurement of Time, see No. 17 of the present series.

THE MOON.

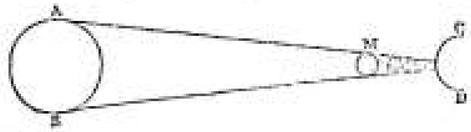
Next to the sun, the moon is to the inhabitants of the earth the most remarkable and important of all the heavenly bodies. The mean horizontal parallax of the moon is 57' 18''; and her mean distance from the earth 236,947 miles. Like the sun, the moon advances in the heavens in a motion contrary to that of the stars. Notwithstanding the vast distance she is from us, it is little more than one-fourth of the sun's diameter, and the globe of that magnificent luminary would nearly *twice* include the whole orbit of the moon! It has various motions; as a secondary planet, it revolves round the earth, which is its primary. Along with the latter, it revolves round the sun, and it has a rotatory motion upon its own axis. Owing to the sun's apparent movement in the heavens being in the same direction with that of the moon, only slower, the latter has to make up for that slowness in the same way as we have mentioned with regard to the earth, and the time it takes constitutes the difference between the sidereal and synodic month or lunation. The sidereal month is 27 days 7 hours 43 minutes 11''.5, in which time the moon performs a complete revolution round her primary; and the other is 29 days 12 hours 44 minutes 2''.87, the time which elapses between two new moons, or two conjunctions of the sun with the moon. It happens that its revolution upon its axis is performed in the same time as its revolution round the earth, so that the same side of her orb is always presented to the latter planet. Although the moon's rotation on her axis is uniform, her motion in her orbit is not so, and we are by this means enabled at times to obtain a peep of the equatorial portions of her eastern and western sides. Her axis, also, is not perpendicular to her orbit, and a small part of each of her poles alternately becomes visible. These phenomena are known by the name of *librations* of the moon, and they are of two distinct kinds, the result of different causes.

The wisdom and beneficence of the Deity are strikingly displayed in the economy of moonlight, as distributed to our globe during various seasons of the year. The remarkable phenomenon of the *harvest* moon is familiar to every one. During the time that our satellite is full, and for a few days before and after, in all about a week, there is less difference between the time of her rising on any two successive nights, than when she is full in any other month of the year. By this means an immediate supply of light is obtained after sunset, so beneficial for gathering in the fruits of the seasons. To conceive of this phenomenon, it must be recollected that the moon is always opposite to the sun when she is full; that she is full in the signs Pisces and Aries, these being the signs opposite to Virgo and Libra, which the sun passes through in September and October, our harvest months. Thus, although, whenever the moon enters the two former signs (and she does so twelve times in a year), the same circumstance takes place with regard to the time of her rising; yet it is not observed on these other occasions, just because she is not *full* at the time. The reason of there being little difference in the time at which she rises on several consecutive nights is, that at these periods her orbit is nearly parallel to the horizon. The harvest moons are as regular in south latitude as with us in north latitude, only they happen at different periods of the year.

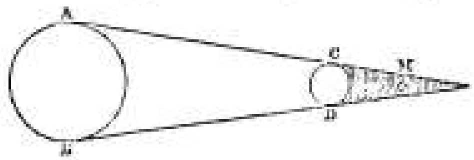
ECLIPSES.

Eclipses are caused by the positions of the earth and moon with respect to each other and to the sun. An eclipse of the sun takes place when the moon is between the sun and earth; and an eclipse of the moon is the result of the earth being between the sun and moon. In other terms, the shadow of the earth cast upon the moon causes a lunar eclipse, and that of the moon upon the earth causes a solar eclipse.

The following figure explains an eclipse of the sun. A B is the sun, M the moon, and C D the earth. The



shadow of the moon falls upon a part of the earth's surface; and there, accordingly, the sun appears in eclipse, the body of the moon being placed between. Another diagram represents an eclipse of the moon. In this instance, A B is the sun, C D the earth, while



the moon appears as a small circle (M) involved in the shadow thrown by the earth.

The planes of the earth's orbit and the moon's do not exactly coincide, but cross or intersect each other; and the consequence is, that in general the moon, when she is in conjunction with the sun, either passes on one side or the other, and therefore does not intercept the sun's rays, or produce an eclipse. An eclipse of this kind can only take place when the earth and moon are in conjunction in that part of their orbits which cross each other (called the nodes), because it is then only that they are both in a right line with the sun. If the orbit of the moon were parallel to that of the earth, an eclipse would happen every month. Partial eclipses, again, are caused when the moon, in passing the earth, is not directly in a line with the sun, but a little on either side; the consequence of which is, the edge of one side of the moon only dips into the sun's disk. When the sun is eclipsed, the total darkness is confined to one particular part of the earth, but the lunar eclipses can be seen from every part of the earth, when the moon is above the horizon; and both circumstances prove that the earth is a good deal larger than the moon. The moon arrives very nearly at the same situation with respect to the earth, after making 223 revolutions, which are performed in eighteen years, of 365 days 15 hours 7 minutes and 43 seconds each; so that, after a period of about eighteen years, the series of eclipses recommences nearly in the same order; a circumstance observed by the ancients. The mean number of eclipses which occur in a year is about four, and there are sometimes as many as seven. There must necessarily be two solar eclipses, but it is possible that there may not be even one lunar. A remarkable eclipse, called an annular (or circular) solar eclipse, happens when the moon, being in conjunction with the sun, the edge of the latter appears for a few minutes as a narrow ring of light encircling all round the dark disk of the moon. A great solar eclipse, visible in England, will take place in March 15, 1858, and a still more remarkable one, when the whole disk will be nearly covered, in August 18, 1887.

THE SATELLITES.

The earth, we have seen, is attended in her annual circuit round the sun by one satellite, the moon, which revolves round her as a centre. Strictly speaking, both move round a common centre of gravity in an elliptic orbit, the regularity of which is disturbed by their mutual attractions, so that it is undulated or waved, thus, ... The number of undulations in a whole revolution is, however, only thirteen, so that the deviation from the ellipse is exceedingly trifling. Jupiter, Saturn, and Uranus, are all attended by satellites, as we have seen; and they form, as it were, each of the primaries with its attendant moons, a sort of miniature system, similar in the laws by which they are governed to the great system to which they all belong, where the sun may be termed the primary planet, and the primary planets the satellites. Their orbits are circles or ellipses of small eccentricity, the primary occupying one focus. Of these systems, that of which Jupiter forms the head has been studied with the greatest attention. The discovery of Jupiter's satellites by Galileo, was one of the first fruits of the invention of the telescope, and forms a remarkable era in the history of astronomy. From it resulted a solution of the great problem of the longitude, and the grand discovery of the velocity of light. It also established completely the Copernican system, and confirmed the laws of Kepler. The satellites of Jupiter revolve from west to east like our moon, but they are much less in comparison with their primary than it, whilst their orbits are of smaller dimensions, and less inclined to the ecliptic of their primary than that of our satellite. The largest of them is about 3377 miles, and the least about 2068 miles in diameter. The satellites of Saturn have been much less studied, and have fewer peculiarities. Those of Uranus, however, are remarkable, inasmuch as their orbits are nearly perpendicular to the ecliptic, and in these orbits they are supposed to have a retrograde motion—that is, from *east* to *west*, instead of from *west* to *east*, like the other planetary bodies. No satisfactory cause for this departure (if it be one) from the general rule can be given. It is by accurate observation of the satellites that the densities of the planets, or their mass as proportioned to their bulks, have been ascertained; as also, by watching their frequent eclipses, that the velocity with which light travels from the heavenly bodies to the earth has been brought within our calculation.

PERTURBATIONS.

The name of *perturbations* has been applied to those inequalities in the lunar and planetary motions which arise from the universality of attraction. Thus not only does the sun attract the earth, and the earth the moon, but the latter attracts the preceding, and both are again influenced in their movements by the great centre of the system to which they belong. Not only is this the case, but every individual planet in the system attracts, and is attracted by, all the rest, although certainly in a very trifling degree when compared with that exercised by the sun over the whole of them. But in those miniature systems—such as the moon and earth, Jupiter and his satellites, &c.—the perturbations thus arising, though insensible in short intervals, become apparent when accumulated, and derange the elliptic motions and relations. The calculation of the effects of these disturbing forces is famous in the history of analysis, under the name of *The Problem of the Three Bodies*. It is so worded, because the Sun, Moon, and Earth, and the Sun, Jupiter, and Saturn, form each separately a system little influenced by the rest. Anything like an attempt to exhibit the method by which these nice calculations are made, is impossible in this place: of its difficulty, some idea may be formed, when we consider, what is apparent to every one, that the bodies under investigation are continually shifting their relative distances from each other, and altering the intensity of the disturbing force, which evidently must materially increase the abstruseness of the calculation. Yet great as the difficulty may be, the effect of these disturbances has been ascertained in many instances with the most rigid accuracy, enabling the astronomer not only to predict positions and revolutions with certainty, but to point, as in the case of the planet Neptune, to the heavens, and to pronounce that there, in such a spot, would a planet appear to the telescope of the observer. One of the principal effects produced on our globe by this play of gravitation is denominated

THE PRECESSION OF THE EQUINOXES.

The equinoctial points, we have already explained, are Aries and Libra, where the ecliptic cuts the equator. They are also termed nodes, and the line which joins the two is called the line of the nodes. The longitudes of the stars, as has been also observed, are counted on the ecliptic from the vernal equinox Aries. Now, if the line of the nodes is invariable, the longitude of the stars will of course remain the same from age to age. But on comparing the actual state of the heavens with the recorded observations of ancient astronomers, it is perceived that the longitudes of the stars have considerably increased; so that, to explain the circumstance, we must either suppose that the whole firmament has moved in the order of the zodiacal signs, or else that the equinoctial points have gone backwards, or retrograded westward; since these points depend entirely upon the motion of the earth, which was far more likely to be disturbed by some cause or other, than that the countless multitude of stars should have a motion relative to these points. Accordingly, the phenomenon has been explained, by attributing to them a retrograde motion from *east* to *west*, in consequence of which the sun arrives at them sooner than if they had remained at rest. Hence the equinoxes, spring and autumn, and the other seasons, happen before he has completed an entire circuit. This motion, however, is extremely slow, amounting only to a degree in about seventy-six years; so that the equinoctial points will take nearly 26,000 years to make an entire revolution of the heavens. This motion was known in very ancient times, and its discovery is ascribed to Hipparchus, who lived about 140 years before Christ. The consequence of this retrograde movement is, that the sun's place amongst the zodiacal signs, at any season of the year, is greatly different from what it formerly was. The vernal equinox now happens in the constellation Pisces; the summer solstice in Gemini; the autumn equinox in Virgo; and the winter solstice in Sagittarius. Astronomers, however, still count the signs from the vernal equinox, which always corresponds to the intersection of the ecliptic with the equator; and on this account it is necessary carefully to distinguish between them.

The cause of precession is to be found in the combined action of the sun and moon upon the protuberant mass of matter accumulated at the earth's equator, the attraction of the planets being scarcely sensible. The attracting force of the sun and moon upon this shell of matter is of a twofold character; one is parallel to the equator, and the other perpendicular to it. The tendency of the latter force is to diminish the angle which the plane of the equator makes with the ecliptic; and were it not for the rotatory motion of the earth, the planes would soon coincide; but by this motion the planes remain constant to each other. The effect produced by the action of the force in question is, however, that the plane of the equator is constantly, though slowly, shifting its place in the manner we have described.

NUTATION.

The action of the sun and moon in producing precession is various, at different periods of the year, according to the relative distance of the earth from them. Twice a-year, the effect of the sun in producing it is nothing; and twice a-year—namely, at the solstices—it is at maximum. On no two successive days is it alike, and consequently the precession of the equinoctial points must be unequal, and the obliquity of the ecliptic subject to a half-yearly variation; for the sun's force, which changes the obliquity, is variable, while the rotation of the earth, which counteracts it, is constant. By this means the plane of the equator is subject to an irregular motion, which is technically called the *solar nutation*. Its amount, however, is so exceedingly small, as not to be appreciable by observation. That resulting from the moon's action, however, is sufficiently so, as to have been discovered by Bradley before theory had indicated its existence. Its period depends upon the revolution of the moon's nodes, which is performed in 18⅔ years, and in about that period of time the axis of the world describes a small circle in the heavens, about eighteen seconds in diameter, contrary to the order of the signs. This apparent vibratory motion is denominated the nutation of the earth's axis. The two phenomena of precession and nutation are intimately connected, or rather are constituent parts of the same phenomenon, and dependent upon the same cause, as noticed above under Precession. It is impossible here to enter more minutely into the subject, or explain it more in detail. For an admirable account of it, we refer the reader to Herschel's Treatise on Astronomy, p. 333. We also would direct the inquirer to the same admirable work for further information upon the subject of perturbations, comprising all the complicated varieties of motion. In general, they may be said to arise from the play of attractions kept up by the whole of the planets amongst themselves, they with the sun, and the sun with them; the distances of the bodies from each other, which are always varying; and the masses of matter, and the shape of the bodies, which are invariable. In concluding this part of our subject, we may remark that it is by means of the perturbations of those planets which have no satellites, that astronomers have arrived at a knowledge of their masses. Every planet produces an amount of perturbation in the motions of any other, proportioned to its mass, and to the degree of advantage or *purchase* which its situation in the system gives it over their movements.

STABILITY OF THE SYSTEM.

It is natural to inquire whether the numerous perturbations which all the heavenly bodies are subject to, are such as, in the long-run, to overthrow the present arrangements of the System. If any cause were at work to diminish steadily the mean distance of a planet, it must of course ultimately fall into the sun. It has, however, been proved, that the total effect of all the mutual disturbances has no such tendency, and that the planets and satellites may revolve for countless ages without any radical change happening to the character of their orbits; they will preserve both their mean distances, and the average shape of their ellipses. The only thing that remains under any suspicion as a means of bringing about a decay in the System, is a resisting medium: that is, if the planetary spaces, instead of being perfectly blank and void, are filled with a very thin gas or ether that would impede the motion of bodies, as our own atmosphere resists any body that is impelled through it. It is at present doubtful whether such an ether exists; it is certain that, if it does exist, it is exceedingly rare, and cannot produce any sensible effect in less than thousands of years. Still, if it exist at all, it must tell some time or other, and will have the effect of lessening the mean distances, and contracting the orbits, so that an end to planetary revolution must be the inevitable consequence. It has been suggested, on the other hand, as probable, that the planetary periods may continue to diminish for thousands of years yet to come, then reach a limit, and afterwards gradually return to their former periods of revolution. This progressive and retrograde, or oscillatory kind of motion, is by no means uncommon in nature, a noted example being found in the magnetic needle, which seems to oscillate between 23 degrees west and 23 degrees east of due north in the course of several hundred years. It is expected, however, that the question of a medium will shortly be decided by a more rigid and extensive study of the comets, which are so light, and so much spread out, that the slightest resistance would soon show itself in contracting their orbits.

GEOLOGY.

Geology (from the Greek *gê*, the earth, and *logos*, discourse), is that science which treats of the materials composing the earth's crust, their mode of arrangement, and the causes which seem to have produced that arrangement. By the earth's *crust* is meant that external shell or covering of solid matter which is accessible to man's investigation; the term being used in contradistinction to the interior mass, respecting the nature and composition of which we can know nothing by inspection. Thin as this crust may seem, it nevertheless presents innumerable objects for investigation; hence the magnitude of the science, which has been ranked in point of importance second only to that of astronomy. The materials which constitute the crust of the globe are exceedingly varied; but whatever their composition, origin, or aspect, they are known by the name of *rocks*. It is with rocks and rock formations which the geologist has to do; arrange and classify them, discover their origin, treat of the organic remains imbedded in them, and thus arrive at some conclusion as to the phases which our planet has assumed during their formation. Geology, therefore, in its widest sense, includes—*physical geography*, which limits itself to the mere surface configuration of the earth, as occupied by land and water, mountains and valleys, and other external appearances; *lithology*, which refers to the composition, order, and relation of the rock masses composing the crust; *mineralogy*, which treats of the individual crystals, or mineral elements, of which rock masses are composed; and *oryctology*, or *palæontology*, which directs itself exclusively to the consideration of the fossil plants and animals that may be found imbedded in the rocky strata. In the present sheet, we shall endeavour to exhibit an outline of the lithology, or rocky structure of the globe, embodying therewith an account of the fossil remains characteristic of the successive steps or formations of that structure; this we may designate *descriptive geology*. Economic geology, as concerns minerals and metals, physical geography, and the other subordinate branches, will form the subjects of separate treatises.

It is necessary, however, before entering upon any analysis of the materials of the earth's crust, to examine the causes which have determined, and which still continue to determine, the formation and arrangement of these materials. We know that some rocky masses are hard and crystalline, others loosely aggregated and earthy; the merest tyro can distinguish between granite, marble, sandstone, and coal, which all differ in composition, and maintain different positions in the crust; some rocks appear always in strata or layers, other in irregular masses, without any determinate arrangement; the petrified remains of land plants and animals are found imbedded in some layers, those of marine animals in others, while many are utterly destitute of such reliquiæ. What, then, are the grand causes for this variety and arrangement of material? Rocks have no inherent vitality, like plants and animals; they cannot add to their material, or transport themselves from place to place; they are inert, lifeless masses, subject in every respect to the physical laws of the universe. Obeying the laws of attraction and gravitation, acted upon by electrical and chemical agencies, worn down by the mechanical effects of winds, frosts, rains, and rivers, borne seaward and strewn in layers beneath the waters, and upheaved again by earthquakes and volcanoes—they are ever being displaced and re-formed, each new formation of material enclosing some relic of vitality, which becomes the test and type of the earth's conditions during the period of its enclosure. Here the ocean encroaches upon the land, there new land emerges from the ocean; what is now dry land and rocky heights, was once loose material beneath the waters; and seas now roll their waves over the surface of ancient continents. Nor is there any cessation of this alternating process: a little shifting of the theatre of activity, periods of greater or less intensity, and a progress in vital development, are the only diversities which mark the onward operation of these ever-modifying causes. As they are the prime sources of all geological phenomena, so a knowledge of their power and mode of action forms the basis of all true geological knowledge.

CAUSES MODIFYING THE EARTH'S CRUST.

These causes chiefly resolve themselves into *degrading* and *elevating*; that is—whether they be mechanical, chemical, or vital in their nature—their effects mainly tend to raise or to depress certain portions of the earth's crust beneath the surface-level of the ocean.

Degrading Causes.—These refer to the wearing down of the elevated portions of the earth's surface, and the transport of the materials to lower levels. The *disintegration* is brought about by certain mechanical and chemical forces, and the *carrying down into low levels* is, in the main, a result of the law of gravitation. Considering that the solid parts of the earth are in their very nature liable to the operation of these forces, it appears quite unavoidable that land should be degraded. The causes of this degradation may be considered under three heads—*meteoric*, or those connected with the atmosphere; *fluviatile*, or those depending on rivers; and *oceanic*, or those in which the sea is the immediate agent.

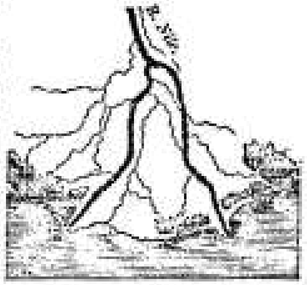
The operation of the atmosphere and its vapoury contents upon the land proceeds in two ways—chemical and mechanical. There is a tendency in the hardest rock to absorb oxygen and carbonic acid from the atmosphere, and to be by that union dissolved. And this is a union which is always occurring, though in some places with more conspicuous results than elsewhere. If the soil on any hill of volcanic rock be examined, we shall first find a fine powdery earth, then a mixture of earth and splinters of rock, next splinters alone, graduating into the hard rock below; and such may be considered as an exhibition of the gradual process by which any rock is disintegrated into soil under the action of the atmosphere. In Jamaica, this disintegration of volcanic rock has taken place to a great depth. In granite, which is considered the most durable of all rocks, one of the component substances (felspar) has a great tendency to be decomposed; hence even this rock is sometimes found to have been reduced to gravel or powder to a considerable depth. A hollow way, blasted through granite, was found in one instance to have been in six years pulverised to the depth of three inches. These are solely *chemical* phenomena.

Again, water percolates through minute fissures in rocks. When frost arrives, the water freezes and swells, and thereby dislodges parts of the rock, which are precipitated into lower levels. Or it may meet some clayey veins or strata, hitherto sufficient to keep various masses together: these veins or strata, being gradually softened by the water, lose their power of cementing the masses; and the upper then fall away or slide into a lower level. A *slide* of rock from the Ruffiberg, in Switzerland, in 1806, filled the bottom of the vale below, destroying many villages, and causing the loss of 800 lives. The impulse of wind and rain on the surface of rock is also of great efficacy in pulverising and wearing it down, sharp parts being rounded, and soft parts hollowed. In Sweden there are some large detached masses of granite, containing perforations produced by this cause, some so very large as to admit of a horse and cart passing through them. These effects may be considered as chiefly *mechanical*.

When water collects into channels, and follows its well-known tendency to find the lowest level to which it has access, it becomes a mechanical instrument of still greater force for wearing down the land. In its smallest rills, as it descends the mountain side, it cuts into the soil, and carries off whatever particles it can disengage. When gathered into brooks, its operations are still more powerful. When one of these is placed amongst mountains, every heavy shower swells it into an impetuous river, by which large quantities of detached rock and soil are brought down. In the upper parts of the courses of almost all rivers, the greater speed of descent makes up for the smaller volume of water, as far as the power of bringing down stones and soil is concerned. Again, in the lower part of the course, the smaller speed is sometimes compensated by the unevenness of the course; in which case the water is incessantly driven from one projection of the banks against another, and by that means wears away a great quantity of solid matter. The mere flowing of pure water would exert little influence on hard rocks; but all rivers carry down sand and gravel according to their velocity;* and these, by rubbing and striking against the sides and bottoms of the channel, assist in scooping out gullies and ravines, which everywhere present themselves. The Nerbuddah, a river of India, has scooped out a channel in basaltic rock 100 feet deep. The river Moselle has worn a channel in solid rock to the depth of 600 feet. Messrs Sedgwick and Murchison give an account of gorges scooped out in beds of the rock called conglomerate, in the valleys of the Eastern Alps, 600 or 700 feet deep. A stream of lava, which was vomited from Ætna in 1603, happened to flow across the channel of the river Simeto. Since that time the stream has cut a passage through the compact rock to the depth of between forty and fifty feet, and to the breadth of between fifty and several hundred feet. The cataract of Niagara, in North America, has receded, according to most authorities, nearly fifty yards during the last sixty years. Below the Falls, the river flows in a channel upwards of 150 feet deep, and 100 yards wide, for a distance of seven miles; and this channel has manifestly been produced by the action of the river.

Sometimes, during floods, rivers produce great changes in very short periods. A flood caused by the bursting of the barrier of a lake in the valley of Bagness, Switzerland, moved at first with the tremendous velocity of thirty-three feet per second. From the barrier burst by the waters to Lake Geneva, there is a fall of 4187 Paris feet; the distance is forty-five miles; and the water flowed over all this space in five hours and a half. It carried along houses, bridges, and trees; and masses of rock equal in size to houses were transported a quarter of a mile down the valley.

The matter carried down by rivers is often deposited at their sides, when it constitutes what is called *alluvial land*. Sometimes it is deposited at the bottom of lakes, when it forms what are termed *lacustrine deposits*. In many instances it has been deposited in large quantities at the mouths of rivers, giving rise to alluvial flats, which, from their resemblance in shape to the Greek letter Δ, have been denominated *deltas*. The triangular form of a delta, like that of the Nile, for example, is produced by the river at a certain point inland, dividing itself into two main streams, which gradually diverge till they reach the ocean, enclosing the space which constitutes the delta. As an instance of the great amount of new land formed at the mouths of rivers, the delta of the Ganges is 220 miles in one direction, by 200 in another.



The matter carried down by rivers, and thus deposited, is nothing in amount compared to that transported to the ocean. The quantity of sand and mud brought down by the Ganges to the Bay of Bengal, is in the flood season so great, that the sea is discoloured with it sixty miles from the river's mouth. Mr Lyell states the quantity of solid matter brought down by this river every day, as equal in bulk to the greatest of the Egyptian pyramids. According to Captain Sabine, the muddy waters of the Amazon river may be distinguished 300 miles from its mouth.

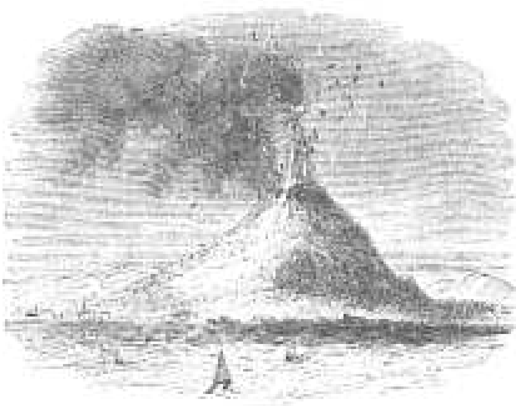
The constant action of the sea upon the land is strikingly apparent to the inhabitants of coasts. Whole islands have been destroyed by the action of tides, waves, and oceanic currents, while the remains of others rise above the surface of the water, like the ruins of some desolated city. Many instances of the encroachment of the sea upon the land have been recorded. An inn on the coast of Norfolk, built in 1805, then seventy yards from the sea, was, in 1829, separated from the coast by only a small garden. A church on the coast of Kent, which, in the reign of Henry VIII., was a mile inland, is now only about sixty yards from the water's edge. The island of Nordstrand, on the coast of Schleswig, was, in the thirteenth century, fifty miles long and thirty-five broad. About the end of the sixteenth century, it was reduced to an area of only twenty miles in circumference. The inhabitants erected lofty dikes for the purpose of saving their territories; but in the year 1634 a storm devastated the whole island, by which 1340 human beings, and 50,000 head of cattle, perished. Three very small islets are all that now remain to point out the place where once flourished the fertile island of Nordstrand.

It thus appears that there are causes in continual operation for the wearing down of the elevated parts of the earth's crust, and taking the component particles into lower levels. The effects of these causes may be easily traced in the aqueous rocks, many of which are simply deposits of sediment carried by water from high into low places, and subsequently hardened, probably by heat from below and pressure from superincumbent materials. Were such causes not in some way counteracted, dry land could not long exist; all would be taken down and buried in the sea—our planet being reduced to a plain spherical mass. We find the counteraction in certain forces incessantly tending to elevation of the superficial rocky crust.

Elevating Causes.—As degrading forces are chiefly owing to water, so those of an elevating character are chiefly owing to fire. They are therefore sometimes comprehended under the term *Igneous Agency*.

The manifestations of igneous agency at present observable may be considered under three heads—namely, *volcanoes*, *earthquakes*, and *gradually-elevating forces*. These phenomena may be viewed as the effects of subterranean heat, operating under different circumstances. A volcano may be described as an opening in the earth's surface, bearing the general appearance of a vent of subterranean fire, and through which smoke, cinders, and ashes are almost continually issuing, but which sometimes discharges great fragments of rock, and vast quantities of melted rocky matter, or *lava*. The general effect is a throwing up of earthy material, in a conical form, from a low to a high level, as represented in the following view of Mount Ætna.

* It has been calculated that water running with a force of 3 inches per second will tear up fine clay, 6 inches will lift fine sand, 8 inches sand as coarse as linseed, and 12 inches fine gravel; while it requires a velocity of 24 inches per second to roll along rounded pebbles an inch in diameter, and 36 inches per second to sweep forward angular stones of the size of a hen's egg.



Geographers at present reckon about 200 volcanic vents in activity throughout the earth. The greater number of the whole are in a line along the west coast of South and North America. There are many in the islands of the Pacific and Indian Oceans, and in the central regions of Asia. In Europe, there are only three in great activity—Ætna in Sicily, Vesuvius in Italy, and Hecla in Iceland. But a vast number of hills throughout France, Britain, and other countries, bear the appearance of having once been active volcanoes. As volcanic action often takes place in the bed of the sea (submarine volcanoes), and as there are probably many on land not yet described by geographers, the number of such vents throughout the earth must be considerably more than two hundred.

Of the power of volcanoes to throw up large quantities of solid matter, we have many examples. During an eruption of Ætna, a space around the mountain, 150 miles in circumference, was covered with a layer of sand and ashes, generally about twelve feet thick. In the first century, the cities of Herculaneum and Pompeii were buried beneath such a layer of matter by Vesuvius. In 1660, the philosopher Kircher, after accurately examining Ætna, and the ground adjoining its base, calculated that the whole matter thrown out by it at its various active periods, would form a mass twenty times as large as the mountain itself, which is 10,870 feet high, and thirty miles in diameter at the base. From this mountain, in 1775, there issued a stream of lava a mile and a half in breadth, twelve miles long, and 200 feet thick. At an earlier period, there was a stream which covered eighty-four square miles. In 1538, a large hill, since named Monte Nuovo, was thrown up in the neighbourhood of Naples in one night; and in 1759, in a district of Mexico previously covered by smiling plantations, a sudden outburst of volcanic action, which lasted several months, terminated in leaving six hills, varying from 300 to 1600 feet in height, above the old plain.

Of the effect of submarine volcanoes, some interesting observations have been made in recent times. In June 1811, an island was thrown up by volcanic agency, near St Michael's, in the Azores. Columns of cinders rose 700 or 800 feet above the surface of the sea, with a noise resembling that of distant artillery. In the course of a few days, the island was a mile in circumference, and about 300 feet in height, having a crater in the centre full of hot water. Some time afterwards it disappeared. In July 1831, a similar island was thrown up, under precisely similar circumstances, in latitude 37° 11′ north, and longitude 12° 44′ east, off the coast of Sicily. It consisted of stones, mud, and cinders, and was of circular form, about a mile and a half in circumference, with a crater of hot water in the centre, 400 yards in diameter. This island, named Sciacca, or Graham's Island, existed so long above the sea as to allow of many persons landing upon it. The Bay of Santorin, in the Greek Archipelago, which is about six miles long and four broad, contained, a few years ago, three volcanic isles, the first of which rose about the year 200, the second in 1650, and the third in 1709. In a part of the bay, where the water is generally several hundred feet deep, a shoal has for several years been gradually rising: about 1816, there were fifteen fathoms water upon it; in 1830, there were only three or four; the later accounts reduced it to two and a-half. This rising mass was ascertained to be of solid rock, about half a mile in length, by one-third of a mile in breadth; the water deepening suddenly all round it.

Many islands which have long been inhabited by man, bear all the appearance of having risen, in like manner, from the bosom of the deep. The islands of St Helena and Ascension, the Azores, the West India islands, Iceland, and many of the islands in the Pacific, are evidently the produce of volcanic action. "Owhyhee," says M. de la Beche, "is a magnificent example of such an island: the whole mass, estimated as exposing a surface of 4000 square miles, is composed of lava, or other volcanic matter, which rises in the peaks of Mouna Roa and Mouna Kaa, to the height of between 15,000 and 16,000 feet above the level of the sea."

The causes of earthquakes have not as yet been satisfactorily explained, but they are now generally allowed to be connected with volcanic agency. They occur less frequently, and generally with less tremendous effect, in Europe, than in some other parts of the world—those parts where volcanic agency is most active, being also the parts where earthquakes are most frequent and most dreadful. Though their effect is sometimes to cause a sinking of the ground, they may, upon the whole, be considered as among elevating causes. It is conceived that they are produced by gases confined in the molten interior of the earth, similar to those which find vent by volcanoes. Such gases, prevented by local circumstances from escaping, may, it is thought, thus shake the solid ground over a large tract, and even cause it to rise to a certain extent above its former level. The most striking proof which has been adduced in support of this doctrine, is the effect of the earthquake which took place in Chili in 1822. This is part of that continent in which volcanoes are most numerous and active. On the occasion referred to, a shock was felt along the coast for more than 1000 miles. The land for 100 miles along the coast, and backwards to the line of the Andes, was raised above its former level. At the shore, and for some distance along the bottom of the sea, the rise was three or four feet; so that rocks formerly submerged, and covered with shellfish, were now exposed above the sea. Old beaches, similar to that now raised, have also been observed in parallel lines along the coasts of Chili and Peru, ranging, according to Mr Darwin and M. Von Tschudi, from twenty to 120 feet above the ocean.

It has since been observed that old beaches, similar to those in Chili, exist in the neighbourhood of many seas. Along the Firth of Forth, in Scotland, there is one very conspicuous about forty feet above the present level of the sea, and which generally appears as a kind of bank a few hundred yards back from the present shore. In the Firths of Clyde and Cromarty, and indeed in every place along the British coasts favourable for their preservation, similar beaches, from twenty to several hundred feet above the present sea level, can be traced. They may always be detected by their terrace-like level, and by the presence of rounded pebbles, gravel, sand, and in some instances sea-shells, such as usually compose beaches at the present day. In some places, old beaches have been conspicuous enough to become objects of popular wonder. In the vale of Glenroy, in Inverness-shire, as also in some neighbouring vales connected with Glenroy, there are three terraces along the sides of hills, at the successive heights of 972, 1065, and 1165 feet, which the ignorant people of the district firmly believe to have been roads formed by the hero Fingal for hunting, but which are now shown pretty clearly to have been the shores of quiet estuaries or arms of the sea, similar to many which still exist in the Scottish Highlands. Among the Alps, in Spain, France, Norway, in North and South America, and indeed in almost every region which has undergone a narrow inspection, there are vales marked in exactly the same way as Glenroy.

The existence of a force which *gradually elevates* the land in many places out of the water, was discovered by Mr Lyell. His chief observations were made upon the shores of the Gulf of Bothnia, which he ascertained to have risen several feet in the course of the last century, and a few inches even since 1820.

Besides the greater elevating causes arising from subterranean fires, there are some lesser ones of less mysterious origin. The sands deposited on beaches are sometimes blown by winds in upon the land, covering the vegetable soil throughout a large space, and in some instances forming hills of considerable height and magnitude. Some parts of the coast of Holland are thus fenced with ranges of sand-hills, the whole mass of which has been blown back from the sea. On some parts of the French coast, large tracts, once smiling with cultivation, are thus buried under a sterile layer of sand, which is continually advancing, notwithstanding every effort of man. On the coast of Moray, in the north of Scotland, a tract once forming the barony of Culbleen, has been transformed into a sandy tract since the fifteenth century.

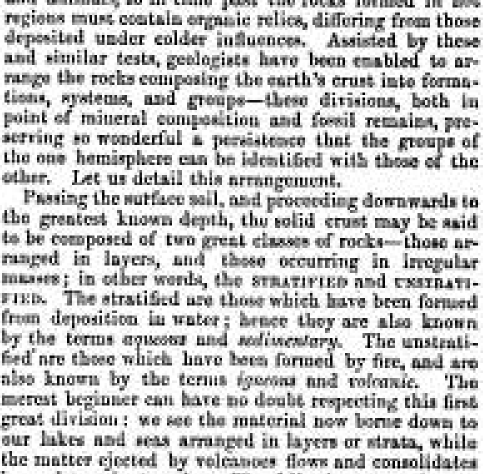
In various parts of the world, new land is elaborated by the efforts of coral insects. The works of these creatures are seen upon a vast scale in the Pacific, where whole ranges of islands are formed by them. On the coast of New Holland, there is a coral reef which stretches out to a thousand miles in length. The insects do not commence their laborious operations at a great depth below water; from sixty to 100 feet is considered the utmost extent to which the coral extends downwards. Many of these islands are of a circular or oval shape; hence the opinion that corals build upon the rims and in the centers of submarine volcanoes. The outer wall of the building emerges first above the waves, enclosing a pool of tranquil water. The seeds of vegetables are either brought there by sea-birds, or wafted by the ocean, and the islands soon become clothed with a mantle of green. The substance of which these islands and reefs are composed is lime, which the insects secrete from the sea-water, and cement together with a glutinous matter contained in their bodies. Mr Lyell, while surveying the Isthmus of Panama, detached a quantity of these animals, and placed them on some rocks in a shallow pool of water. On returning to remove them a few days afterwards, he found they had secreted stony matter, and had firmly attached themselves to the bottom. To such *organic* agencies of elevation as the coral animalcule, may be added the growth of shell-beds, the formation of peat, and other accumulating vital forces which contribute to the solid material of the earth's crust.

If we consider the operation of the elevating causes, we can be at no loss to understand how we should now see, as composing dry land, and sometimes in very lofty situations, strata which were once at the bottoms of seas; neither will it be surprising, if the irregular nature of volcanic forces is considered, that the strata so elevated rarely are found in their originally level position, but in all degrees of inclination—sometimes quite on edge, and even in certain rare instances folded backwards, so as to be upside down.

CLASSIFICATION OF ROCKS.

Subjected from the earliest periods to these conflicting forces, the crust of the earth must have undergone frequent and extensive modifications—modifications not merely as regards distribution of land and water, or of relative elevation and depression, but changes as to the composition and arrangement of the rocky material. The material of the first-formed rocks must have gone to compose those that followed, and so on in succession, to the present age. The series of rocks formed during any one era must present certain differences characteristic of that era, whether it was one of comparative quiet or of volcanic disturbance, and whether it was distinguished for exuberance or comparative destitution of vegetable and animal life. Again, just as at present fresh-water deposits differ from marine, so must rocks formed in lakes and estuaries differ from those deposited in the ocean; and as different climates are peopled by different kinds of plants and animals, so in time past the rocks formed in hot regions must contain organic relics, differing from those deposited under colder influences. Assisted by these and similar tests, geologists have been enabled to arrange the rocks composing the earth's crust into formations, systems, and groups—these divisions, both in point of mineral composition and fossil remains, preserving so wonderful a persistence that the groups of the one hemisphere can be identified with those of the other. Let us detail this arrangement.

Passing the surface soil, and proceeding downwards to the greatest known depth, the solid crust may be said to be composed of two great classes of rocks—those arranged in layers, and those occurring in irregular masses; in other words, the STRATIFIED and UNSTRATIFIED. The stratified are those which have been formed from deposition in water; hence they are also known by the terms *aqueous* and *sedimentary*. The unstratified are those which have been formed by fire, and are also known by the terms *igneous* and *volcanic*. The merest beginner can have no doubt respecting this first great division: we see the material now borne down to our lakes and seas arranged in layers or strata, while the matter ejected by volcanoes flows and consolidates in no determinate order. The following engraving represents the appearance which the stratified and unstratified rocks present in a section of the earth's crust.



Unstratified. Stratified.

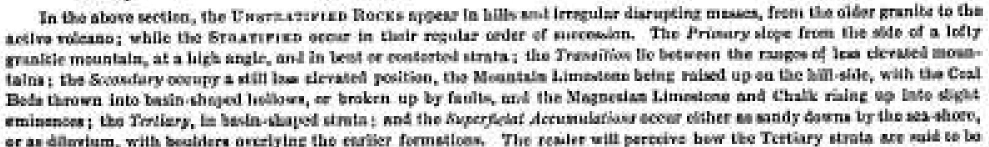
Reverting to the stratified division, the geologist finds them consisting of various materials, variously consolidated and crystallised, variously impregnated with metallic substances, and characterised by different remains of plants and animals. Here he finds sand and gravel, there clay and boulders; in one place chalk, in another coal; here marble, there roofing-slate; and so on in vast variety. He observes, besides, a certain order of superposition, notwithstanding that the igneous rocks have often disturbed the regularity of the stratified, and broken them up into inclined, contorted, and confused positions. On these grounds, the stratified rocks have been arranged into formations, systems, series, and groups. Thus the term *formation* is applied to designate strata which seemed to have been formed under nearly similar circumstances. A formation may consist of several *systems*—that is, strata having nearly the same mineral and fossil character; and there may be several *groups* in a system, such as a sandstone or limestone group. All these groups consist of *strata* which, according to their thickness or external appearance, are designated *beds*, *seams*, *layers*, *schists*, or *slates*. Bearing these terms in mind, the reader will be prepared to understand the following tabular arrangement of stratified rocks as they occur in the British islands:—*

* At this stage the student should direct his attention simply to the names and order of the formations, systems, and groups—returning to the details of the TABLE as a study after he has perused the descriptive portion of the treatise.

SUPERFICIAL.		SOIL—decomposed vegetable and animal matter, with earthy admixtures.
		ALLUVIUM—deposits of sand, gravel, and clay, formed by the ordinary action of water.
		DILUVIUM—deposits of gravel and clay with boulders, formed by unusual operations of water.
TERTIARY.		CRAG—calcareous conglomerate of marine shells and gravel; beds of marl.
		FRESH-WATER, OR ESTUARY BEDS—consisting of marls, imperfect limestones, and clays.
		MARINE BEDS—consisting of blue and plastic clays, thin beds of sand, lignite, &c.
SECONDARY FORMATION.	*Chalk System.*	CHALK—soft and white, with layers of flint; chalk, hard, and without flints.
		GAULT, or beds of bluish marly clays, with green sand.
		GREEN-SAND—beds of green ferruginous sands, with chert nodules.
	Oolitic System.	WEALDEN GROUP—beds of clay, argillaceous limestones, and sands.
		OOLITE—beds of oolite limestone, calcareous grits, sands, and clays, all calcareous.
		LIAS GROUP—bluish clays, alum shales, marls, and limestones, all finely stratified.
	New Red Sandstone System.	SALIFEROUS MARLS—variegated shales and shell limestone, with bands of sandstone.
		RED SANDSTONE GROUP—fine-grained, sometimes conglomerate.
		MAGNESIAN LIMESTONE—thick-bedded limestones and calcareous conglomerates.
	Carboniferous System.	COAL MEASURES—alternating beds of coal, shale, ironstone, and sandstone.
		MOUNTAIN LIMESTONE—thick-bedded grayish limestones and shales.
		CALCIFEROUS SANDSTONES—white, thick-bedded sandstones, and calcareous shales.
	Old Red Sandstone System.	YELLOW SANDSTONES, with beds of mottled shales and marls.
		RED SANDSTONES—sometimes fine-grained, sometimes quartzose and conglomerate.
		GRAY OR RUSTY-COLOURED SANDSTONES—micaceous, and often in flags or thin bedded.
TRANSITION.	*Silurian System.*	UPPER SILURIAN rocks—gray and bluish limestones, with coloured micaceous shales.
		LOWER SILURIAN rocks—impure shelly limestone, mottled sandstones, dark calcareous flags.
	Grauwacke System.	HARD ARGILLACEOUS rocks—thick-bedded sandstones, slaty sandstones and limestones.
		FINE AND COARSE-GRAINED slaty rocks—gray micaceous slates.
PRIMARY.	*Clay-Slate System.*	CLAY-SLATE—finely laminated; dark, liver, and purplish-coloured.
		HORNBLENDE AND CHIASTOLITE SLATES—finely laminated.
	Mica Schist System.	CHLORITE SLATES—greenish-coloured slates, with mica, mica-schist, talc schist, crystalline limestone, and quartz rock.
	Gneiss System.	GNEISS ROCKS—intermingled with irregular beds of quartz rock, crystalline limestone, and mica schist.

It must not be supposed, however, that the stratified rocks always occur in any portion of the earth's crust in full and complete succession, as represented above: all that is meant is, that such would be their order if every group and formation were present. But whatever number of groups may be present, they never happen out of their regular order of superposition—that is, clay-slate never occurs above coal, nor coal above chalk. Thus at London, tertiary strata occupy the surface; in Durham, magnesian limestone; in Fife, the coal measures; and in Perthshire, the old red sandstone and clay-slate: so that it would be fruitless to dig for chalk in Durham, for magnesian limestone in Fife, or for coal in Perthshire. It would not be absurd, however, to dig for coal in Durham, because that mineral underlies the magnesian limestone; or for old red sandstone in Fife, because that formation might be naturally expected to occur under the coal strata of that county, in the regular order of succession.

The unstratified or igneous rocks occur in no regular succession, but appear amidst the stratified without order or arrangement, heaving them out of their original horizontal positions, breaking through them in volcanic masses, and sometimes overrunning them after the manner of liquid lava. From these circumstances, they are in general better known by their mineral composition than by their order of occurrence. Still, it may be convenient to divide them into three great classes—*granitic*, *trappean*, and *volcanic*; granitic being the basis of all known rocks, and occurring along with the primary and transition strata; the trappean, of a darker and less crystalline structure than the granitic, and occurring along with the secondary and tertiary rocks; and the volcanic, still less crystalline and compact, and of comparatively recent origin, or still in process of formation. This division of the igneous unstratified rocks subserves many useful purposes in geology, at the same time that it is a distinction warranted by the nature, aggregation, and aspect of their component minerals. The *granitic*, so named from their distinctly granular and crystalline texture, comprise granite, syenite, serpentine, porphyritic, and other varieties of granite. The *trappean* (Swedish, "trappa," a stair) are so called from the step-like or terraced sides of the hills formed by these rocks, which include basalt, greenstone, clinkstone, trachyte, amygdaloid, &c. The *volcanic*, as the name implies, are those products discharged by recent or active volcanoes, such as lava, scoriæ, pumice, and tufa. As associated in the crust of the earth, the unstratified and stratified rocks would present something like the annexed section:—



Tertiary. | *Secondary.* | *Transition.* | *Primary.*

In the above section, the UNSTRATIFIED ROCKS appear in hills and irregular disrupting masses, from the older granite to the active volcano; while the STRATIFIED occur in their regular order of succession. The *Primary* slope from the side of a lofty granitic mountain, at a high angle, and in bent or contorted strata; the *Transition* lie between the ranges of less elevated mountains; the *Secondary* occupy a still less elevated position, the Mountain Limestone being raised up on the hill-side, with the Coal Beds thrown into basin-shaped hollows, or broken up by faults, and the Magnesian Limestone and Chalk rising up into slight eminences; the *Tertiary*, in basin-shaped strata; and the *Superficial Accumulations* occur either as sandy downs by the sea-shore, or as diluvium, with boulders overlying the earlier formations. The reader will perceive how the Tertiary strata are said to be above the Coal Measures, though they do not overlie them; and how the Coal Beds are above the Transition Rocks, though removed from each other by a wide extent of country.

ROCK FORMATIONS AND ORGANIC REMAINS.

PRIMARY.

Granite.—Geologists have been accustomed to describe this as the lowest and oldest of all rocks; and certainly no other rock has ever been found beneath it, except in peculiar circumstances afterwards to be described. If the mass of the earth, therefore, were to be judged of from the thin superficial crust with which we are acquainted, and were we not aware of its inconsistency with the mean density of the globe, as ascertained by astronomy, granite might appear to constitute the bulk of our planet—a vast nucleus on which all the stratified rocks rested. Geologists are now disposed, under a sense of their limited knowledge, to speak of granite, not as the lowest and oldest of all rocks, but as the lowest as yet discovered, and as one which, though in most of its forms old, is yet sometimes found of recent development. Granite, in fact, often appears as an igneous rock, which has been thrown up in a state of fusion through superincumbent strata of all kinds, penetrating into their chinks, and spreading over them on the surface. Even tertiary rocks are found broken up and covered by it—a proof that it has been formed since the deposition of those rocks, which is one of the most recent events in geological chronology. These are the peculiar circumstances in which it may be said that other rocks sometimes lie beneath granite.

Granite, then, may be described as generally forming a basis or bed for all the other rocks—as rising in some places from its unmeasured depths into chains of lofty hills—and as in other places penetrating in veins through superincumbent rocks, and partially covering them. It composes a considerable portion of the mountain ranges of Cornwall, Cumberland, Wicklow in Ireland, and the Scottish Highlands. The Alps, the Pyrenees, the Dofrefelds, the Abyssinian and other ranges in Africa, and the Andes in South America, are all more or less composed of rocks partaking of a granitic character.

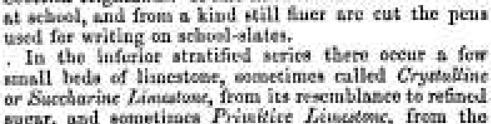
Three substances usually enter into the composition of granite; namely, (1) *quartz* or silex, a whitish glassy substance, composed of oxygen in union with one of the metallic base, silicium; (2) *felspar*, also a crystalline substance, but usually opaque and coloured pink or yellow, composed of siliceous and clayey matter, with a small mixture of lime and potash; (3) *mica*, a silvery glittering substance, which divides readily into thin leaves or flakes, and consisting principally of flint and clay, with a little magnesia and oxide of iron. In some granites, instead of mica, we find *hornblende*, a dark crystalline substance, composed of alumina, silex or flint, and magnesia, with a considerable portion of the black oxide of iron. Such granites are called *Syenite*, from their abundance at Syene in Egypt. Other varieties are—*Serpentine*, in which there are dark spots like those on the skin of the snake (hence the name), and *Porphyry* (from its reddish colour), of which the distinguishing peculiarity is its containing little angular pieces of felspar enclosed in the mass. Any igneous rock containing such fragments, distinct from the common mass, is said to be *porphyritic*.

Granite may then be regarded as a true igneous rock,* associated principally with the primary and transition formations, but occasionally exhibiting itself in outbursts and elevations among the strata of later eras. It presents numerous varieties; but these, either in the field or in cabinet specimens, are readily distinguishable from trappean and volcanic compounds.

Inferior Stratified Series.—Above the granite, in its ordinary position, lies the inferior stratified series, consisting mainly of two kinds of rock—gneiss and mica-slate—with alternating strata of hornblende rock, quartz rock, eurite, talcose slates, chlorite slates, and argillaceous slates; of all of which it may be said that they follow no very determinate order. The lowest of these rocks are of the same materials as granite, in a very slightly modified form, and they are nearly as crystalline in their texture. Geologists also find in many places that the granite *passes* into them—a term expressing a blending of the characters of rocks at the line of their junction. These two facts have led to the supposition, that the inferior stratified rocks were formed from the materials of the granite, disintegrated by mechanical or chemical means, and washed into the beds of vast seas, where, on their deposition, they were reached by the high temperature of the interior, and thereby reconsolidated in a crystalline form. To account for the rocks composed exclusively of one of the materials of the granite, we may suppose some chemical separation of those materials.

The most prevalent rock of the series is *gneiss*, a compound, like granite, of quartz, felspar, mica, and hornblende, and so highly crystalline as to be sometimes scarcely distinguishable from granite. A great portion of the Highlands of Scotland is composed of strata of gneiss, of vast thickness. *Mica-slate* or *mica-schist*, the next most prevalent rock of the series, is composed of mica and quartz. It is the surface rock of many extensive tracts of country. *Quartz rock*, which we may suppose to have been formed by a chemical separation of that component of granite, is also a prevalent rock. Humboldt takes notice of a mass of it in South America, more than 9500 feet in thickness. The round white pebbles, or "candy" stones, so often found on sea-beaches, and in the beds of rivers, are pieces of quartz rock. *Eurite*, of which felspar is the main ingredient, and *hornblende rock*, the chief element of which is signified by its name, may also be accounted for by a chemical origin.

Clay-slate is the geological term for the well-known stone with which houses are roofed. It is, as its name imports, composed mainly of clay—a substance too liberally diffused amongst the ingredients of granite, to admit of any wonder as to its being found in a nearly distinct state in this rock. Mica-slate and clay-slate are *fissile* in their structure—that is, capable of being split into very thin plates: hence the utility of slate as a material for covering houses. But a curious diversity exists in this respect between mica-slate and roofing slate. In the former, the *cleavage*, or direction in which it splits, is in the same line as the stratification; but in roofing slate, the cleavage is always more or less transverse. What makes the latter circumstance the more remarkable—when strata of roofing slate are found, as often happens, contorted or wavy, the direction of the cleavage is in one straight line through them all, indicating that the influence which produced the cleavage in that rock took effect after the whole had been laid down, and after, by some subsequent accident of pressure, they had been forced into a wavy direction.



Section Exhibiting Lines of Cleavage in Clay-Slate.

Probably this phenomenon owes its origin to electric or magnetic agency. Clay-slates are found in great abundance in Cornwall, Wales, Cumberland, and the Scottish Highlands. A fine kind makes the slates used at school, and from a kind still finer are cut the pens used for writing on school-slates.

In the inferior stratified series there occur a few small beds of limestone, sometimes called *Crystalline* or *Saccharine Limestone*, from its resemblance to refined sugar, and sometimes *Primitive Limestone*, from the period of its occurrence in the series. In Greece and Italy this rock has been subservient to the development of national talents, the highest that have ever been known of their class, for it is the marble from which the works of the Greek and Italian sculptors have been formed. In the geological history of our globe, its first appearance in the ascending series of rocks is an event of no small consequence, for limestone strata form a large proportion of the superior formations, and the manner in which they have been formed has engaged much attention. Limestone is the *carbonate of lime*; that is, a combination of the earth lime (itself a union of the metal calcium and oxygen) with carbonic acid (this being, again, a union of oxygen with the elementary substance carbon). Carbon is the largest element in the composition of vegetable and animal substances, and this its first appearance in the structure of rocks is of course a point of much interest, more especially as it is generally concluded that many of the superior limestone strata have been entirely formed

* To avoid all theory as to the origin of the Granitic Group, some geologists employ the term *hypogene rocks* (Gr. *hypo*, under; and *ginomai*): that is, nether or under-formed rocks.

of animal remains. We are thus tempted to surmise that the formation of the limestone beds of the inferior stratified series, marks some early and obscure stage of organic existence on the surface of our planet. No distinct remains of plants or animals have, indeed, been found in the series; and it is customary to point to the next upper series, in which both do occur, as the dawn of organic life. Yet many geologists are of opinion that the inferior stratified rocks might have contained such remains, though the heat under which the rocks seem to have been formed may have obliterated every trace of such substances. The inferior stratified series constitutes in most regions the great depository of the metals—gold, silver, tin, copper, &c.—which occur in irregularly-intersecting veins, composed of ore-stone differing in composition from that of the containing strata. For opinions as to the origin and character of veins, we must refer to the sheet—"METALS AND METALLURGY."

TRANSITION.

Grauwacke and Silurian.—All the rocks hitherto described are of crystalline texture, and, apparently, chemical phenomena have attended their formation. In the group we have now arrived at, traces of mechanical origin and deposition become apparent; but still a few strata resembling the preceding occur throughout the lower parts of this series, as if the circumstances under which the earlier rocks were formed had not entirely ceased. Hence the term *transition*, as implying a passing from one state of things to another.

The rocks forming the lower part of this group, and which are sometimes separately classed as the *Lowest Fossiliferous Group*, are an alternation of beds of chlorite, talcose, and other slates, resembling those of the inferior stratified series, with beds of clayey and sandy rock, of apparently mechanical origin, and thin beds of limestone in which a few fossils are found. It thus appears that the cessation of the chemical origin of rocks, and the commencement of organic life, are events nearly connected; and it has thence been surmised that the temperature of the earth's surface was now for the first time suitable to the production and maintenance of organic things. At the same time, the alternation of the rocks teaches us the instructive fact that the change was not direct or uniform, but that for some time the two conditions of the surface superseded each other. This is conformable with a general observation, which has been made by Sir H. de la Beche—namely, that however sudden changes may have taken place in particular situations, a general change of circumstances attending rock formations is usually seen to have been more or less gradual. The few fossils found in this part of the series—the Grauwacke proper—are, as far as ascertained, the same, or nearly so, as those of the superincumbent Silurian.

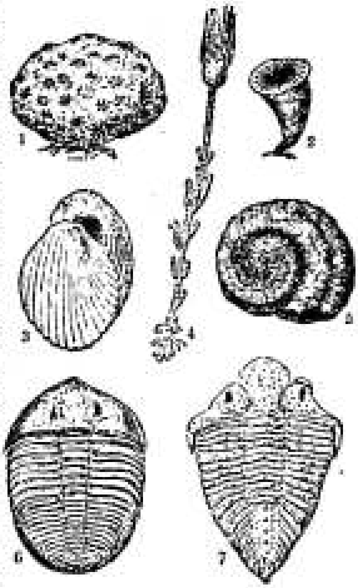
The Silurian group—so called from its being very clearly developed in that district of country between England and Wales which was inhabited by the ancient *Silures*—consists of arenaceous and slaty rocks, of evidently mechanical origin, intermixed with numerous beds of limestone and calcareous shales. The general composition of the series indicates its having been formed, like the grauwacke, of a fine *detritus* (matter washed from other rocks), and its having been deposited slowly; although, as in the case of the grauwacke, the arenaceous beds occasionally pass into coarse conglomerates. Indeed, until a recent period, this system was considered as a portion of the grauwacke group, and as marking its passage into the gray micaceous beds of the Old Red Sandstone. Merely looking at cabinet specimens, it would be impossible to distinguish between many of the grauwacke and silurian rocks; but taking them in the mass, they are readily distinguishable. In the first place, their sedimentary character is very marked; they present more rapid alternations from one kind of strata to another; they have undergone fewer changes by heat; and are generally looser and more earthy in their texture. The limestones are less crystalline than those of the early grauwackes; the arenaceous beds are also less siliceous, and more closely resemble ordinary sandstones; while the abundance of organic remains justifies their arrangement into a separate system.

The grauwacke forms the immediate surface in many large districts in Scotland, England, France, Germany, and North America, showing that, at the time of its formation, "some general causes were in operation over a large portion of the northern hemisphere, and that the result was the production of a thick and extensive deposit, enveloping animals of similar organic structure over a considerable surface." The igneous rocks associated with the transition series are chiefly granitic; effusions of trap making their appearance only among the later strata. Perhaps the most extensive and gigantic efforts of volcanic power were exhibited at the close of this period; and there is abundant proof that all the principal mountain-chains in the world were then upheaved. The Grampian and Welsh ranges, the Pyrenees, Hartz mountains, Dofrafelds, Uralian, Himaleh, Atlas range, Mountains of the Moon, and other African ridges, the Andes, and Alleghanies—all seemed to have received their present elevation at the close of the transition period.

Fossils of the Grauwacke and Silurian.—The fossils of the grauwacke and silurian (a few of which extend to the clayey and sandy slates immediately below) are of both plants and animals. Amongst the plants are algæ, or sea-weeds, showing that seas like the present now existed. Some land plants are also found, but of the simpler structures—as *filices*, or ferns; *equisetaceæ*, a class of plants of the character of the mare's-tail of our common marshes; and *lycopodiaceæ*, a class of the character of our club mosses. All of these land plants are *monocotyledons;* that is, produced from seeds of a single lobe, and therefore *endogenous*, that is, growing from within—timber plants being, on the contrary, the produce of two-lobed seeds, and growing by exterior layers. The *Flora* of this era thus appears of a very simple kind, indicating, generally, low-lying and marshy habitats.

The animals are also, in general, of a humble and simple kind. There is abundance of those creatures (*polypi*) resembling plants, which fix themselves on the bottom of the sea by stalks, and send forth branch-like arms for the purpose of catching prey, which they convey into an internal sac, and digest. At present, these creatures abound in the bottoms of tropical seas, where they live by devouring minute impurities which have escaped other marine tribes, and thus perform a service analogous to that of earth-worms and other land tribes, the business of which is to clear off all decaying animal and vegetable matter. But the class of animals found in greatest numbers in the grauwacke series of rocks are *shellfish*, possibly because the remains of these creatures are peculiarly well calculated for preservation. All over the earth, wherever grauwacke and silurian rocks are found, shellfish are found imbedded in vast quantities, proving that shellfish were universal at the time when that class of rocks were formed. Among the radiata or rayed animals, the *crinoid* or *encrinite* family occur for the first time, these differing from other corals in the self-dependent nature of their structure, their fixed articulated stalk, and floating stomach, furnished with movable rays for the seizure and retention of their food. As we ascend in the silurian group, the shellfish become more numerous and distinct in form; *spirifera*, *terebratulæ*, and *productæ*, are everywhere abundant; and *chambered* shells, like the existing nautilus, begin to people the waters. It must be remarked, however, that the encrinites and chambered shells of this early period are not so numerous, so gigantic, or so elaborate in their forms as those of the Secondary strata: it is in the mountain limestone group that the encrinites attain their meridian, and in the lias and oolite that the *ammonites* and *nautili* are most fully developed.

Of the crustacea of this era, the most interesting and abundant type is the *trilobite* (three-lobed), of which several genera and many species have been described, and to which scarcely any existing creature bears an analogy. The trilobite (see fig.) was a true crustacean, covered with shelly plates, terminating variously behind in a flexible extremity, and furnished with a head-piece composed of larger plates, and fitted with eyes of a very complicated structure. It is supposed by some to have made its way through the water by means of soft paddles, which have not been preserved; and by others, merely to have sculled itself forward by the aid of its flexible extremity. Of its various organs, the most interesting is the eye, of which several specimens have been obtained in a very perfect state. This organ, according to fossil anatomists, is formed of 400 spherical lenses in separate compartments, on the surface of a cornea projecting conically upwards, so that the animal, in its usual place at the bottom of waters, could see everything around. As there are two eyes, one of the sides of each would have been useless, as it could only look across to meet the vision of the other; but on the inner sides there are no lenses, that nothing may, in accordance with a principle observable throughout nature, be thrown away. It is found that in the serolis, a surviving kindred genus, the eyes are constructed on exactly the same principle, except that they are not so high, which seems a proper difference, as the back of the serolis is lower, and presents less obstruction to the creature's vision. It is also found, that in all the trilobites of the later rocks the eyes are the same. This little organ of a trivial little animal carries to living man the certain knowledge, that, millions of years before his race existed, the air he breathes, and the light by which he sees, were the same as at this hour; and that the sea must have been in general as pure as it is now. If the water had been constantly turbid or chaotic, a creature destined to live at the bottom of the sea would have had no use for such delicate visual organs.



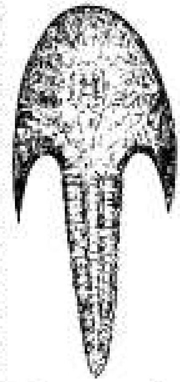
1. Astrea; 2. Turbinolia Fungites; 3. Leptena Lata; 4. Actinocrinites; 5. Euomphalus Rugosus; 6. Trilobite—Asaphus de Buchii; 7. Trilobite—Asaphus Tuberculatus.

A few bones and teeth of fishes have been found in the Silurian; but further exploration is necessary before we can pronounce decisively as to the abundance of vertebrated life at this period. The remains of this era, therefore, may be said to include specimens of all the four divisions of the animal kingdom—radiated, jointed, pulpy, and vertebrated animals; or radiata, articulata, mollusca, and vertebrata.

LOWER SECONDARY.

The Old Red Sandstone System, as indicated by the name, is chiefly arenaceous, presenting a succession of sandstones alternating with subordinate layers of sandy shale. The sandstones pass, in fineness, from close-grained fissile flags to thick beds of conglomerate, the latter being composed of pebbles from the size of a hazel-nut to that of a man's head. The whole system is tinged with the peroxide of iron, the colours ranging from a dark rusty gray to brick-red, and from a mottled purple and fawn shade to a cream-yellow. There are some calcareous beds in the system; but these are not regularly developed, and are all siliceous and concretionary in their composition and texture. Taken in the mass, the composition of this system is sufficiently indicated by the term *old red sandstone*—the epithet "old" being applied to distinguish it from another series of red sandstones which occurs above the coal measures, and is usually designated the *new red sandstone*.

The organic remains of the system, if not so numerous as those of the grauwacke beneath, or the carboniferous measures above, are at least equally interesting, on account of their peculiarities and adaptation to the conditions under which they were destined to exist. The remains of plants are few and indistinct, but are apparently allied to those found in the true silurian rocks. Taken as a whole, the old red sandstone system is particularly barren of vegetable remains, and seems to evince a condition of the earth which did not permit of the growth of plants unless in detached and limited areas; these plants being by no means high in the scale of vegetable organisation. Its animal remains are more abundant and distinct, but present little variety—the prevailing types being marine fishes of simple but curious structure. These *fossil fishes*, or *ichthyolites*, present the first distinct trace of the existence of the highest division of the animal kingdom—namely, *vertebrata*. It must be remarked, however, that the earliest genera are not of the most perfect structure, but form, as it were, a link between the humbler crustacea and fully-developed fishes, as represented in the accompanying figure of the *cephalaspis*, or buckler-head.



Carboniferous System.—This is a very extensive system, comprehending not only the coal measures proper, from which it takes its name, and which consists of alternating strata of coal, shales, sandstones, ironstones, &c. but embracing also the mountain limestone, which always underlies the coal group, and which, in turn, comprehends alternations of limestone, shales, sandstones, and imperfect coal beds.

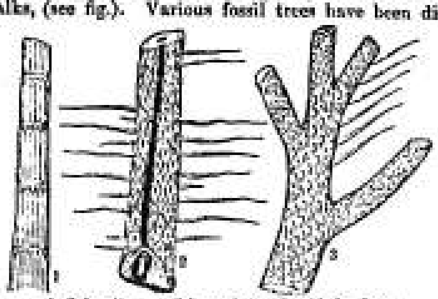
Mountain Limestone, so called from its being generally found flanking or crossing the trap hills which intervene between the old red sandstone and the coal measures, is an abundant rock. It is frequently traversed by beautiful veins of calcareous spar, and many valuable veins of lead-ore are associated with it in Britain and elsewhere. It is of various colours, but mostly gray, varying in intensity of shade. Its associated rocks are principally calcareous sandstones and shales, abounding in organic remains, corals, encrinites, &c. which point to a marine origin.

The superior group more particularly called *Carboniferous*, and variously termed the *Coal Measures*, is composed of beds of that mineral, often very numerous, alternating with beds of sandstone, shale, limestone, ironstone, and some other substances. As many as forty beds of coal exist in the neighbourhood of the town of Newcastle. The great utility of this mineral as a domestic fuel, and in the arts, gives it a high importance; and happy is the country in which it exists in any considerable quantity. In a merely geological point of view, it is equally important. This rock is entirely a mass of vegetable matter, which has accumulated in certain situations, and afterwards been covered over, pressed upon, and converted, by bituminous fermentation, into several varieties of coal.

Two hypotheses have been advanced respecting the circumstances under which coal was formed. According to one, the vegetable matter must have grown in dense forests and jungles for many years; then the land must have sunk, and become the basin of a lake or estuary, in which situation rivers would wash into it mud and sand, which would cover over the vegetable mass, and form superincumbent beds of shale and sandstone respectively. Then the ground would be once more elevated, or sufficiently shoaled up, to become again a scene of luxuriant vegetation. When the vegetation had again become accumulated, the land would be again sunk, and become once more the basin of a lake, in which case the beds of mud and sand might again be formed by rivers. And this alternating process is supposed to have taken place as often as there are beds of coal to be accounted for. The other hypothesis is, that, into lakes and estuaries, rivers coming from different quarters would bring the various matters forming the strata of the carboniferous group—a river from one direction bringing the mud which would form shale, another from another direction the vegetable matter which would form coal, and so on, each deposit perhaps taking place through the efficacy of some local circumstances, while the causes for the other deposits were temporarily suspended. Both theories are beset with difficulties; and perhaps the true solution is to be found in a combination of the two. Estuary and lake deposits, inundating rivers, a high temperature, a prolific Flora, and frequent elevations and subsidences of the land, seem to have been the conditions under which the coal measures were deposited.

Fossils of the Carboniferous Group.—In this group of rocks, upwards of 300 species of plants have been discovered, all of them now extinct. About two-thirds of them are ferns; the others consist of large *coniferæ* (allied to the pine), of gigantic *lycopodiaceæ*, of species allied to the *cactus* and *euphorbiaceæ*, and of palms. Most of these plants probably exist in the coal beds, forming, in fact, their sole composition; but the peculiar nature of this mineral renders it difficult to detect them by examination. Thin slices, however, have been examined by the microscope, and the vegetable structure has then been detected, where no external trace of it was visible. In cannel coal, a kind peculiarly compact, the vegetable structure is observed throughout the whole mass, while the fine coal retains it only in small patches, which appear, as it were, mechanically entangled. Splint and cannel coal often bear distinct impressions of plants. The plants are such as grow in hot moist situations; and it is therefore presumed that a climate of that nature existed at an early period where coal is now found, even in Melville's Island, which is within the polar circle.

Large fragments of trees are often found in the shale and sandstone beds of the carboniferous group—more frequently in the former than in the latter. As usual with fossil substances, they are converted into the material in which they are imbedded, but preserve all their original lineaments, except that they are generally changed from their original round to a flattened form, the result of the pressure they have sustained. In most instances, these fragments of trees appear to have been transported from a distance, and laid down horizontally in their present situation; but some have been found with their roots still planted in their native soil of mud, and the stems shooting upwards through several superior beds of various substances. Even in some coal beds, there are found stems of trees in their original vertical position—the roots being imbedded in shale beneath. In these instances, we must suppose the fossil to be on the spot where the living tree was planted, grew, and died. In the Bensham coal seam, in the Jarrow coal-field, a few years ago, there was found an upright tree of the kind called lepidodendron, thirteen and a half feet wide at the base, and thirty-nine feet high, the branches at the top being also entire: the lepidodendron is so called from the scaly appearance of its stem, the scales being the roots of the leaf stalks, (see fig.). Various fossil trees have been dis-



1. Calamites; 2. Stigmaria; 3. Lepidodendron.

covered in the sandstone beds of the carboniferous group at Craigleith and Granton, in the county of Edinburgh. One found in Craigleith quarry was twenty feet long, three feet in diameter, with scars where the branches had been torn off, and was ascertained, by microscopic inspection of slices of the trunk, to have been a conifera of the existing genus *Araucaria*.

The animal remains of the carboniferous group consist of zoophytes (corals, encrinites, &c.) in vast profusion, of shellfish, crustacea, and fishes. In the mountain limestone the crinoidea seem to have attained their meridian, for whole beds, many feet thick, and square miles in extent, are almost wholly composed of them; hence the not unfrequent term, *Encrinital Limestone*. Shellfish univalve, chambered, and bivalve, also abound; the trilobite and crustacea, allied to the modern *chiton*, are by no means uncommon; and fishes of a gigantic size and sauroid structure are scattered throughout the strata both of the mountain limestone and the coal measures.

New Red Sandstone System.—This series of strata, lying above the carboniferous system, comprehends rocks called the *red conglomerate*, formed of pieces of earlier rocks, some rough, some smoothed by rolling, all caked together; *magnesian limestone*, abounding in Germany and the north of England; *red or variegated sandstone*, a group of many varieties of colour, and principally of argillaceous and siliceous consistence; *muschelkalk*, a limestone varying in texture, but most frequently gray and compact—not found in Britain or France, but occurring in Germany and Poland; and *variegated marls*—beds of different colours, red, blue, and gray, composed of the remains of shellfish.

To these also belong beds or masses of *rock salt*, of which many exist in England, particularly in the county of Chester. Rock salt is a crystalline mass, forming irregular strata, sometimes of the thickness of several hundred feet. The substance is rarely pure, but generally contains some portion of argillaceous oxide of iron, which gives it a red colour. It is dug like coal and other minerals, and when dissolved and subjected to proper purification, is sold for domestic purposes.

Fossils of the New Red Sandstone Group.—The vegetable remains of this group belong to the same families as those of the coal strata, only they are found very sparingly and of diminished dimensions; but in the department of animal life, when we arrive at the muschelkalk, or shell limestone, we find a great difference, leading to a supposition that, at this era of geological chronology, circumstances had arisen changing the character of marine life over certain portions of Europe; that certain animals abounding previously, and for a great length of time, disappeared never to reappear, at least as far as we can judge from our knowledge of organic remains; and that certain new forms of a very remarkable kind were added.

The new creatures were of such a class as we might expect to be first added to the few specimens of fish which had hitherto existed: they were of the class of Reptiles—creatures whose organisation places them next in the scale of creation to fish, but yet below the higher class of animals which bring forth their young alive and nourish them by suck (mammalia). The earth was as yet only fit to be a partial habitation to creatures breathing its atmosphere and living upon its productions. The lands which existed were probably low and marshy, with a hot, moist atmosphere, so as to present an appropriate field of existence only for lizards, crocodiles, and creatures of similar character. It is also to be supposed that the land was at this period undergoing frequent changes and convulsions, so that only a class of creatures to which submersions and deluges were matters of indifference, could reside upon it without a greater waste of life than was part of the Great General Design. The reptiles, which first begin to appear in the muschelkalk, continued to flourish while a great succession of other rocks was forming: throughout the whole of the Secondary Formation, there were *few* other land animals.

UPPER SECONDARY.

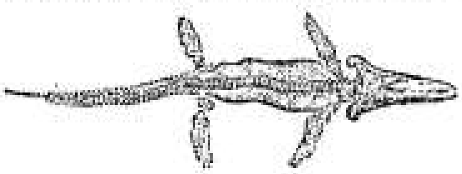
Oolitic System.—After the deposition of the new red sandstone, a further change was effected upon the general conditions of the globe, so as to produce not only an entirely different set of strata, but also different races of plants and animals. In most districts, the red sandstones and magnesian limestone were upheaved, to form new land, while portions of the former dry land were submerged beneath the ocean. By this process of elevation and depression the courses of previous rivers would be altered, former seas circumscribed and rendered more shallow, plants and animals subjected to a new distribution, and thus a different set of deposits would necessarily ensue. Instead of magnesian rocks, we have dark argillaceous and oolitic limestones; for variegated saliferous marls, we have blue pyritous clays; and instead of red and mottled sandstones, yellow calcareous grits. All this points to a new epoch in the terrestrial conditions of the world; and to the system of strata thus deposited geologists apply the term *oolitic* (Gr., *oon*, an egg, and *lithos*, a stone), from the resemblance which the texture of many of the beds bear to the roe or eggs of a fish. The system in England comprises three well-defined groups; namely, the Lias, the Oolite proper, and the Wealden clays—all of which are less or more developed in other parts of the eastern hemisphere.

The Lias, the lowest group in the system, is composed of dark argillaceous limestones, bluish clays, and shales. As indicated by the name (*lias*, corruption of *layers*), the limestones are finely stratified, and have evidently been deposited in tranquil waters. *The Oolite* is more varied in its composition, consisting of oolite limestones, calcareous conglomerates, yellowish sands, and clays, all more or less calcareous. The peculiar rounded grains which constitute the oolitic texture, consist either entirely of lime, or of an external coating of lime, collected round minute particles of sand, coral, shells, &c.; the grits are composed of sand, lime, fragments of shells and corals; and many of the clays present the same brecciated texture. *The Wealden group* (from the *wealds* or *wolds* of Kent and Sussex, where the deposit prevails) consists of beds of bluish clay, argillaceous limestones, impure oolites, and ferruginous sandstones. Fossil plants are abundant; and, as may be expected from this circumstance, local traces of coal are not unfrequent.

The organic remains of the Oolitic system are very numerous, and have long attracted the attention of geologists. They show a decided advance upon pre-existing races, inasmuch as insects, amphibious reptiles, and mammalia, make their appearance in the animal kingdom; while new tribes of vegetables, such as the cycadeæ, liliaceæ, &c. are added to the former Flora. The organisms of the lias, the oolite, and the lower members of the wealden, indicate the marine origin of these deposits; those of the upper weald an estuary character, from the comminglement of fresh water with marine species. With this distinction, the Fauna and Flora of this epoch may be thus summarily detailed:—*Plants*—seaweeds; a few equisetums; many ferns allied to those of the coal measures; cycadeæ, allied to the existing cycas revoluta and pine-apple; coniferæ, resembling the yew and pine; besides liliaceæ and other undescribed genera. *Animals*—zoophytes, more like existing species than those of the mountain limestone and silurian rocks; crinoidea, chiefly the pear-shaped encrinite pentacrinite; star-fishes, resembling the common ophiura and asterias; echinida (sea-urchins), of which the cidaris is one of the most beautiful and abundant; shellfish, both bivalves, univalves, and chambered; annulosa, like the common serpula and land-worm; crustacea, resembling the lobster tribe; insects like the beetle and dragon-fly; fishes, chiefly with enamelled scales; reptiles allied to the tortoise, to the crocodile, and gavial of existing rivers, but differing widely in their external forms and modes of existence; mammalia, two or three specimens of small marsupial animals allied to the opossums, and the somewhat doubtful remains of a monkey. In the upper or fresh-water wealden, there are no zoophytes or marine mollusca; but there are, according to Phillips, various land plants, fresh-water bivalves and univalves, some fishes, sauroid animals, and remains of turtles, both fresh-water and marine.

The reptiles of this early age were peculiar both in size and in structure. Some, which inhabited the seas, resembled lizards, but were of gigantic size; others, designed for land as well as sea, resembled the crocodiles which still exist in warm climates.

One of the most remarkable kinds (genera) has received the name of *Ichthyosaurus* (Fish Lizard), of which seven species or varieties have been discovered. The head is like that of the crocodile, composed of two long slender jaws, provided with a great number of teeth (in some cases 180), and eyes of great size (in one



Skeleton of the Ichthyosaurus.

instance, the cavity for the eye has been found to measure fourteen inches), while the nostril, instead of being near the snout, as in the crocodile, was near the anterior angle of the eye. The body was fish-like, arranged upon a long spinal column, which consisted of more than a hundred joints, and to which a series of slender ribs was attached, and terminating in a long and broad tail, which must have possessed great strength. The whole length of some specimens of the ichthyosaurus was about thirty feet. Instead of the feet, with which the lizard and crocodile are furnished, the ichthyosaurus had four paddles like those of the whale tribes, fitting it to move through the waters in the manner of those animals. It had also a construction of the sternum or breast-arch, and of the four paddles, similar to that found in the ornithorynchus, an aquatic quadruped of New Holland, and evidently designed, as in the case of that animal, to enable it to descend to the bottoms of waters in search of food. While the ichthyosaurus, then, is mainly allied to the lizard tribes, it combined in itself the additional characters of the fish, the whale, and the ornithorynchus.

The internal structure and the modes of living of the ichthyosaurus, have been in a most unexpected manner made clear by the discovery of the half-digested remains of animals found within them or in their neighbourhood. It appears that the creature possessed a large stomach, extending throughout nearly its whole body, and that it lived upon fish and other reptiles, including its own kind. It must have occasionally devoured creatures several feet in length. Masses of the refuse of the ichthyosaurus, petrified as hard as the finest marble, and well known to geologists under the name of *coprolites*, are found to be marked spirally, like the voidings of certain species of sharks and dog-fish, the intestinal gut of which winds greatly, in order that it may take up the least possible room. We thus obtain a distinct idea of the nature of a very important part of the bodily economy of this long extinct race of animals. The stomach occupied so large a space in their bodies, for the reception of large quantities of food, and it was at the same time so necessary that the speed of the animal in pursuit of prey should not be clogged by a very large or long body, that the smaller intestines had been, by a wise arrangement of nature, reduced nearly to the state of a flattened tube, coiled like a cork-screw around itself; "their bulk being thus diminished," says Buckland, "while the amount of absorbing surface remained nearly the same as if they had been circular."

The name *Plesiosaurus* is applied to another highly remarkable reptile of gigantic size, which inhabited the world before the days of mammalia. A particular species has been described as having a body and paddles which bore some resemblance to those of the ichthyosaurus, the former being more bulky, and the latter longer and more powerful. At the end of a long neck, like the body of a serpent, was a head resembling that of a lizard, but also partaking of the characters of the head of the crocodile and ichthyosaurus. The tail was short. The backbone of this creature, and the neck and tail continuing it, contained in all about ninety vertebral pieces, thirty-three of which composed the neck; and the vertebræ are found to be of a less fish-like structure than those of the ichthyosaurus, and not nearly so well calculated for rapid motion. The plesiosaurus probably lived chiefly on or near the surface of the water, breathing the air, and dabbling for prey like a duck or swan, but might also be able to descend to the bottom, and even to move, though awkwardly, upon land. One part of its organisation is peculiarly striking, as foreshadowing a structure of a more important kind: the paddles, which may be considered an advance or improvement upon the fins of fishes, are at the same time the type of the legs of quadrupeds and of the arms and limbs of man. The fore-paddle consists of scapula (shoulder-blade), humerus (shoulder), ulna (upper bone), and radius (lower bone), succeeded by the bones of the carpus and metacarpus, and the phalanges, equivalent to those which compose the palm and fingers of a human being.—(See ANATOMY, No. 13.) The hind paddle presents femur, tibia, and fibula, succeeded by the bones of the tarsus and metatarsus, and five toes. Thus "even our own bodies, and some of their most important organs, are brought into close and direct comparison with those of reptiles, which at first sight appear the most monstrous productions of creation; and in the very hands and fingers with which we write their history, we recognise the type of the paddles of the ichthyosaurus and plesiosaurus."

Of the crocodile family, found in abundance in this class of rocks, the *Iguanodon*, may be cited as a specimen. It was a huge animal, resembling the present iguana of South America, which chiefly lives upon plants and seeds. The smallest part of the thigh-bone of an iguanodon was found to be twenty-two inches in circumference, and much larger than that of any existing elephant. Species resembling the present gavial of the Ganges have also been found. It may fairly be inferred from the present habits of the gavial and other kinds of crocodiles, that at the time when the extinct species flourished, the world must have contained many low shores and savannahs, fitted for the residence of such creatures. Some parts of England are thus proved to have had at one time shores of lakes and estuaries resembling those of the Ganges, the Nile, and other waters in hot countries, and consequently a much higher temperature than at present.

But perhaps the greatest wonder of the reptile age was the creature called the *Pterodactyle*. Mainly a reptile of the lizard kind, its body possessed some of the characteristics of the mammalia: it had the wings of a bat, the neck of a bird, and a head furnished with long jaws, full of teeth, so that in this last part of its organisation it bore some resemblance to the crocodile. Eight species of the pterodactyle which have been found, vary from the size of a snipe to that of a cormorant. The eyes were of enormous size, apparently enabling it to fly by night. From the wings projected fingers, terminated by long hooks, like the curved claw on the thumb of the bat. These must have formed a powerful paw, wherewith the animal was enabled to creep or climb, or suspend itself from trees. It has been conjectured that the pterodactyle would chiefly live on flying insects, of which, it is important to notice, several varieties existed at the same time, their remains being found in the same rocks. And it is likely, from the size of the eyes, that it searched for prey by night as well as by day. But it has also been argued, from the great length and strength of the jaws, and the length of the neck, that the pterodactyle did not live solely upon flies, but likewise sought for fish in the manner of our own present sea-birds.

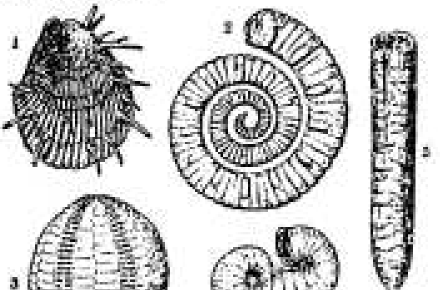
Tortoises also existed during this and the preceding age, as is proved by the marks of their feet (technically, *Sauroidichnites*) on beds of sandstone, and by their remains. But as yet few animals of a higher class had appeared upon earth—for the remains of certain creatures of the Opossum family, found in the oolite at Stonesfield, near Oxford, stand as yet so solitarily, that we can scarcely consider them as proving that mammalia were added to reptiles. With, then, flocks of pterodactyles flying in the air in pursuit of huge dragon-flies; gigantic crocodiles and tortoises crawling amidst the jungles of low, moist, and warm shores, and such monsters as the ichthyosaurus and plesiosaurus swarming on the surface of the sea, while its depths were peopled by infinite varieties of fish, shelled and vertebrated; we can form some faint idea of what sort of world it was while the strata between the coal and the chalk were in the course of being deposited.

Cretaceous or Chalk System.—Immediately overlying the wealden, and forming the upper portion of the secondary formation, occurs a set of calcareous, argillaceous, and arenaceous strata, distinguished in Europe as the Cretaceous System, from its containing the well-known mineral, *chalk* (Lat., *creta*). In this system, the arenaceous members are no longer sandstones, but loose unsolidified sands; the argillaceous beds are generally soft and marly clays; and the calcareous, instead of compact or crystalline limestones, present that soft earthy texture which prevails in chalk. All this attests a comparative recentness of formation, apart from great pressure, long-continued chemical action, or the indurating effects of heat. The strata occupy very limited spaces, and being decidedly of marine origin, point more to detached and inland seas as the areas of their deposit, than to the shores or bays of the ocean. Being thus, as it were, a local deposit, and of a thickness not exceeding 800 or 900 feet, the chalk has been more thoroughly explored than any of the older systems, and its fossils more rigidly compared with existing species. Upon investigation, it has been found that it embraces three well-marked groups; namely, the *Green-sand*, the *Gault*, and *Chalk*.

The *Green-sand*, which forms the lower division, is so named from its prevailing green colour, which it owes to a chloritous silicate of iron. In England, they are usually divided into the Lower and Upper green-sands, because of a bed of soft bluish marly clay which occurs about the middle of the group. The *Gault*, or *golt* (a local term), overlies the green-sand, and is not of great thickness, nor very regular in its occurrence. It is a bluish chalky clay, interstratified with layers of green-sand, and holds irregular balls of clay, ironstone, and iron pyrites. The *Chalk*, which forms the upper group of this system, is too well known to require description.

It consists chiefly of carbonate of lime, has an earthy texture, and is so soft as to yield to the nail. Though generally white, it sometimes passes into a dusky gray, or even red colour; and where it has come in contact with igneous rocks, it is indurated, and of a crystalline texture, like that of statuary marble. In England, the chalk strata average from 600 to 800 feet in thickness, and are usually divided into the lower and upper beds; the former being more compact, of a dusky white, varied with green grains, and containing few flints—the latter being a soft white calcareous mass, with chert nodules and regular layers of flints. Traces of stratification are scarcely distinguishable in the mass of the chalk, but are clearly evinced by the lines of flints and other nodular concretions. All the members detailed above do not occur in all chalk districts: for example, the green-sand is wanting in the north of England, chalk in the Carpathian deposits, gault in North America, while in South America the system is altogether imperfectly represented.

The organic remains found in the system are eminently marine. There are very few *plants*, and these chiefly of marine types, such as algæ, confervæ, and other sea-weeds. Rare fragments of ferns, cones of coniferous trees, cycadites, and dicotyledonous wood, have been detected in the green-sand; but, generally speaking, there is no formation so destitute of terrestrial organisms as the chalk. Among the *animal remains*, sponges, corals, star-fishes, annulosa, univalve, bivalve, and chambered mollusca, crustacea, fishes, and reptiles, are found in abundance; but, with one exception, mammalia are not known in the cretaceous rocks. The same races which appeared in the oolite appear also in the chalk, but of very different genera; so much so, that it has been observed that the cretaceous system contains genera never found in any rocks more ancient or more modern. The following are characteristic fossils:—



1. Plagiostoma spinosum; 2. Hamites intermedius; 3. Galerites albogalerus; 4. Scaphites striatus; 5. Belemnites mucronatus.

TERTIARY.

The Tertiary Formation comprises all the *regular strata* of limestone, marl, clay, sand, and gravel, which occur above the chalk. Before the labours of the celebrated Cuvier and M. Brogniart, these beds were regarded as mere superficial accumulations, not referrible to any definite period. Now, however, they are recognised as constituting a distinct formation—differing, on the one hand, from the cretaceous not only in its mineral composition, but in the higher order of organisms which it contains, and, on the other, from the superficial sands and clays, in being regularly stratified, and in imbedding the remains of animals distinct from existing races.* In general, the strata are loosely aggregated, are of no great thickness, and present appearances which indicate frequent alternations of marine and fresh-water agencies. Thus, marine remains are found in some beds, while others contain exclusively land animals and plants, and fresh-water shells. The whole suite being less consolidated than any of the secondary systems, and containing plants and animals approaching to existing forms, it presents a freshness of aspect which serves to distinguish it from older deposits; at the same time, the regularity of its deposition prevents it from being mistaken for any mere alluvial accumulation. In general, it occupies very limited and detached areas, as if it had been formed in shallow inland seas and estuaries, to which the waters of the ocean at times had access, and where, at other periods, fresh-water inundations prevailed. Another essential difference between the tertiary and the more ancient formations, consists in the fact, that the latter maintain a wonderful uniformity in their composition and character all over the globe; whereas the former present almost as many distinctions in composition as there are areas of deposit. For this reason it is impossible to give a description applicable to all tertiary strata; those of England and France, however, may be taken as types sufficiently characteristic.

The following is a descending section of the Paris basin, according to Cuvier and Brogniart:

5. Upper fresh-water group—marls, marly sands, shelly limestone, and siliceous or burr limestone.
4. Upper marine group—marls, sands and sandstones of a white or ochraceous colour, and loosely aggregated; thin layers of limestone.
3. Lower fresh-water—marls, gypsum (sulphate of lime), with bones of animals, and siliceous limestones.
2. Lower marine—consisting principally of a coarse sandy limestone (*calcaire grossier*), with calcareous marls and layers of greenish sand.
1. Plastic clay group—consisting of bluish plastic clays, with layers of sand, beds of lignite, and rolled pebbles. Supposed to be of estuary origin.

Although a very different succession takes place among the tertiaries of the south of England, yet there is sufficient resemblance in the position and aggregation of their strata, as well as in their organic remains, to establish the fact, that they belong to the same epoch as the rocks of the Paris basin. The annexed section shows the order of their occurrence to the south of London:—

4. Bagshot sands.
3. London clay—of a dull gray, or blue, or ochraceous colour; often full of green grains. Septaria and other ferruginous nodules occur in some parts. Numerous fossils.
2. Plastic clay and sands—sands of various colours, with occasional beds of lignite; also layers of sandy clay, with or without shells.
1. Sands—green and ferruginous, accompanied by flint pebbles, oyster shells, &c.

In other parts of England, the order of occurrence is somewhat different. It may be stated, however, in general terms, that the sands are most extensively developed: the clays chiefly in the southern basins; while at Oxford, Ramsholt, &c. the upper beds consist of a coarse conglomerate of corals, sand, pebbles, shells, &c. locally known as the "Crag," and so calcareous in some places as to be used as a limestone. As with the Paris and English deposits, so with other tertiary basins in Europe; those of southern France, Spain, Italy, Austria, Hungary, &c.—all showing an irregular succession of clays, sands, marls, lignite (wood-coal), and gypsum, which, when examined in relation to their positions, modes of aggregation, and fossils, are clearly referrible to the same period of formation.

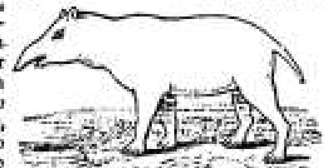
As to the extent of country occupied by tertiary deposits, there is yet no very accurate knowledge, inasmuch as many sands and clays, now regarded as the alluvium of existing valleys, may hereafter be referred to this system; and several areas of gravel, now looked upon as tertiary, be classed with more recent accumulations. As developed in Europe, the system spreads over wide areas, all remarkable for their conformation and connection with the outline of existing seas. Indeed, were the islands and continent of Europe to be submerged to the depth of 600 or 800 feet, the waters of the German, Baltic, English Channel, and Mediterranean seas, would cover most of the tertiary strata, showing that, with the exception of the general elevation which raised them into dry land, there has been comparatively little subterranean disturbance since the time they were deposited.

Igneous rocks are not found in connection with the tertiaries of England, though subterranean movements have thrown them into anticlinal ridges and basin-shaped hollows. In the south of Europe the case is otherwise, and the geologist finds in the igneous discharges of Auvergne, Switzerland, the Rhine, Hungary, and Italy, a link which connects the traps of the secondary period with the products of recent and active volcanoes.

The organic remains of the system constitute its most important and interesting feature. The fossils of earlier periods presented little analogy, often no resemblance, to existing plants and animals; here, however, the similitude is frequently so complete, that the naturalist can scarcely point out a distinction between them and living races. Geology thus unfolds a beautiful gradation of being from the corals, molluscs, and simple crustacea of the grauwacke—the enamelled fishes, encrinites, and cryptogamic plants of the lower secondary—the chambered shells, sauroid reptiles, and marsupial mammalia of the upper secondary—up to the true dicotyledonous trees, birds, and gigantic quadrupeds of the tertiary epoch. The student must not, however, suppose that the fossils of this era bring him up to the present point of organic nature, for thousands of species which then lived and flourished became in their turn extinct, and were succeeded by others, long before man was placed on the earth as the head of animated existence.

From their relative position, and from the organic remains contained in them, geologists have been enabled to distinguish, in the tertiary series of strata, four great eras of deposit. To the oldest of the tertiary eras, the term Eocene is applied; the second is called the Miocene period; the third, the Older Pliocene; and the fourth and latest, the Newer Pliocene; names founded on the respective proportions which their fossil shells bear to shells of existing species. In each of these periods is included a great fresh-water, as well as a marine deposit. Of the animals which flourished in each of these periods, we shall endeavour to give some account—premising in reference to the vegetable world, that the fresh-water beds have yielded cycadeæ, coniferæ, palms, willows, elms, and other families exhibiting the true dicotyledonous structure.

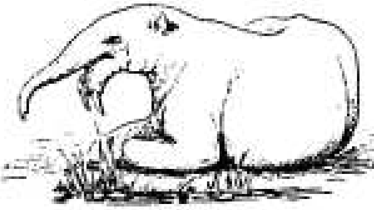
After the chalk formation, a period of considerable repose seems to have ensued, during which a large portion of the existing continents, and in especial the hollows and basins on their surface, appear to have been the site of vast lakes, rivers, and estuaries. From these was deposited the first great fresh-water formation of the Eocene period. While this deposit was going on, the globe was tenanted only by such quadrupeds as live beside rivers and lakes. Nearly fifty extinct species of mammalia, chiefly of this character, were discovered by Cuvier in the first Eocene fresh-water formation. The most of these belonged to the class Pachydermata (*thick-skinned* animals), of which the elephant, the rhinoceros, the hog, the tapir, and the horse, are remarkable existing examples. This class of animals, it may be observed, only includes such thick-skinned creatures as have no more prominent mark to distinguish them than their *skins*. The seal and river-horse, for example, are thick-skinned; but then they are *amphibious*, and that is a more prominent distinction. The extinct animals to which we now refer resemble the tapir more than any of the other Pachydermata. Among these extinct creatures, the most worthy of notice are the Palæotherium, the Anoplotherium, the Lophiodon, Anthracotherium, and one or two other families, including, some of them, not less than eleven or twelve distinct species. These mammiferous families had some general traits of resemblance, and the description of the great *Palæotherium* (ancient wild beast) may afford an idea of the main features of all. This animal was about four feet and a half in height to the wither, and somewhat squat and clumsy in its proportions. On each foot were three large toes, rounded, and unprovided with claws; the upper jaw was much longer than the under. The tapir, and partly also the hog, if large enough, would closely resemble the great palæotherium. "The palæotheria," says Buckland, "probably lived and died upon the margins of the then existing lakes and rivers, and their dead carcasses may have been drifted to the bottom in seasons of flood." The other mammiferous families of the first Eocene formation were all, like the palæotheria, herbivorous, and had, it is probable, similar habits.



Palæotherium.

The number of animals, aquatic and terrestrial, whose remains are found in the other deposits of the Eocene period, is immense. In some gypsum quarries of that era, scarcely a block can be opened which does not disclose some fragment of a fossil skeleton. The following list of the animals found in the gypsum quarries of Paris, will show sufficiently how very different from the gigantic reptiles of the secondary eras were the creatures that tenanted, and found fitting sustenance on, the earth during the Eocene period:—Besides various extinct pachydermatous families, there were found extinct species of the wolf and fox, of the racoon and genette, among the carnivorous tribes; of the opossum; of the dormouse and squirrel; nine or ten species of birds, of the buzzard, owl, quail, woodcock, sea-lark, curlew, and pelican families; fresh-water tortoises, crocodiles, and other creatures of the reptile class; and several species of fishes:—all of these animals, be it remembered, being *extinct species* of existing families, exclusive of the pachydermatous animals, and the fishes, which were extinct species of *extinct families*. The number of fossil shells found in the Eocene formations is estimated by Mr Lyell at 1238. As in the case of the terrestrial creptures, few of these shellfish are of recent or existing species, not more, at the utmost, than three and a half in every hundred. We do not, moreover, recognise in the strata now under consideration, these prodigious accumulations of *microscopic* shells, as they are called from their extreme minuteness, that distinguish the formations of the secondary or preceding ages. One small piece of rock, of the ages in question, has been found to contain above ten thousand chambered shells, though the whole weighed only an ounce and a half. In fact, great beds of secondary limestone seem to be almost wholly composed of microscopic shells. Such phenomena are not presented in the Eocene or subsequent tertiary deposits. The shells of these periods, as has been already observed, approximate more to the character of recent or existing species.

The second, or Miocene period, however, of the tertiary ages, brings us a step nearer to the existing condition of things. Whereas only three in the hundred of Eocene fossils were of recent species, of the Miocene shells we find eighteen in the hundred to have existing representatives. Along with the mammalia, also, of the Eocene period, we find that the Miocene deposits present us with the earliest forms of animals existing at the present time. In Dr Buckland's Bridgewater Treatise, a table is given, exhibiting the animals found at Darmstadt, in a bed of sand referrible to the Miocene period. In this list are mentioned two skeletons of the dinotherium, a large herbivorous animal; two large tapirs; calicotherium—two large tapir-like animals of this name; two rhinoceroses; hippotherium, an animal allied to the horse; three hogs; four large cats, some as large as a lion; the creature called the glutton; agnotherium, allied to the dog; and an animal allied to the bear. From this list the reader will perceive the gradual approach in the Miocene animals to existing species. The largest of the terrestrial mammalia yet discovered belongs to the period now under notice; it is the dinotherium, or gigantic tapir, already mentioned. No complete skeleton has yet been discovered; but from the bones found, Cuvier and others imagine the animal to have reached the extraordinary length of eighteen feet. The most remarkable peculiarities of its structure consist in two enormous tusks at the end of its lower jaw, and the shoulder-blade, which resembles that of a mole, and is calculated to have



Dinotherium.

given the power of digging, or other free movement, to the fore-foot. It is probable that this stupendous creature lived in fresh-water lakes, and had the half terrestrial half aquatic habits of the walrus or river-horse.

In the Miocene period, the seas became the habitation of numbers of marine mammalia, consisting of dolphins, whales, seals, walrus, and the lamantin, or manati. Few of these animals were of the same species as those which exist at present; but the differences were far from being great or remarkable. This circumstance, as well as the considerable number of fossil shells identical with existing ones, exhibits an approach in the character and tenantry of the Miocene seas to the present state of things in these respects. The discovery, also, of true terrestrial mammalia, as the rhinoceros and hog, in the Miocene formations, shows, that since the era of the gigantic reptiles, a large portion of the earth's surface had assumed the condition of dry land, fit for the support of the common herbivorous creatures. At the same time, the occurrence of such animals as the dinotherium proves, as Dr Buckland remarks, that many regions were still covered with great lakes and estuaries. It now remains to inquire into the nature and peculiarities of the animals characterising the Pliocene age, which, for convenience, has been arranged into two periods, the Older and Newer Pliocene, the latter of which immediately preceded the formation of the diluvial layer constituting the present superficial matter of the globe: whereas only eighteen in the hundred of the Miocene shells were of recent species; in the Older Pliocene from thirty-five to fifty, and in the Newer Pliocene not less than from ninety to ninety-five in the hundred, are identical with shells of existing species. This great change is accompanied by the disappearance of the Palæotherian family and others, which formed the most striking animal remains of the periods immediately preceding. In place of these extinct species of *extinct* Pachydermatous or thick-skinned families, we observe in the strata of the Pliocene periods a vast number of remains of *existing* Pachydermatous families, such as the elephant, the rhinoceros, and the hippopotamus, though these remains belong to varieties that are now extinct. The first traces also now appear of ruminant animals—of oxen, deer, camels, and other creatures of the same class. But though it is of importance to notice the existence of such remains in the Pliocene ages, in order to exhibit the progressive approach to the present state of things in the animal kingdom, it is in the huge and extraordinary creatures, now no longer to be seen on the face of the earth, that the interest of such an investigation as the present chiefly lies.

The enormous creature called the *Great Mastodon* belongs to the Pliocene era. Of all the fossil animals whose skeletons have been found *complete*, or nearly so, the mastodon is the largest. It is about one hundred and twenty years since its remains were first discovered in America, and vast quantities of them have been since found in the same region, buried chiefly in marshy grounds. One skeleton, nearly complete, was dug up on the banks of the Hudson in 1801, and it is from this that a correct knowledge of the animal has been principally derived. In height, the mastodon seems to have been about twelve feet, a stature which the Indian elephant occasionally attains. But the body of the mastodon was greatly elongated in comparison with the elephant's, and its limbs were thicker. The whole arrangement of the bony structure resembled that of the elephant, excepting in one point, which Cuvier regarded as of sufficient consequence to constitute the mastodon a different genus:—this was the cheek-teeth, which are divided, on their upper surface, into a number of rounded, obtuse prominences, arranged not like the elephant's, but like those of the wild boar and hippopotamus; whence it is concluded, that, like the latter animals, the mastodon must have lived on tender vegetables, roots, and aquatic plants, and could not have been carnivorous. The lower jaw of the skeleton found on the Hudson is two feet ten inches in length, and weighs *sixty-three pounds*. Like the elephant, the mastodon had two tusks, curving upwards, and formed of ivory; and in the opinion of Cuvier, it had also a trunk of the same kind with the former animal's. Altogether, making an allowance for several additional feet of length, it may be considered as varying but little from the larger specimens of the elephant. From the immense number of mastodon bones which have been dug up in various parts of the earth, and particularly in the new world, we must conclude that at no distant period of time the terrestrial surface was extensively peopled by these enormous creatures.

Another creature, belonging to the later Pliocene ages, if not indeed to the era of the diluvial formation, has been discovered in America, both north and south. This is the *Megatherium* (great wild beast), an animal more widely removed in character from any existing creature, than any of the other fossil remains that have been yet observed. The megatherium was discovered towards the end of the last century. A skeleton, almost entire, was found nearly at one hundred feet of depth, in excavations made on the banks of the river Luxan, several leagues to the south-west of Buenos Ayres. The megatherium was a tardigrade (slow-moving) animal, like the sloth, but of gigantic dimensions, and calculated to subsist on roots and succulents, and on the foliage and young shoots of trees, for the uprooting and overturning of which its structure seems to have been admirably adapted. Its habits and peculiarities are thus described by Dr Buckland. After stating, that with the head and shoulders of a sloth, it combined, in its legs and feet, an admixture of the characters of the ant-eater and the armadillo, and resembled them still more in being cased in a coat of armour, he continues—"Its haunches were more than five feet wide, and its body twelve feet long and eight feet high; its feet were a *yard in length*, and terminated by most gigantic claws; its tail was probably clad in armour, and much larger than the tail of any other beast among living or extinct terrestrial mammalia. Thus heavily constructed, and ponderously accoutred, it could neither run, nor leap, nor climb, nor burrow under the ground, and in all its movements must have been necessarily slow. But what need of rapid locomotion to an animal whose occupation of digging roots for food was almost stationary? And what need of speed for flight from foes to a creature whose giant carcass was encased in an impenetrable cuirass, and who, by a single pat of his paw, or lash of his tail, could in an instant have demolished the cougar or the crocodile? Secure within the panoply of his bony armour, where was the enemy that would dare encounter this behemoth of the Pampas (the South American region where it existed), or in what more powerful creature can we find the cause that has effected the extirpation of his race? His entire frame was an apparatus of colossal mechanism, adapted exactly to the work it had to do; strong and ponderous, in proportion as this work was heavy, and calculated to be the vehicle of life and enjoyment to a gigantic race of quadrupeds, which, though they have ceased to be counted among the living inhabitants of our planet, have, in their fossil bones, left behind them imperishable monuments of the consummate skill with which they were constructed."

Associated in the same set of deposits—that is, in detrital beds of somewhat later origin than the tertiaries of Europe—Mr Darwin has discovered in South America the remains of several gigantic quadrupeds besides those of the megatherium. Of these, the most remarkable are—the *Megalonyx*, nearly allied to the megatherium; the *Scelidotherium*, an animal as large as the rhinoceros, but partaking of the character of the Cape ant-eaters and armadillos; another great armadillo-like animal with a bony covering; the *Macrauchenia*, a huge beast, with a long neck like a camel; and the Toxodon, perhaps the strangest animal ever discovered. The macrauchenia is described as belonging to the same division of the pachydermata as the rhinoceros and tapir, but showing in the structure of its long neck a clear relation to the camel, or rather to the alpaca and llama. As to the toxodon, it equalled in size the elephant or megatherium; but the structure of its teeth proves indisputably that it was intimately related to the gnawers, the order which, at the present day, includes most of the smallest quadrupeds. In many details it is allied to the thick-skinned animals; and, judging from the position of its eyes, ears, and nostrils, it was probably aquatic, like the dugong and menatee, to which it is also allied. "How wonderfully," remarks the discoverer, "are the different orders, at the present time so well separated, blended together in different parts of the structure of the toxodon!"

SUPERFICIAL ACCUMULATIONS.

After the deposition of the tertiary strata, a great change took place in the relative distribution of land and ocean. Most parts of Europe, America, and the other continents were elevated above the waters; other regions seem to have been submerged, and an arrangement of physical conditions established not differing widely from those now existing. But these new conditions did not for an instant arrest the degrading and transporting power of water, the wasting effects of the atmosphere, the disturbing efforts of volcanoes, or the progressive developement of organic life: the same agents which had exerted themselves, from the beginning of time, in modifying the physical features of the world, continued their career, only differing in power and degree according to this new arrangement. Thus accumulations of sand, gravel, clay, vegetable and animal matter, took place above the previously deposited strata—every river, lake, sea-shore, shell-bed, coral-reef, and peat-moss, contributing its peculiar quota. The term Superficial Accumulations is applied to these loosely-aggregated masses of matter—whatever be their composition or mode of formation—to distinguish them from the tertiary sands and clays, in all of which *stratification* is distinct and undeniable. Other designations have been proposed; but most of them are objectionable, on the ground of involving theoretic opinions as to the time and origin of the deposits. The following synopsis exhibits both the nature of the accumulations, and the agencies concerned in their aggregation:—

Agencies.	*Nature of Accumulations.*
DETRITAL.	Erratic blocks or boulders; dark tenacious clays.
	Ossiferous gravels, sands, and pebbly clays.
	Ossiferous caves, fissures, and breccia.
MARINE.	Raised or ancient beaches; submarine forests.
	Marine silt, sand-drift, shingle beaches, &c.
	Submarine deposits and accumulations.
FLUVIATILE.	Terrace-deposits on valley sides, marking successive water-levels, and distinct from general oceanic levels.
	Valley deposits, consisting of river sand, gravel, silt, &c.
	Deltoid or estuary deposits, ancient and progressive.
LACUSTRINE.	Sites of ancient lakes now silted up with various debris.
	Marls—such as shell, clay, and calcareous marls.
	Lacustrine silt, and accumulations now in progress.
MINERAL AND CHEMICAL.	Calcareous—calc-tuff, sinter, travertine, stalactites, and stalagmites.
	Siliceous and aluminous deposits from springs, &c.
	Saline and sulphureous deposits from springs, from the sea, volcanoes, &c.
	Bituminous exudations, pitch lakes, &c.
ORGANIC.	Vegetable—peat-mosses, jungles, vegetable drift.
	Animal—shell-beds, coral-reefs, &c.
	Soils—primitive earths, with admixtures of organised matter.
VOLCANIC.	Earthquakes—elevations and depressions, caused by
	Volcanoes—elevations, disruptions, and other changes caused by
	Discharges and accumulations of lava, scoriæ, dust, &c.

The above synopsis comprises all masses of matter which produce any sensible modification of the earth's surface; other accumulations than these must be of a very local and limited description. All these masses are, moreover, of obvious formation, and are either still in progress of accumulation, or have been accumulated since the Tertiary era; that is, since our planet assumed its present superficial aspect, and relative distribution of land and sea, or nearly so. On this account they may be designated "Formations of the Current Era," none of them presenting much difficulty of solution, with the exception, perhaps, of the *Erratic Block* or *Boulder Group;* the others have been already noticed under the head of MODIFYING CAUSES.

The boulder formation, or diluvial drift, consists, as stated, of a thick mass of dark tenacious clay, which overlies extensive districts, intermingled with numerous boulders having a rounded and water-worn appearance. There is nothing like regularity of deposit in the mass, unless it may be said that it attains the greatest thickness and uniformity of composition on extensive plateaus like those of the coal measures, at the eastern extremity of certain valleys, and on the south-eastern flank of hills belonging to the secondary period. The clay is generally of a dark-blue colour, though in some localities it assumes a reddish hue. There are few lines of lamination in the mass, and no appearances of regular stratification, unless in some districts where there is a sort of natural division into "upper and lower clays"—the lower being dark and more compact, the upper lighter in the hue, and separated from the other by a thin reddish streak. Waiving these minutiæ, the whole may be described as a covering of compact dark clay, from 10 to 120 feet in thickness, full of boulders and rolled stones, from the size of an egg to many tons in weight; these blocks occupying the bottom, middle, or surface of the mass, without regard to gravity or any other law of arrangement. The boulders are principally of primitive rocks, the more friable strata of the secondary measures being less capable of resisting the drifting action to which the mass has evidently been subjected, and which in all cases appears to have passed in a direction from north-west to south-east.

To account for this deposit, many theories have been advanced; but the one chiefly worthy of notice is that which supposes that those portions of Europe now covered with erratic blocks were submerged after the deposition of the stratified formations; that this submergence was caused by some extraordinary revolution in the planetary relations of our earth; that it was accompanied by a change of climate, and other terrestrial conditions; that while in this state icebergs and avalanches formed around the earlier mountains which were still left above water; and that these icebergs, as they were loosened from the shore by the heat of summer, and floated southward by the currents of the ocean, dropped their burden of boulders and gravel precisely as Captain Scoresby found modern icebergs dropping their debris in the northern seas, and as the officers of the recent antarctic expedition observed similar phenomena in the Southern Polar Ocean. It is further supposed, that while icebergs distributed the erratic blocks and other debris in deep waters, avalanches and glaciers were forming moraines of gravel in the valleys of the then existing land analogous to what is observed in the alpine glens of Switzerland. Again, one cannot read Mr Simpson's account of the shores of the Polar Seas, and learn that the ice formed during winter over whole leagues of gravel, breaks up during summer, and is blown on the beach by winds, or piled up by the tides, where, melting, it leaves long flat-topped ridges, without perceiving a wonderful resemblance between these effects and the long singularly-shaped ridges of "diluvial" gravel. According to this theory, it is easy to account for the south-eastward direction of the drift, for the Polar Ocean still maintains its great southward current to the equatorial seas, modified, undoubtedly, in its course by the inequalities of the bottom over which it passes. The chief difficulty to be obviated, is the temporary diminution of temperature which the north of Europe and Asia must have then experienced.

The igneous rocks connected with these superficial accumulations are essentially the products of active existing volcanoes; the raised beaches and old water-levels so frequent along our shores, whether resulting from elevation of the land or subsidence of the ocean, seem to indicate a more general, tranquil, and gradual cause than any set of volcanic operations.

The remains found in the superficial accumulations, for we can scarcely regard them as fossils, are all of a comparatively recent character and construction. A few of the animals existing during the deposition of the lower beds are now extinct, others present variety, if not specific distinctions; while in the higher accumulations nothing occurs which partakes not of the character of the current era. The boulder clays and gravels are all but void of organic relics; and it is only after that truly glacial period is passed, that the remains of land and sea animals are to be discovered—in some districts abundantly, in others rarely, and over all, a distribution somewhat analogous to that now existing. One of the most curious, as well as the most gigantic animals found in these deposits, is the *Mammoth*, or *fossil elephant*. It was surmised, when numbers of mammoth bones were first discovered in Italy, and other southern countries of Europe, that they were the remains of elephants brought by the Romans and others from Asia and Africa; but the incalculable quantities of them ultimately detected in Russia, Siberia, and other districts, where elephants were never brought in the shape of Oriental tribute, as they were to Rome, showed that their presence was to be attributed to natural causes, and not to the casual agency of man. In truth, the beds of the Volga, Don, and other northern rivers, are filled with them; and this can be accounted for only on the hypothesis, either of an alteration in the habits of the elephant, or of a great change of climate in these parts, or of some immense moving force on the face of the earth, which has carried them thither. The instance in which part of the flesh was found along with the bones, will supply us with a general description of the mammoth. When the animal, on this occasion, was first seen through the mass of ice in which it lay, the soft parts were nearly entire. After the natives had fed their dogs for a long time with the mountainous bulk of flesh, Mr Adams of St Petersburg heard of it, and set out to see it. When he reached the spot, the skeleton was entire, with the exception of a fore-leg. The spine of the back, a shoulder-blade, the pelvis, and the rest of the extremities, were still united by ligaments and a portion of the skin. The other shoulder-blade was found at some distance. The head was covered with a dry skin. One of the ears, in high preservation, was furnished with a tuft of hair, and the pupil of the eye was still discernible. The brain was found in the skull, but in a dry state. The neck was furnished with a *long mane*, and the skin, generally, was covered with black hairs and a reddish sort of wool. Of the quantity of hair and bristles that had been on the body, some idea may be formed from the fact, that thirty pounds of them were gathered from the ground, where the dogs, in eating the flesh, had dropt them. The tusks were more than nine feet long, and the head, without the tusks, weighed more than four hundred pounds. Altogether, the skeleton of this mammoth was about the size of a large elephant's. Skeletons similar to this have been found in abundance in the islands of the Arctic Sea. They differ in several minute points of structure from the common elephant, and on this circumstance the most rational explanation of their being found in such cold climates is founded: this explanation is, that the mammoth elephant was of a species fitted to be a native of cold countries; and of this reasoning, the different structure, and the long thick hair, are held to be proofs. Whether this may be the case or not, it seems certain that the mammoth's existence must have been very recent, and must have approached closely to, if not encroached on, the era of man.

Of man himself no remains have been found, save in the most recent and superficial deposits—as alluvial mud, calcareous breccia, volcanic tufa, and the like—thus proving him to be one of the latest, if not the very latest, inhabitant of this globe.

SUMMARY.

The history of the earth thus presents a long series of mineral and vital gradations, as yet but imperfectly interpreted by geology. The stratified formations, from the gneiss to the existing surface, bear evidence of these gradations, both in their composition and mode of aggregation; so also do the unstratified rocks—the granitic, trappean, and volcanic compounds—by the order in which they succeed each other. On the other hand, organic being rises, as it were, from the simple zoophyte to man himself, appearing at successive eras, as new conditions permitted its development. As system gradually merges into system, so the Fauna and Flora of one period seem to live into that of another, there being always certain races which serve as links of connection between succeeding eras. This idea of gradation implies not only an incessant onward change among the rock materials of the earth, but also that certain races of plants and animals must be perpetually dropping out, as links from the great chain of animated nature. And such is the fact even with respect to the current era. The mammoth, mastodon, megatherium, and other huge pachydermata, which passed from the tertiary to the modern epoch, have long since become extinct, leaving their bones in the clays and gravels of our valleys. The elk, bear, wild boar, wolf, and beaver, are now extinct in Britain; and what takes place in limited regions, must also occur, though more slowly, in wider continents. The dodo of the Mauritius, the dinornis and apteryx of New Zealand, are now matters of history; and the same causes which led to their extinction seem hurrying onward to the obliteration of the beaver, ostrich, kangaroo, and other animals whose circumscribed range of existence is gradually being broken in upon by new conditions. Such facts as these, taken in connection with the numerous superficial changes produced by rivers, lakes, seas, peat-beds, coral-reefs, earthquakes, and volcanoes, have led to speculations as to the conditions which yet await our planet.

Respecting the future history of the globe, it were vain to offer any conjecture. Subjected as it is to the numerous modifying causes previously described, we know that vast changes are now in progress, and that the present aspect of nature is not the same as that it must assume a thousand years hence. But what may be the character and amount of these changes, what the new conditions brought about by them, or what the races of plants and animals adapted to these conditions, we have no means of determining. This only we are assured of, that whatever vicissitudes may affect the globe, they will be tempered in perfect accordance with the happiness of organised existence: that Supreme Intelligence which has maintained the past will continue to protect and superintend the future.

METEOROLOGY—THE WEATHER.

Meteorology is the science of the Weather, and treats of the phenomena which occur in the atmosphere, their causes and effects. Men in all ages of society have been led, by motives of necessity or comfort, to study the indications of the weather in the different appearances of the skies. The mariner, the shepherd, the husbandman, and the hunter, have the strongest motives to examine closely every varying appearance which may precede more important changes. The result of these observations forms a body of maxims, in which facts are often stated correctly, but mixed with erroneous deductions and superstitious notions, such as the credulity of ignorant people always renders them ready to adopt. Hence the disposition to refer the ordinary changes of the weather to the influence of the moon, and to the stars; and to look for signs of approaching convulsions, even in the moral world, in comets, meteors, and other unusual phenomena. The progress of science, which tends to separate the casual precursors from the real causes of events, refutes these false reasonings, dissipates the empty terrors to which they give rise, and aims, by more patient, long-continued, and wide-extended observations, to deduce the general rules by which the phenomena of the atmosphere appear to be regulated.

Meteorology, therefore, taken as a distinct branch of knowledge, rests on no idle conjectures or imaginary fears, but has its foundations in the ascertained truths of physical science. The phenomena to which it refers are accounted for by natural laws disclosed to us in the study of chemistry, electricity, the atmospheric properties, optics, acoustics, heat, and other departments of physics. Of all branches of learning, none perhaps is more serviceable in clearing the mind from superstition; and on that account alone, independently of all other considerations, we are anxious that meteorology, as a science, should be extensively understood among the classes whom we have the pleasure to address. That nothing may be left to doubt, we commence by a recapitulation of the leading facts connected with the extent, composition, density, and other mechanical properties of the atmosphere.

THE ATMOSPHERE.

The atmosphere is an invisible aëriform fluid, which wraps the whole earth round to an elevation of about forty-five miles above the highest mountains. This great ocean of air, as we may call it, is far from being of a uniform density throughout its mass. At and near the level of the sea it is most dense, in consequence of the pressure of the superincumbent strata. As we ascend mountains, or in any other way penetrate upwards, the air becomes gradually less dense; and so thin is it at the height of three miles, as, for instance, on the summit of Mont Blanc, one of the Alps, that breathing is there performed with some difficulty. Beyond this limited height, the density of the air continues to diminish in the duplicate ratio of the altitude; and at the elevation of about forty-five miles it is believed to terminate, or at least to become so attenuated, that its density is inappreciable. So dense are the lower in proportion to the higher regions, that one-half of the entire body of air is below a height of three miles, the other half being expanded into a volume of upwards of forty miles in altitude.

The atmosphere, like all liquid and aëriform fluids, pressing equally in every direction, must exert a certain pressure on all objects, the degree of pressure being of course in proportion to the height above the mean surface of the earth. The part at which the pressure is greatest is at the level of the sea, for there the atmosphere is highest. The pressure at that level is ordinarily computed to be about 15 lbs., or, more correctly, 14.6 lbs. avoirdupois on every square inch of surface. The surface of a man of ordinary stature is about 15 square feet, or 2160 square inches, whence the whole atmospheric pressure which his body sustains amounts to the enormous sum of 31,536 lbs.! This great pressure is not sensible, however, because it is balanced by the reaction of the elastic fluids in the interior of our bodies. Under the exhausted receiver of an air-pump animal life is soon destroyed: on the summit of a very high mountain not only is fatigue and difficulty of respiration experienced, but the pulse is accelerated; and it has happened that the blood has started from the eyes and ears, and other tender parts of the body, in consequence of the diminished pressure.

The extreme height of the atmosphere is not observable from the situation in which we are placed on the earth. Our eye, on being cast upwards, perceives only a vast expanded vault, tinted with a deep but delicate blue colour; and this in common language is called the heavens or the sky. The blueness so apparent to our sense of sight is the action of the rays of light upon the thin fluid of the upper atmosphere, and the brightness is in proportion to the absence of clouds and other watery vapours. In proportion as the spectator rises from the surface of the earth, and has less air above him, and that very rare, the blue tint gradually disappears; and if he could attain a height at which there is no air, say fifty miles above the level of the sea, the sky would appear dark or black. Travellers who have ascended to great heights on lofty mountains, describe the appearance of the sky from these elevated stations as dark, or of a blackish hue.

Notwithstanding its transparency, the air thus intercepts and reflects the sun's rays, multiplies and propagates them by an infinity of repercussions; and were it not for this property, objects would never be illuminated unless exposed to the direct light of the sun. It is also the recipient and retainer of the solar heat reflected from the earth; and were it not so constituted, the solar rays would be returned to space, and an excessive cold continually prevail. Chemically speaking, it is a gaseous admixture—every hundred parts of which are composed of 79 nitrogen, and 21 oxygen—with about one part in a thousand of carbonic acid. Besides these, which are the permanent constituents of the atmosphere, there is always a certain amount of aqueous vapour, amounting from 1 to 1·0 per cent.; and in certain localities traces of ammonia, sulphurous acid, muriatic acid, and other ingredients are to be occasionally detected. The atmosphere may therefore be regarded as the laboratory in which clouds, rain, snow, and other vapours are formed—the medium through which the light and heat of the sun are diffused and equalised—an element without which animal and vegetable life could not exist, for both incessantly inhale and exhale its elements; and an agent indispensable to those physical operations which constitute the progressive history of our planet.

The Barometer.—The pressure of fifteen pounds to the square inch at the level of the sea, is found by experiment to be equal to the weight of a column of mercury of thirty inches in height; and the fact of such being the case, has suggested the construction of an instrument to measure the atmospheric pressure at different points and in various circumstances. This instrument is called the *barometer*, a compound from two Greek words, signifying weight-measurer.

The barometer in common use consists of a narrow glass tube upwards of thirty inches in length, and bent upwards at its lower extremity, as represented in fig. 1. The mercury is introduced into the tube with great care, so that a perfect vacuum exists at the upper extremity. The surface of the mercury in the bent part is open to the action of the atmosphere, and buoys up a small plummet or float F, to which a thread is attached; the thread proceeds upwards to a small pulley G, over which it goes, and terminates in a small ball W. The friction of the thread on the pulley turns a small index H, which points to figures on the surrounding dial. Commonly, the whole apparatus, except the dial-plate, is concealed in an ornamental frame. Barometers of this description are adjusted in such a manner that the smallest rising or falling of the mercury from atmospheric action, affects the index on the dial, and consequently shows the degree of pressure.

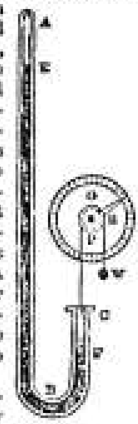


Fig. 1.

In common circumstances, the mercury ranges from twenty-nine to thirty inches. It seldom sinks so low as twenty-eight or rises to thirty-one. When it falls, an indication is given of diminished pressure; and as diminished pressure causes the air to expand, and consequently to be sensibly cooled, moisture is liable to be precipitated in the form of rain. Hence a fall in the mercury of the barometer is considered a prognostic of rain or wet weather, and a rise the reverse. The dial of the barometer is marked accordingly.

The usual rules, however, as to prognosticating the state of the weather from the action of the barometer, are in many cases very illusory; because much depends on the situation in which the instrument is placed. If situated near the sea's level, the pressure on the mercury will appear greater than if on a high ground, and, consequently, no general scale can apply to conditions so very dissimilar. In alluding to the vulgar errors entertained on this subject, Dr Lardner remarks—"It is observed that changes of weather are indicated, not by the actual height of the mercury, but by its change of height. One of the most general, though not absolutely invariable rules is, that where the mercury is very low, and therefore the atmosphere very light, high winds and storms may be expected. The following rules may generally be relied upon, at least to a certain extent:—1. Generally the rising of the mercury indicates the approach of fair weather; the falling of it shows the approach of foul weather. 2. In sultry weather the fall of the mercury indicates coming thunder; in winter the rise of the mercury indicates frost; in frost its fall indicates thaw, and its rise indicates snow. 3. Whatever change of weather suddenly follows, a change in the barometer may be expected to last but a short time. Thus, if fair weather follow immediately the rise of the mercury, there will be very little of it; and in the same way, if foul weather follow the fall of the mercury, it will last but a short time. 4. If fair weather continue for several days, during which the mercury constantly falls, a long continuance of foul weather will probably ensue; and again, if foul weather last for several days, while the mercury continually rises, a long succession of fair weather will probably succeed. 5. A fluctuating and unsettled state of the mercurial column indicates changeable weather. The domestic barometer would become a much more useful instrument, if, instead of the words usually engraved on the plate, a short list of the best established rules, such as the above, accompanied it, which might be either engraved on the plate or printed on a card. It would be right (concludes this writer) to express the rules only with that degree of probability which observation of past phenomena has justified. There is no rule respecting these effects which will hold good."

The Thermometer.—The atmosphere possesses the capacity of receiving and containing heat from the sun's rays or any other source of warmth, but this capacity is proportionate to the degree of density of the air, and accordingly varies in different situations. It is well known that the air is more warm on low than on high grounds, and this is a peculiarity in its condition arising from the difference of density at the two places. If we take a pound weight of air near the sea's level, and another pound weight at a spot a mile above the sea, we shall find that each pound contains precisely the same quantity of heat; but in the case of that taken near the sea, the air will feel warm, and in the case of the other, the air will feel cool. This seems a contradiction, yet it is a truth. A pound weight of air taken near the sea, is compact in substance, and goes into a comparatively small bulk; but that taken from a high part of the atmosphere is thin, and occupies a much larger space. This explains why the thin air on high grounds is seemingly colder than on low situations. Aloft, the air is as warm as it is below, but there is less of it; the particles are more widely asunder, and this produces the effect of a greater coldness. Properly speaking, the cold in high situations arises from the want of air, rather than from the air itself.

In the warmest regions of the globe, the air is cold at the tops of high mountains, merely because the air is there thin and incapable of forming a medium for the retention of the sun's rays. In every country there is a point of altitude at which water freezes on all occasions, whether summer or winter. In Europe, this point—called by some the snow line, or point of eternal snow—is from five to six thousand feet above the level of the sea; in the hot regions of Africa and America, it is fourteen thousand feet high. At these points of altitude respectively, snow lies constantly unmelted on the mountain sides and summits. In the warm regions of Hindostan, the atmosphere is as cool and pleasant at a certain height on the Himalaya Mountains as it is in the northern part of Europe. The plains of Mexico, under a burning sun, would not be endurable by man, if they were not at such an elevation as to possess an atmosphere so rare as to be incapable of being heated to excess.

Although the heat of the atmosphere thus depends on the density of the fluid, it is proper to state that it is likewise influenced by other circumstances. Certain bodies have the power of heating the atmosphere in a greater degree than would otherwise be the case. For example, in valleys the heat is thrown off from the sides of adjacent hills, from forests of trees, or other objects; and in these situations the air is hotter than if there were no such radiation. If the spot be sheltered from the cooling effect of winds, there is another cause of increase to the temperature.

Fig. 2.

The degrees of heat and cold in the atmosphere are called its temperature; and for finding this correctly, with reference to a standard, an instrument has been invented, called the *thermometer* a word signifying heat-measurer. It is a glass tube with a bulb at the bottom, into which mercury or quicksilver is put, with a scale of figures along the tube to mark the rising of the quicksilver. This instrument differs from the barometer, inasmuch as the quicksilver is sealed up close from the air. The atmospheric heat, however, affects the metallic fluid in the bulb, and, according to its warmth, causes it to expand and rise in the tube. The degree of temperature is indicated by the figures to which it ascends.

Our common thermometer (Fahrenheit), of which a representation is given in fig. 2, has a gradation from zero, near the bulb, to 212, the degree of heat of boiling water. In the scale of figures, 32 is marked as the freezing-point—that is to say, when the mercury is at the height of 32, *water* freezes; and the more it is below that point, the more intense is the frost: 55 is reckoned moderate heat, and 76 summer heat, in Great Britain: 98 is the heat of the blood in the average of living men.

Different nations adopt different graduations in the scale of thermometers, which is a fertile source of error and confusion in estimating and comparing the statements of temperature made by scientific men in different countries. Wherever the English language prevails, the graduation of a person called Fahrenheit is generally preferred. By the Germans, Reaumur's is used; and the French now adopt what they term a centigrade thermometer. In the French centigrade thermometer, 0 is the freezing-point, and 100 the boiling-point; in Reaumur's thermometer, 0 is the freezing-point, and 80 the boiling-point. Each degree of Reaumur is equal to two and one-fourth of Fahrenheit. It was at one time imagined that the greatest cold could make the fluid in the thermometer fall only 32 degrees below the freezing-point, the place to which it then fell being *zero*, and therefore the notation has been commenced by Fahrenheit at that place. But much greater degrees of cold exist at different parts of our globe in winter, and may be produced artificially, so that the fluid in the stem of the thermometer often descends below that point, and is then said to be at so many degrees below zero.

Water, as above mentioned, boils at 212 degrees, but this is only under the common pressure of the atmosphere near the sea's level. By removing a portion of the pressure either by an air-pump or by ascending a height, the vaporific or boiling point will be reached correspondingly sooner. On this account, we might ascertain with tolerable accuracy the height of mountains, by noticing at what degree of heat by the thermometer water boiled. A writer in the *Encyclopædia Britannica* has given the following instructions on this subject:—

"Boil pure water in an open vessel at the bottom of the elevation, and observe on the thermometer the point at which it boils. Boil it again at the top of the mountain, and observe with the thermometer the point at which it now boils; the difference of temperature, multiplied by 530 feet, will give a close approximation to the height of the upper above the lower station. This will give an approximation; but if greater accuracy be required, it will further be necessary to correct for the difference of the temperature of the air at the two stations, in the following manner:—Add the temperatures of the air at the stations, and subtract sixty-four from their sum; multiply the remainder by one-thousandth part of the height found, and this will be the correction to be added to the height formerly found. The result thus found will still require a slight correction for the figure of the earth and latitude of the place; but this does not amount to more in our latitude than an addition of about two feet in a thousand, which forms a second correction.

To illustrate the mode of deducing heights from the boiling-point, as we have given it, we take the following example:—Water boils on the top of Ben Nevis at 203·8 degrees, while at the side of the Caledonian Canal it boils at 212 degrees, the temperature being 30 degrees on the summit of the mountain, and 35 degrees below. In order to determine the height,

From 212°
Take 203·8°
There remains 8·2°
Multiply by 530
2460
410
4346 first approx.
4 first correct.
4350 second approx.
8·7 second correct.

To 30°
Add 35°
Sum 65°
Subt. 64°
Remain 1° mult. by 4·35.

Latitude 56° nearly
Mult. 4·350
by 2
8·700

Calc. height, 4358·7 third approximation.
4358, true measured height—the difference being less than 1 foot.

This method, however, is seldom susceptible of so high a degree of accuracy, even with the most carefully conducted experiments."

The Hygrometer.—One of the principal meteorological phenomena of the atmosphere is its capacity for receiving and holding moisture. Evaporation, to a lesser or greater extent, is in constant exercise over the whole earth. The ocean, lakes, rivers, fields, are ever yielding up water to the atmosphere, and plants and animals are also at all times giving forth exhalations. The atmosphere is thus a great receptacle for the moisture of the earth, and its capacity in this respect is increased by an increase of temperature. In a hot day, much more evaporation is produced than in one which is cold, but it is not on that account more perceptible by the senses. The more warm and free the air, so is the moisture less observable in its mass; and it is only when the atmosphere sinks to a certain pitch of cold, that we begin to see the suspended moisture in the form of mists and clouds. Thus, in a hot day, we do not see the breath issuing from our mouth, it being conducted away in an ethereal state, but in a cold damp day in winter, we see it proceeding in puffs at every expiration.

The state of the atmosphere as respects its moistness, is called its *hygrometric condition*, from the hygrometer, an instrument for ascertaining the relative degree of moisture in the air. There are various kinds of hygrometers, depending on the principle of the shrinking and expanding of bodies in relation to the degree of humidity with which they are affected. Fibrous vegetable substances, such as ropes, contract by imbibing moisture, while, on the contrary, hairs and catgut (strings of violins), contract by drought. Hair has been found to be the most delicate in hygrometrical motions. The celebrated Saussure, a Swiss philosopher, accomplished the construction of a hygrometer from a single long hair, previously cleaned in a soda ley. Various philosophical toys, as ornaments for mantel-pieces, have also been constructed to indicate the dryness or moistness of the atmosphere, all on the similar principle of contraction and expansion of a hair, piece of catgut, or part of the beard of the wild-oat. One of the most useful instruments of this class is a small object resembling a watch in external appearance, designed to prove the dampness or dryness of beds: a moveable hand on the dial-plate points out very speedily the hygrometrical condition of the bedclothes on which the instrument is laid.

Hygrometers of the kind just mentioned, however ingenious, fail as instruments of science or comparison, chiefly from the circumstance of their liability to lose their contractile and expansive energy, as well as the difficulty of making many of them possessing similar powers. To supply the required instrument of comparison, Professor Daniel contrived a very elegant hygrometer, which is now universally in use. It consists of a glass tube, bent nearly in the form of ⫍, supported on a stand, with a ball at each extremity, and containing only some ether. Within one of the depending limbs a thermometer is placed. The instrument operates on a little ether being dropped on one of the balls; evaporation immediately takes place, heat is abstracted, and the ball containing the thermometer is so cooled, that a dew perceptibly gathers on its surface. The degree of temperature at which the dew is seen to collect, marks the exact hygrometric condition of the atmosphere. The principle is precisely that on which a bottle of cold liquor, on being brought into a warm apartment, collects dew on its surface. If no dew appears on a bottle in such circumstances, the atmosphere of the room is certainly very dry.

CLOUDS.

The capacity of the atmosphere for moisture, even in the most favourable circumstances, is limited. The air cannot be loaded with water, in any form, beyond a certain point. Meteorologists mention, that if saturated with vapour even to its utmost extent, the whole would not form more than from six to seven inches of rain; in other words, not more than six or seven inches of water can be maintained in solution throughout the forty-five miles of atmosphere above, at any one time. The capacity for retaining moisture is greatest in the lower strata of the atmosphere, or where it is most dense and warm. At great elevations, such as eight or ten miles, the air is too thin to hold water in solution; and in all ordinary circumstances, the vapours of the earth do not ascend above four or five miles from its surface at the sea's level. Above those heights, whatever be the state of the weather beneath, all is clear and comparatively dry. In very few cases do clouds rise above the height of three miles; the field of their evolutions in temperate climes is most frequently not above a mile or a mile and a-half high.

Clouds, it will be perceived, are in reality dependent on temperature, and temperature is often dependent on winds. In a warm and dry summer day, evaporation proceeds with great activity, and, in a manner invisible to the eye, the moisture rises to the higher regions of the air. If the sun be powerful, the moisture may thus ascend several miles, and be dispersed like a gas, leaving no cloud to indicate its existence. All, therefore, appears clear, serene, and beautiful. Currents of cold air may now be supposed to intrude on the scene—the vapour is condensed—and clouds consequently make their appearance. A similar occurrence will take place by the weakening of the sun's rays, and withdrawal of heat at the approach of night, when clouds, as is well known, are always most numerous.

Clouds are commonly formed by the ascending of the invisible vapour into the cold regions of the air, where they take shapes conformable to the degree of temperature and action of varying currents. These currents, and other circumstances affecting them, are so constantly changing, that seldom for a single minute do they remain in one form, but shift into all sorts of postures, rise, fleet away to a distance, congregate, sink, disperse, and vanish. While the aggregation of clouds is caused by their coming in contact with cold currents of air, their evanishing is attributable to their being acted on by currents or strata of air warmer than those in which they have previously been sustained. The dispersal and evanishment of clouds may occasionally be seen to advantage in the neighbourhood of ranges of hills terminating abruptly. The clouds resting on the hill-tops are seen to begin to move towards the precipitous declivity, in consequence of the springing up of a breeze in that direction; and when they arrive at the precipice, they seem to tumble over and vanish in the fall. Dr Arnott speaks of the beauty of this phenomenon at Table Mountain, at the Cape of Good Hope; and we have observed it occurring at the termination of the range of Pentland Hills, near Edinburgh. The explanation of the phenomenon is simple: the cloud, on rolling from the summit of the hill, falls into an atmosphere of a higher temperature, and its particles being diminished into the gaseous form, disappear. When, on the contrary, a cloud is seen to ascend a hill, it enters a region of cold, and being condensed, it is precipitated as a shower of rain.

Luke Howard, in his Essay on Clouds, distributes them into four essentially different formations. These formations are—1. *Cirrus*, consisting of thready fibres diverging in all directions, or curled up at one end; 2. *Cumulus*, or roundish bank of cloud, increasing from a horizontal base upwards; 3. *Stratus*, layers vastly extended, connected, and horizontal; 4. *Nimbus*, the heavy black cloud dissolving in rain. The intermediate stages between these formations are designated by the compounds *cirro-cumulus*, *cirro-stratus*, *cumulo-stratus*, and *cirro-cumulo-stratus*.

By the same meteorologist, the clouds are generally assigned to three atmospherical regions—the upper, the middle, and the lower one, to which a fourth, the lowest, may be added. In the upper region, the atmosphere is in such a state, that it can receive and sustain only light and thin vapours; and to this district belongs the *cirrus*, a representation of which is given in fig. 3. Of all the various forms of cloud, it has the least density, but the greatest height and variety of shape and direction. It is the first indication of serene and settled weather, and first shows itself in a few fibres, spreading through the atmosphere. These fibres by degrees in-

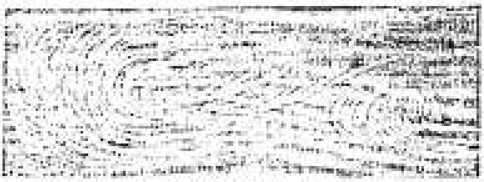


Fig. 3.—The Cirrus.

crease in length, and new fibres attach themselves to the sides. The duration of the cirrus is uncertain—from a few minutes to several hours. It lasts longer, if it appears alone and at a great height; a shorter time, if it forms in the neighbourhood of other clouds. From its usually curling appearance, the cirrus is called in England the *mare's-tail* cloud.

The *cirro-stratus* exists in a high region of the air, and is often the cirrus in an altered shape. It is gene-

Fig. 4.—Various forms of Cirro-stratus.

rally in the form of long horizontal streaks, which are ever shifting their figure and position. Sometimes it is a long row of slanting streaks, and at other times an apparently drawn out and translucent cumulus. In the latter form, when shone upon, at the close of day, it is not unlike a long feathery streak of fire.

The *cirro-cumulus*, of which a representation is given in fig. 5, consists of a collection of small white clouds,

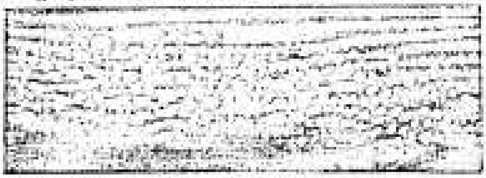


Fig. 5.—Cirro-cumulus.

of a roundish form, which give to the sky the appearance called dappled, and are in summer considered a prognostic of settled weather, or at least of an increase of temperature. Occasionally, the cirro-cumulus may be observed to change into the cirro-stratus.

The *cumulus* is a cloud of a much more massive character. It is vapour in the most compact form, and usually moves with the stream of air nearest to the earth. This region can receive much humidity, but not in perfect solution. The humidity becomes collected, and shows itself in masses rising conically, and resting on a region of air capable of giving it support. The annexed

Fig. 6.—Various forms of Cumulus.

engraving, fig. 6, represents the more usual forms of cumulus, whether in separate or congregated masses. The appearance, increase, and evanishing of cumulus, in fine weather, are often periodical, and correspondent to the degree of heat. Generally, it forms a few hours after sunrise, attains its highest degree in the hottest hours of the afternoon, and decreases and vanishes at sunset. Great masses of cumulus, during high winds, in the quarter of the heavens towards which the wind blows, indicate approaching calm and rain. If the cumulus does not disappear, but rises, a thunder-storm is to be expected during the night. If the upper region, with its drying power, predominates, the upper parts of the cumulus becomes cirrus. But if the lower region predominates (into which the densest vapours are attracted and dissolved into drops), the basis of the cumulus sinks, and the cloud becomes stratus, which is of moderate density, and its lower surface rests generally upon the earth or the water.

The *stratus* is the proper evening cloud, and is in reality the vapour which creeps along the ground or mounts into the lowest region of the air at sunset, after a fine summer day. All mists and fogs are of this species of cloud, which in its lightest state does not wet leaves or any objects with which it comes in contact. In calm evenings, the stratus may be seen ascending from the valleys to the higher grounds, and there, as

Fig. 7.—The Stratus.

shown in fig. 7, it extends itself in masses like a fleecy mantle. It generally arrives at its point of greatest density about midnight, or between that time and daylight, and disappears at sunrise by the gradual elevation of temperature in the atmosphere. Sometimes it remains quiet, and accumulates in layers, till the atmosphere is incapable of sustaining its weight, when it assumes the condition of the heavy and dark *nimbus*, and falls in a shower of rain.

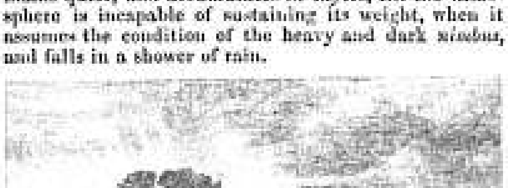


Fig. 8.—The Nimbus.

The various circumstances which concur to precipitate moisture in the atmosphere into the visible form of clouds, are summed up as follows by Mr Graham Hutchinson, in his Treatise on Meteorological Phenomena (Glasgow, 1835):—"1. When a diminution of the atmospheric temperature, unaccompanied by atmospheric rarefaction or transportation, takes place. 2. When a diminution of the atmospheric temperature, arising from atmospheric rarefaction, takes place. 3. When a diminution of the atmospheric temperature, arising from the transportation of air from a warm to a cold climate by the agency of winds, takes place. 4. When an intermixture, and consequent reduction to a mean temperature, of different portions of air, of previously different temperatures, takes place. If any one, or any combination of these circumstances happens to occur, when the atmosphere is previously saturated with humidity; or supposing the atmosphere previously somewhat under-saturated, if they take place to such an extent as to produce over-saturation, a precipitation of moisture into the visible form of cloud or mist is the necessary consequence."

Clouds of the cumulus form are frequently seen to rest or hover over the tops of mountains, and it has therefore been supposed that hills attract clouds. Undoubtedly, from electric causes, clouds are occasionally attracted by mountain-tops, where they discharge their contents in a thunder-storm; but in common circumstances, attraction is not the cause of cumulus on hills. The ordinary cause is a low temperature of the atmosphere at these altitudes—a temperature lower than that of the region of air at the same height away from the hills. The mode of cloud-formation on mountain ranges seems to be this: the warmer air of the valleys or of the sea, loaded with invisible particles of moisture, is blown in the direction of the hills, and being compelled to ascend, the particles become visible when they attain the summit. But the wind does not rest there: the particles are blown away beyond, and perhaps vanish in a warmer region of air, but new particles are constantly coming up to supply their place; and thus a shifting appearance is given to the masses of clouds which we observe hovering on the tops of the hills. "Mountains of themselves," observes Mr Hutchinson, "that is to say, without wind, can form no clouds; and winds of themselves, that is to say, without the aid of atmospheric rarefaction which accompanies their exaltation while passing over mountains, are, in this respect, equally inefficient. In short, mountains in all climates may be regarded as passive instruments in the formation of clouds only during windy weather. And whenever their height is such that the temperature of the lower atmospheric strata, while surmounting them, becomes so much reduced as to cause over-saturation, the formation of clouds must take place. Hence, the higher the mountains, the more certain they are, during windy weather, to cause the formation of clouds; and the nearer the hygrometric condition of the aërial strata, before beginning to ascend the mountains, is to the point of saturation, the less height will suffice for that purpose. Accidental coldness on the tops of mountains sometimes adds to their efficacy in causing the formation of clouds. Such may be occasioned by snow-falls during the cold season remaining unmelted, or only partially melted (as frequently happens on the northern exposure of mountains in the northern hemisphere), till long after the returning heat of spring and summer has rendered the falling of snow, at corresponding altitudes, extremely improbable.

Haze—Mist—Fog.—Mists or fogs, as has been noticed above, are a variety of clouds, and are scientifically described by the term *stratus*. A haze is that species of vapour in which the watery particles are only partially or imperfectly condensed, so as to produce an indefinite obscuration, which generally may be observed in the evening, when the temperature of the air becomes diminished by the decline of the sun towards the horizon. When viewed from a distance, the surface of the earth always appears enveloped in a haze of greater or lesser density; and although, when sailing on an open expanse of ocean, the atmosphere may appear very clear, yet, on being viewed from a high mountain, the water will appear obscured by a haze, which will be found to extend many feet above its surface. When the watery vapour in the surrounding air becomes more condensed, with a defined outline in the form of a cloud, either resting on the surface of the earth, or a few feet above it, then it is termed a mist; and when the whole atmosphere around appears equally obscured, then we give it the name of a fog, which, however, is not to be confounded with that moist and obscured state of the air which often accompanies our easterly and westerly winds.

Mists, as well as fogs, consist of thin vesicles of water containing air. How these vesicles are formed, is not well understood; but the general opinion is, that mists and fogs arise from air of unequal temperatures, holding moisture in solution, mingling together. Accordingly, the mixture of the evening sea-breeze with the air above the land often produces dense mists; for the air above the sea is warmer than that above the land, and when they intermix, a condensation of aqueous vapour into mist or fog takes place. Besides this, the contraction of the air, from its becoming colder after sunset, often produces a condensation of the watery particles floating in it. In addition to which, there can be no doubt that a certain quantity of vapour rises up, or evaporates, from the earth itself, which we may suppose to have been within a short period moistened by rain, and this, having become elevated to some distance above the ground, in like manner becomes condensed. During the night, therefore, the air above the surface of the earth is thus generally rendered hazy, and light mists are observed hanging in gauzy folds along the sides and around the summits of hills and mountains; hence Lord Byron, in noticing the approach of morning, gives us this beautiful passage:—

> "Night wanes; the vapours round the mountains curl'd
> Melt into morn, and light awakes the world."

Fogs are often, especially in large towns, remarkably dense; indeed, so much so as to occasion serious accidents from their interference with distinct vision. This frequently happens in London, and in other large cities, and arises from smoke, vapours, dust, &c., being stagnated in the thick fog. On certain calm winter days it may be observed, that the smoke, on leaving the chimneys, descends towards the ground, and downward currents often set through flues at the bottom of which there is no fire. Fogs seldom rise high in the atmosphere; hence Dr Darwin, in giving an account of one which overspread a tract of ground through which he had occasion to ride, states, that on every rising of the ground he was quite above its level, though in descending again it was so thick that he could scarcely see a yard beyond his horse's head. In the northern regions, fogs are extremely dense, owing, doubtless, to the difference between the temperature of the air which sweeps over the immense tracts of ice extending through those desolate regions, and that of the air which passes over the warmer surface of the ocean. It is one of the greatest annoyances which the whalers and navigators in those dangerous seas have to encounter.

Colour of the Clouds, &c.—Clouds being composed of pure watery particles, cannot intrinsically possess the colour of any foreign body; nevertheless, by the peculiar action of the rays of light on different parts of their mass, they frequently assume a variety of tints, particularly red and orange, at and shortly after sunset. The sun and moon likewise, when shining through a dense vapoury medium, assume a deep red tinge. Superstition would ascribe these phenomena to supernatural causes; but, in truth, all is but a simple effect of the refrangibility of the rays of light. The white rays are decomposed in shining through the globules of vapour, and they shine as if coming from a prismatic spectrum. In the article OPTICS, it will be explained that each of the seven rays of which the white light is composed has a different degree of refrangibility, and it is on this account that a variety of colours exist in nature. "Had it been otherwise—had the objects of the material world," says Sir David Brewster, "been illuminated with white light, all the particles of which possessed the same degree of refrangibility, and were equally acted upon by the bodies on which they fall, all nature would have shone with a leaden hue, and all the combinations of external objects, and all the features of the human countenance, would have exhibited no other variety than that which they possess in a pencil sketch or china-ink drawing. But he who has exhibited such matchless skill in the organisation of material bodies, and such exquisite taste in the forms upon which they are modelled, has superadded that ethereal beauty which enhances their more permanent qualities, and presented them to us in the ever-varying colours of the spectrum."*

In cold climates the sky has generally a dull blue or grey tinge, even in fine weather, a circumstance arising from the prevalence of moisture in the air, which forms a kind of gauze, through which our eye is unable to penetrate. In more warm and genial climes, such as that of Italy, the colour of the sky is a bright blue, and in hot weather slightly purplish. This brilliance arises from the comparative absence of vapoury particles; yet that vapour does exist in the clearest azure sky is indisputable, for it is by refraction of light that the colour appears. If moisture were entirely absent, there would be no refrangibility, and consequently no blue colour. The sky, as formerly mentioned, would be black. The reason assigned for the prevalence of a blue colour in the sky is, that the blue rays are reflected more copiously than any of the others.

* Life of Sir Isaac Newton, p. 78.

DEW.

Dew is a result of an alteration of temperature after sunset. No sooner does the sun begin to decline towards the horizon, than its rays fall more slantingly on the earth, whereby their intensity is diminished, and a change of temperature immediately ensues; for the air soon feels chilly and damp, and the grass beneath our footsteps becomes moistened with a genial and refreshing dew.

It has been elsewhere explained, that all bodies receive a certain quantity of heat, which in particular circumstances they again emit; in doing which they necessarily become colder than they previously were, unless they receive in exchange another quantity of heat sufficient to compensate for the loss they have sustained. In this case, their temperature will remain stationary; but if they part with more than returns to them, their temperature necessarily must fall. When, then, the object so cooled is encompassed by a warm and moist medium, it condenses, by its cold contact, vapour on its surface, and thereby becomes moistened. Hence the origin of dew; for no sooner does the sun sink towards the horizon, than the blades of grass which clothe the surface of the earth give out the heat which they have been receiving during the day; the consequence of which is, that their temperature falls so much below that of the surrounding air, that they condense on their surfaces part of the moisture which immediately surrounds them. The temperature of the body, as indicated by the thermometer, at which this deposition takes place, is called the "dew point," which, for the formation of dew, must always be below the temperature of the surrounding atmosphere: indeed, the quantity of dew formed will always be in proportion to the coldness of the grass and to the quantity of moisture suspended in the air. Besides this, after the sun has set, the moisture which the earth has imbibed during the day, and which still rests below the grassy surface, rises up or evaporates—in doing which, it rises up through or between the blades of grass, the cold contact of which gradually condenses it. Dew, therefore, on calm and clear nights, is more abundant shortly after rain than during a long season of dry weather. During westerly or southerly winds, which are generally impregnated with moisture, it is also formed more copiously than during easterly and northerly winds. Besides the quantity of moisture existing in the air, the greater or lesser copiousness of the dew formed, depends, as we have premised, on the coldness of the objects on which it is about to be condensed. If the night be calm and clear, the grassy blades emit their heat freely, and it is dispersed through the atmosphere without any equivalent return, whereby the temperature of the grass soon sinks sufficiently low to condense the surrounding vapour; but if, instead of this, the night be cloudy, then the clouds reflect, like mirrors, the rays of heat back again to the grassy blades, and prevent this diminution, so that less dew is then deposited. If, in addition to the sky being overcast with clouds, the weather be windy, no dew will be formed; for the temperature of the grass is then prevented sinking by the agitation of the air, by which a warmer current is continually brought to succeed the colder current by which it is surrounded. Hence, if, during the night, the weather, from having been calm and serene, become windy and cloudy, not only will dew cease to form, but that which has been already deposited will disappear, or diminish considerably. Every kind of covering or shelter which extends above any object, will interrupt the radiation or escape of its heat; for which reason gardeners, to prevent plants being chilled, cover them over, on the approach of evening, with a layer of straw or matting.

For reasons similar to those now advanced, the grass which is situated beneath the boughs of large and spreading trees, becomes only sparingly moistened with dew; for the shelter above interrupts the progress of radiation from the substances underneath, and so preserves their temperature. Accordingly, it is an established axiom, that whatever diminishes the view of the sky, as seen from the exposed body, will occasion the quantity of dew to be less than would have been deposited if the exposure to the sky had been complete. Dew is formed, therefore, more sparingly and irregularly in cities than in the country, where the most open grassy plains are always the most abundantly bedewed. In this country it begins to appear in shady places as soon as the heat of the atmosphere has declined; but though the grass on clear still evenings often becomes moist several hours before sunset, dew is seldom present in such quantities as to exhibit visible drops until the sun reaches the horizon; nor does it become copious until some time after sunset. It continues to form also in shaded places some time after sunrise; and it is remarkable, that more dew forms a little before, and in shaded places a little after sunrise, than at any other period. It has also been observed, that more dew is formed between midnight and sunrise than between sunset and midnight—a circumstance which is owing to the cold of the atmosphere being greater in the latter than in the former part of the night. As the quantity of dew deposited thus depends so much on the degree of coldness which the body about to be bedewed attains, its quantity must be materially modified by the greater or the lesser facility with which substances part with their heat. Grass, being a filamentous substance, parts more readily with its heat than garden mould or gravel; wherefore dew is more plentifully deposited on meadow grounds than on ploughed lands. Thus, cultivated soils are refreshed with abundance of dew, while barren rocks and sandy deserts do not receive this congenial moisture. Indeed, every shrub and herb, every leaf and blade of grass, possesses, according to its kind, a different power of radiation, so that each condenses as much dew as is necessary for its own individual and peculiar exigencies. Thus, not even a single dew-drop seems to have been formed by the rude hand of chance, but is adjusted by the balance of infinite wisdom to accomplish a definite and benevolent purpose.

THE WINDS.

A change in the temperature, a diminution of the vapour, or any other cause that may occasion a portion of the surrounding atmosphere to contract or expand, will give rise to the aërial currents denominated winds, which, indeed, bear a strong analogy to the currents which occur in the ocean. When the air by which we are surrounded becomes heated, it expands, and grows specifically lighter, in consequence of which it mounts upwards; and the colder and denser air which surrounds the mass thus rarefied, rushes in to supply its place. When the door of a heated apartment is thrown open, a current of air is thereby immediately produced; the warm air from the apartment passing out, and the cold air from the passage rushing in. So, also, in those buildings where the manufacture of glass is carried on, the heat of the furnace in the centre being intense, a violent current of air may be observed to force its way in through the doors or crevices on the opposite sides of the house. On applying these principles to account for the origin of the wind, we find that, when the rays from the sun, by their reflection from the earth's surface, have heated or rarefied a portion of the surrounding air, the air so rarefied ascends into the higher regions of the atmosphere, and the colder air by which it was surrounded moves forward in a sensible current to fill the vacuity. When, also, a condensation of vapour in the atmosphere suddenly takes place, giving rise to clouds which speedily dissolve in rain, the temperature of the surrounding air is sensibly altered, and the colder rushing in upon the warmer, gives rise to a sudden gust of wind. For this reason, a cold heavy shower passing overhead, with a hasty fall of snow or hail, is often attended with a violent and sudden gust of wind, such as sailors call "a squall," which ceases when the cloud disappears, but is renewed when another cloud, sweeping along in the same direction, brings with it a fresh blast.

The general nature of the winds in this and in other countries depends very much on the character of the region whence they may have swept; and, accordingly, it is necessary to remember that the globe is divided into *five* zones or belts—the torrid, which is exposed to the direct rays of the sun; the two temperate zones, which, meeting the rays of the sun obliquely, enjoy a moderate degree of heat; and the two frigid zones, which, deprived of the heat of the sun for a great part of the year, and during the other part receiving his rays still more obliquely, are regions of ice and snow which, it would appear, are destined ever to remain uninhabitable solitudes. Generally, in the British islands, a westerly wind is moist, because it comes from the Atlantic, where a great quantity of vapours arise. When mingled with that of the south, which comes from the torrid zone, it is rendered particularly warm. The east wind is the driest, because it comes from the continent of Asia, where there are few seas. The north wind, however, is the coldest, because it sweeps from the immense tracts of ice and snow in the frigid zone. The north-easterly winds, therefore, being so dry and cold, are in this country proverbially the most chilly and bitter.

While the south-west is the most predominant wind in Europe, the north-east winds in spring may be regarded as periodical in the climate of Britain; it is to be remembered, however, that the succession of the seasons of the year, with their characteristic changes of temperature, depend principally on the relative position of the earth to the sun. The more vertically or directly the sun's rays reach the surface of the earth, descending in a more concentrated manner, the greater is the degree of heat which they produce; but the more obliquely they fall, being thereby more scattered, and consequently falling with less power, the smaller is the degree of heat they impart. Accordingly, in the winter season, the sun's rays reach the surface of the globe in our latitude more obliquely than they do in the summer season; consequently, that season is characterised by the coldness which then prevails; therefore, the winds, powerful as their agency certainly is, exercise only a subsidiary influence in modifying the temperature of the seasons. Besides this, the physical aspect of a country, its mountains and table lands, its chains of hills and its valleys, its rocky elevations and its level plains, its protected or exposed coasts, all influence very materially the direction of the wind, which must, as it sweeps along, coincide with the elevations and depressions of the country over which it passes. Hence it has been shown by physicians, that the climate in certain districts of England, owing to the protection of surrounding elevations, rivals in salubrity, even in the most trying seasons, many of the most favourite and fashionable resorts for invalids in the south of France.

Besides the division of the winds founded on their direction from the cardinal points—as into north, north-east; south, south-east; west, south-west; east, &c.—they are divided by meteorologists into four classes, namely, regular, irregular, periodical, and hot winds; the causes of which, with the phenomena by which they are attended, will now be considered.

Regular Winds—Trade-Winds.—In order that we may distinctly understand the cause and nature of the trade-winds, it is necessary to bear in mind that the earth, in the centre of its circumference, at an equal distance from the poles, is divided by a line called the equator into two hemispheres—the northern and southern. Across the equator, cutting it obliquely, there passes another great circle called the ecliptic, which describes the path the sun traverses. It extends 23½ degrees north and 23½ degrees south of the equator, which is the utmost limit the sun traverses; for, when arrived at either of these boundaries, he again seems to return towards the equator. It must be very evident that the region of the earth included within a circle drawn 23½ degrees north and 23½ south of the equator—which will comprehend the greatest portion of Africa, a considerable part of Asia and America, and many large, fertile, and populous islands in the East and West Indies—will receive constantly the solar rays in a direction so little oblique, that the most intolerable heat might there be anticipated. It was therefore called the torrid zone; and the limits at which the sun stops, and appears to retrace his course, have received the name of tropics, or circles of return. This being premised, and it being also remembered that the earth revolves daily, "her silent course advancing," round the sun from west to east, the cause of the trade-winds will be readily understood. The rays of the sun, in its apparent motion from east to west, obviously rarefy, by the heat they impart, the air beneath, and the air so rarefied rises into the higher regions of the atmosphere. While this takes place, the colder air from the adjoining temperate zones rushes in to supply its place. But it is from the polar regions, north and south, that these colder currents originally come; and did the earth remain at rest, such would be their obvious direction. Instead of this, however, north of the equator the direction of the trade-winds is from the north-east; south of the equator, from the south-east; the cause of which is thus explained:—The velocity with which the earth revolves is inconsiderable, if appreciable, at the poles, but increases as we advance, and is at its maximum at the equator; the winds, in sweeping from the poles, do not acquire a corresponding velocity with the motion of the earth, as they advance towards the equator; therefore, moving more slowly than the earth, they are left behind, striking bodies with the excess of the earth's velocity; so that, to the observer who imagines himself at rest, the air appears to move in a direction contrary to the rotation of the earth, namely, from east to west. While the trade-wind thus blows upon the surface of the earth, there is no doubt that an opposite current, probably that of the rarefied air which has ascended, flows in the contrary direction, at a great elevation in the atmosphere.

The external limits of the trade-winds are 30 degrees north and 30 degrees south of the equator; but each limit diminishes as the sun advances to the opposite tropic. The larger the expanse of ocean over which they sweep, the more steadily do they blow; accordingly, they are more steady in the Pacific than in the Atlantic, and in the South than in the North Atlantic Ocean. Within the region of the constant trade-winds, rain seldom occurs, but it falls abundantly in the adjoining latitudes. The reason is, that rain is produced by the sudden mixture of air of different temperatures charged with moisture; but the constant circulation and intermixture of the air from the upper strata of the atmosphere, or ground current, maintains so equal a temperature in these latitudes, as not to occasion the condensation of vapour which is necessary for the production of rain. Besides which, it is plausibly enough alleged by Daniel, that the aqueous vapour constantly flows off in the current of the equatorial wind into the adjoining temperate zones. Within the limits of the trade-winds, contrary to what might have been anticipated from the latitude, the atmosphere is peculiarly cool and refreshing.

The agency of the winds in clearing the atmosphere from noxious effluvia, and keeping it from stagnating, is so apparent, that it scarcely requires to be noticed. In the case of the regular winds to and from the equator, an interchange of atmosphere is effected, beneficial to both torrid and temperate zones. On this interesting point in natural science, the following observations are made by Leibig in his work on Organic Chemistry (1840):—"The proper, constant, and inexhaustible sources of oxygen gas are the tropics and warm climates, where a sky seldom clouded permits the glowing rays of the sun to shine upon an immeasurably luxuriant vegetation. The temperate and cold zones, where artificial warmth must replace deficient heat of the sun, produce, on the contrary, carbonic acid in superabundance, which is expended in the nutrition of the tropical plants. The same stream of air which moves by the revolution of the earth from the equator to the poles, brings to us, in its passage from the equator, the oxygen generated there, and carries away the carbonic acid formed during our winter. The experiments of De Saussure have proved that the upper strata of the air contain more carbonic acid than the lower, which are in contact with plants; and that the quantity is greater by night than by day, when it undergoes decomposition. Plants thus improve the air, by the removal of carbonic acid, and by the renewal of oxygen, which is immediately applied to the use of man and animals. The horizontal currents of the atmosphere bring with them as much as they carry away; and the interchange of air between the upper and lower strata, which their difference of temperature causes, is extremely trifling when compared with the horizontal movements of the winds. Vegetable culture heightens the healthy state of a country, and a previously healthy country would be rendered quite uninhabitable by the cessation of all cultivation." How grand the theory in these passages respecting the influence of winds on vegetation! Those streams of air, which superstition would ascribe to demons, are among the most beneficent means arranged to preserve atmospheric salubrity, and afford materials for man's subsistence.

The Monsoon.—In India, a very remarkable periodical or half-yearly wind prevails, which is called the Monsoon, from a Malay word *mousin*, which signifies season. It blows one-half the year from the south-west to the north-east, and the other half from north-east to south-west. The former is accompanied by rain and tempest, and constitutes in India the "rainy season;" the latter, although in this respect admitting of some modifications, constitutes the "dry season" of the year. The south-west monsoon, in the southern parts of India, commences about the beginning of June; but in proceeding northwards, it does not commence until later. It is ushered in by vast masses of clouds, which arise from the Indian Ocean; and as they advance towards the north-east, gather and thicken as they approach the land. In a few days afterwards, the sky assumes a more troubled aspect towards the evening, and it is in the night that the monsoon generally sets in. It begins with violent blasts of wind, which are succeeded by floods of rain, during which the lightning flashes without intermission; at first illuminating the sky, showing the clouds near the horizon; then discovering the distant hills, and leaving them again shrouded in darkness; then, in an instant, reappearing in vivid and successive flashes, which exhibit even the nearest objects in all the clearness and distinctness of noonday light. The thunder, in the mean time, continues in loud peals, and when it ceases, the rain pours in heavy torrents. This lasts for several days; the sky then clears, the air becomes soft and pure, the rivers are full and tranquil, and the whole face of the earth, as if by enchantment, appears clothed with thick and luxuriant verdure. The rain, after this, falls at intervals for about a month; then it increases in violence, and attains its height in the month of July, when it descends thickly and heavily *en masse* from the heavens. Then this monsoon, in August, somewhat diminishes; in September it abates, or is entirely suspended until the end of the month, when it again re-appears; and departs, as it came, amidst thunder and lightning, and all the turmoil of tempest.

Such is the south-west monsoon, as it appears in the greater part of India; but it is liable to considerable variations, caused by the influence of the sea and the mountainous regions along which it may sweep. Near the sea, the rain falls more plentifully; because, from the more abundant evaporation, the air is there more charged with moisture. The mountains also affect its course, by interrupting and diverting the progress of the winds and the clouds they bear. Thus, the wind which brings the rain to the north-eastern part of the Indian continent, originally blows from the south-west over the Bay of Bengal, until it reaches the Himalaya Mountains, and those which join them from the south; these check its current, and compel it to follow their range towards the north-west; but when it has continued so far towards the north-west as to meet that chain of mountains called the Hindoo Coosh, then it is by them turned off towards the west, and sweeps along until interrupted by the range of the Solimaun, which prevents its proceeding farther in that direction, or compels it to part with the clouds with which it was laden. If the reader will for a moment trace on the map the course here described, he will at once perceive the influence these mountains must have in modifying the direction and general character of the monsoon.

Hitherto we have principally noticed the south-west monsoon, which constitutes the "rainy season" in India; to this succeeds the north-east monsoon, which, with the exception of the eastern side of the Coromandel coast—to which it brings the periodical rains that begin about the middle of October, and end generally in the middle of December—is attended with dry weather throughout the peninsula. After setting in, during the month of September, with considerable variations in its commencement, the north-east monsoon establishes a milder though not less absolute dominion, which lasts until the end of February or the beginning of March. From that period to the month of June, the winds are irregular, and the heat very great all over the peninsula. In respect to the cause of the monsoons, they are, on the authority of the celebrated philosopher Halley, to be explained on the same principle as the trade-winds; the action of the sun's rays inducing a rarefaction of the air, and consequent rushing in of a colder current from the sea and land; and the physical aspect of the country, its elevations or plains, modifying the reflection and influence of the solar rays: which causes, taken conjointly, sufficiently account for the periodical recurrence and local peculiarities of the monsoons.

Sea and Land Breezes.—The sea and land breezes, occurring in warm climates, may also be classified under the head of periodical winds; they occur in the following manner:—During the day, the wind blows for a certain number of hours from the sea to the land; but when evening arrives, it changes its direction, and blows as many hours from the land to the sea. In this country the sea-breeze sets in about seven or eight in the morning, and is strongest at noon, but continues very sensible until three o'clock, when the surface of the sea will be observed to exhibit ripples of a deep blue colour. After this, at six in the evening, the land-breeze commences. The sea now assumes a greenish hue; and this breeze continues until eight the next morning. The cause of this alternation may be readily explained. During the day, the air over the surface of the earth is more heated by the rays of the sun than that over the surface of the sea; because the earth, from its greater density, comparative state of rest, and numerous elevations, reflects the sun's rays sooner, and with more power than they are reflected from the sea, which, from its state of constant motion and transparency, imbibes the warmth very intimately, though more slowly. Accordingly, when the sun, having arisen above the horizon, has, by the reflection of its rays, thus imparted a sufficient degree of warmth to rarefy the body of air over the land, the air so rarefied ascends into the higher regions of the atmosphere, while that over the surface of the sea, being scarcely at all rarefied, rushes in to supply its place. Hence, a sea-breeze, or current of air from the sea to the land, at this time prevails; but when the sun again begins to sink below the horizon, the body of air over the surface of the land becomes rapidly cold, and the earth itself, by radiation, parts very quickly with the warmth it had absorbed. Then the land air, being below the temperature of the sea air, rushes in to supply its place, and thus during the night, a land-breeze, or a current of air from the land to the sea, is produced. When the sea-breeze first sets in, it commences very near the shore, and gradually extends itself farther out at sea, and, as the day advances, becomes more or less hot. Hence, the sails of ships have been observed quite becalmed six or eight miles out at sea, while at the same time a fresh sea-breeze has been blowing upon the shore. The cause of this is obvious: for it is natural to suppose that the mass of air nearest the land will be the first to rush in, for the purpose of supplying the place of the air which is rarefied immediately above it. On this account the effect of the sea-breeze is said not to be perceptible at a distance of more than five or six leagues from the shore, and for the most part becomes fainter in proportion to its distance from land. The distance, on the other hand, to which the land-breeze extends in blowing across the sea, depends on the more or less exposed aspect of the coast from which it proceeds.

Hot Winds—the Simoom.—Hot winds of a very dreadful character occur in Arabia, Egypt, Syria, and adjacent countries, the moving air having acquired a prodigious degree of heat and aridity in passing over the hot desert continents. One of the most appalling of these winds has been called by the Arabs the *simoom*, from a word meaning poison; and it is also known by the name of the *kamsin*, which signifies fifty days. When the simoom begins to blow in Arabia, the atmosphere assumes an alarming aspect. The sky, at other times so clear, becomes dark and heavy; the sun loses his splendour, and appears of a violet colour. The air is not cloudy, but thick from the subtle dust with which it is loaded. Sometimes the sky appears yellow, from the refraction of light on the minute pieces of quartz which are floating in the air. Sometimes it has a peculiar and frightful blue colour; which variety of this wind comes from those districts where the soil is composed of a great deal of blue-coloured marl and limestone. At first, the wind is light and rapid, and not remarkably hot; its temperature, however, soon increases, until it ranges at upwards of 123 degrees Fahrenheit. The danger, however, is most imminent when it blows in sudden squalls, as then the rapidity of the wind increases the heat to such a degree as to be altogether intolerable. "When this wind occurs," says Volney, "all animated bodies discover it by the change it produces in them. The lungs, which a too rarefied air no longer expands, are contracted and become painful. Respiration is short and difficult, the skin parched and dry, and the body consumed by an internal heat. In vain is recourse had to large draughts of water; nothing can restore respiration: in vain is coolness sought for; all bodies in which it is usual to find it deceive the hand that touches them. Marble, iron, water—notwithstanding the sun no longer appears—are hot. The streets are deserted, and the dead silence of night reigns every where. The inhabitants of towns and villages shut themselves up in their houses, and those of the desert in their tents, or in wells dug in the earth, where they wait the termination of this destructive heat." All travellers bear testimony to the destructive effects of this wind; and it is stated that camels are so conscious of their danger from its influence, that they instinctively bury their nostrils in the sand, and keep them there until the squall is over.

The Sirocco—the Solano.—The sirocco is the name given to the hot wind which occasionally blows in Sicily, and which is supposed to derive its origin from the excessively heated deserts of Africa. The solano is a term applied to a modification of this wind which is met with in Spain and Portugal. The heat of the sirocco wind is described to be excessive. Brydone observes, that, when he experienced its first blast, he felt as if his face had been exposed to the burning steam from the mouth of an oven. When this wind occurs, the inhabitants of every town close their doors and windows against the admission of the external air, and sprinkle their apartments with water. Not a person ventures into the open air. It lasts from six or seven to thirty-six or forty hours. During this period the air is thick and heavy, and the sun does not appear. The thermometer, from 70 or 72 degrees, suddenly rises to 110 or 112 degrees, or even higher. When this sirocco wind, which always blows from the south, shifts, the north wind, which is called the *tramontane*, succeeds, and the country is again relieved from this distressing visitation.

Besides these winds, which are in some degree local, there are the *harmattan*, a cold dry wind, which is frequent in Africa and other eastern countries; the *bize*, a cold frosty wind, which descends from snow-covered mountains like the Alps; and *whirlwinds*, or *tornados*, which are common to all countries, but most destructive in warm regions.

Velocity of the Wind.—The velocity of the wind is from an imperceptible movement to 100 miles in an hour. When it moves at the rate of 1 mile per hour, it is said to be hardly perceptible; at 2 or 3 miles, just perceptible; at 10 to 15 miles, pleasant or brisk; at 20 miles, bracing; at 20 to 25 miles, very brisk; at 30 to 35 miles, high; at 35 to 45 miles, very high; at 50 miles, storm or tempest; at 60 miles, great storm; at 80 miles, hurricane; at 100 miles, hurricane, tearing up trees, and throwing down houses, &c.

The Anemometer.—Many years ago, an instrument called the *anemometer* was contrived, for the purpose of measuring the force of the wind; and latterly an apparatus with the same name has been invented, to measure not only the force, but to indicate the direction of the wind at every minute of the day. From an exterior vane, a connexion is established to a pointed index in the form of a pencil, which, according as the vane moves, travels on a sheet of paper spread on a table in a room beneath, and marks the paper in certain waving lines as it proceeds. The pencil being influenced by the movements of a clock, and the paper being ruled into divisions for every hour of the day, a most effectual record is produced. Anemometers of this kind are now established at all the principal observatories.

RAIN.

It has been explained in the preceding paragraphs, that the waters of the earth yield up a certain quantity of moisture into the air, which, being condensed, assumes the form of clouds of greater or lesser density and magnitude, floating at a variable distance above us in the regions of the atmosphere. It has also been shown that clouds consist of an assemblage of small vesicles, or globules of moisture, which, on being affected by a diminution of temperature, lose their suspensory property, and gathering into larger globules, they drop to the ground in the form of water drops or a shower of rain. The fall of rain, therefore, is the result of so simple and obvious a cause as to require no lengthened explanation; and the only circumstances demanding our attention are the lesser or greater size of the drops, the closer or more distant arrangement of the showers, and the quantity which falls in reference to peculiar localities and different regions of the globe.

Within the tropics, and also in Great Britain when the air has been charged with electricity, as often happens during the dry summer or autumnal months, the rain-drops are very large; but during the wet and chilly season which attends the fall of the year, they are often very small, and, as it is technically termed, *drizzling*. It is a remarkable fact, and worthy of our notice, that drops of rain have always been found larger in the lower regions of the atmosphere. Thus, Dr Walker observed, in going down a high mountain, that the drops gradually increased in size as he descended. At a little way below the summit of the mountain, the precipitation appeared only a gentle mist; but this gradually became denser as he descended, until, on reaching the valley, it increased to a heavy rain. In the year 1776, Dr Heberdeen proved this curious fact. He placed one instrument for measuring the quantity of rain which falls, called the *rain-gauge*, on the square part of the roof of Westminster Abbey; another on the top of a neighbouring house considerably lower than the first; and another on the ground in the adjoining garden. The rain collected on each was as follows:—Top of Westminster Abbey, 12 inches; top of the house, 18 inches; and on the ground, 22 inches: so that much more rain was collected in the lower than in the upper rain-gauge. It has been observed, that this difference may in some measure be owing to the action of the wind, which might drift the rain from the higher and more exposed vessel; but let the greatest pains be taken to avoid this difficulty—which may be done by placing all the vessels in positions equally exposed to the wind—still the fact will hold good, that the quantity of rain increases as we descend in the atmosphere.

It has been conjectured that the increased size of the drops, as we descend mountains into valleys, depends on their uniting together as they fall. But the truth seems to be, that the increased quantity of moisture precipitated is owing to the continued evaporation going on at the earth's surface. When the sun has withdrawn his rays, or is overcast by a dense cloud in the higher regions of the heavens, and when the air is loaded with excess of vapour, should an additional quantity arise from the earth's surface, it must be obstructed in its ascent, and, meeting with a colder current, be condensed, and converted into rain. In traversing a mountainous country during a storm, we have had occasion to observe this fact; for often the rain by which we have been wet through has seemed not so much to descend from above, as to be formed immediately around us. The garments about the knees of the pedestrian will, under such circumstances, be wet through, while his shoulders remain comparatively dry. Hence, marshy and maritime situations which emit much vapour are observed to be remarkably rainy. Mountainous regions are generally visited also with much rain, in consequence of the condensation of clouds on the summits of the hills. When the hills are in the neighbourhood of the ocean, their tendency to excite rain is greatly increased; and in proportion as we leave hills so situated, and pass into inland and more level districts, the less rain will be found to fall.

Winds, however, exert the chief influence over the atmospheric condition which produces rain. Thus, if winds blow from instead of to a hilly country, the clouds will be carried elsewhere, and be precipitated in lower regions at a distance. But if these low-lying regions be warm, the clouds will be radiated, and their particles, in a refined state, will be carried onwards by the winds, till they come over a cold high-lying country, where they will drop in heavy showers. In this manner the vapours from the Mediterranean are carried over Egypt, and do not collapse into rain till intercepted by the higher regions of Abyssinia. In consequence of certain winds blowing within the tropics, most countries near the equator have their *rainy seasons*—periods during which much greater quantities of rain fall than we are accustomed to in temperate climes. The rains in India, which are often so desolating in their effects, as already noticed, generally occur during the shifting of the monsoons, and also during what is termed the south-west monsoon.

In that part of Peru called Valles, which lies on the north and south side of Lima, and is bounded on the east by the Andes, and on the west by the Pacific Ocean, it never rains at all; but during winter, the earth is covered with a fog so thick and dense, as to intercept the rays of the sun. These fogs supply sufficient moisture to render the most arid and barren soil fertile, and to convert the disagreeable dust in the streets of

Lima into mud. The reason why it never rains in this country, is, that the wind always blows from the south, that is, from a colder to a warmer region of the world.

Speculations on the chance falling of rain in such countries as Britain are exceedingly hazardous, in consequence of the variability of the winds, and the conditions of the atmosphere at points far beyond our knowledge. With respect to the likelihood of rain, we can attain only a few general principles, all beyond which is doubt and difficulty. For example, if the weather be steady and dry, the winds, if not distracted by any foreign circumstance, will continue blowing and carrying away the evaporated moisture to distant regions, thus averting rain; but if, in the meanwhile, the temperature suddenly falls, or the winds shift, clouds immediately make their appearance, and showers of rain are the consequence. Yet there are exceptions to these general rules, as we will immediately mention.

In all countries, particular winds are noted for being accompanied either by wet or by dry weather: thus, the south and the south-west winds bring much moisture into Britain, while those from the north and north-east are cold, dry, and penetrating; hence the old proverb—

> "When the wind's in the south,
> It's in the rain's mouth."

Not only does this arise from the immense surface of ocean over which these winds sweep south of the equator, the evaporation from which must be prodigious, but from these southerly winds being of a higher temperature, whereby they hold a greater quantity of vapour in suspension or solution, the condensation of which must be proportionally greater on arriving in this colder climate. Accordingly, it has been observed that the wind will turn from the north to south quietly and without rain, but, on returning from the south to the north, will blow hard and bring much rain. Again, if it begin to rain from the south, with a high wind, for two or three hours, and the wind falls, but the rain continues, it is likely to rain for twelve hours or more, and does usually rain until a strong north wind clears the air. For the same reason, winds from the west and south-west are considered to bring with them wet weather; hence the old saying—

> "A rainbow in the morning is the shepherd's warning;
> But a rainbow at night is the shepherd's delight."

In the morning, the sun rising in the east shines directly upon the rain falling in the west, and thereby warning the watchful shepherd of the approach of wet weather with this humid wind; but at night, when the sun sinks in the west, its rays fall on the rain in the east, and the shepherd then sees the storm departing; hence this is one of the many popular sayings founded on observation of nature.

Men of science have made very careful inquiries to ascertain the quantity of rain which falls in certain places during a given time, and the instrument devised for that purpose is the *rain-gauge*. Its construction is very simple, consisting merely of a graduated tube, surmounted by a funnel-shaped vessel for receiving the rain; the quantity entering the tube (whose area bears a known ratio to that of the receiving vessel) indicating the amount of fall in that particular locality. The annual quantity of rain is greatest in tropical countries, and diminishes as we approach the poles; a circumstance explicable by the greater evaporative qualities of the atmosphere in warm than in cold countries. The following table illustrates the progressive diminution of rain as we reach higher latitudes:—

	North Latitude.	Inches of Rain.
Uleaborg,	65 degrees, 30 minutes.	13·5
Petersburg,	59 — 56 —	17·5
Edinburgh,	55 — 58 —	24·5
London,	51 — 31 —	22·2
Paris,	48 — 50 —	19·9
Rome,	41 — 54 —	30·0
Calcutta,	22 — 23 —	81·0
Vera Cruz,	19 — 5 —	62·0
Bombay,	18 — 57 —	80·0

The mean quantity falling annually in England is reckoned to be 32 inches, or, according to Dalton, 31·3; but this is unequally distributed. At Keswick, in Cumberland, the depth, on an average of seven years, was found to be 67 inches; and at Plymouth, in Devonshire, 45 inches. In the western parts of Scotland, the depth is from 30 to 35 inches, which is from 6 to 10 inches more than that on the east coast.

Although the quantity of rain which falls in tropical countries is usually greater than what is precipitated in colder regions, it is dispersed over less time, and chiefly falls in heavy showers during a limited season of the year. In our temperate climates, therefore, we have more rainy and drizzling days throughout the year than are experienced in warm countries; and it is this which gives the character of moistness and personal discomfort to our climate.

The seasons of the year, while they contribute, by their variety, to our pleasure and happiness, are characterised by such weather as is best adapted to the necessities of the vegetable and animal creation; wherefore the proportions of rain vary in different months of the year. In summer we have not so many rainy days as in winter; but the showers are then heavier, the streams of rain closer together, and the quantity which falls is greater than during any other season. Dr Dalton has ascertained that the first six months of the year may be regarded as dry, and the last six as wet months. Another ingenious author has inferred, from long observation, that in spring it rains oftener in the evening than in the morning, but that towards the end of summer, oftener in the morning than in the evening, and storms at this time are apt to occur a little after sunrise.

The reason that in winter less rain falls, though we have more rainy days than in summer, is, that the temperature of the air is less variable in winter, and the condensation of moisture not so forcible; therefore, the rain continues falling in small drizzling drops, which, accompanied or followed by chilly north-east winds, gives rise to colds and coughs, and many distressing maladies. It is also to be observed, that, while a clouded and damp atmosphere favours the increase of vegetable foliage, it is not so favourable to its fructification. In such seasons, while the blades of grass grow broader, the nutritious principle which they should contain is not well developed; so that animals feeding on this poorer grass are obliged to take a larger portion to satisfy their appetites. Cattle and sheep which feed on such pasturage, may be observed to be almost continually eating; whereas, in moderately dry seasons, when the occasional rains have been heavier, every blade of grass grows more healthily, its nutritious principle is better evolved, and less sufficing, the same animals may be seen lying down and ruminating in the shade. In the progression of the seasons, rain falls at all times during the twenty-four hours; but it has been ascertained that much less falls by day than by night.

Rain has occasionally been known to fall of a peculiar colour or substance; but this, like other atmospheric phenomena, admits of an explanation on natural grounds. In the year 1810, a shower of red rain fell in Hungary. It lasted a quarter of an hour, and the water was like blood. This was ascertained to be owing to the rain-water being loaded with the red pollen of certain kinds of trees from a neighbouring forest. Red rain, however, is more frequently caused by an incorporation with the atmosphere of a minute fungous vegetation or of animalcules, both too small to be seen by the naked eye. *Viscid* or a kind of *glutinous rain* has likewise fallen. In the Transactions of the Royal Society of London, an account is given of a shower of viscid rain which happened in Ireland. On examination, it was found to be owing to the presence of extraneous matter, partly vegetable and partly animal. In 1828, a substance was shown to the French Academy, which fell in the plains of Persia. It was edible, and afforded nourishment to cattle and many other animals. This nutritious matter was found to be a vegetable production—the *Lichen* *esculentis* of botanists—which had been transported thither by the wind.

We are not, in these various instances, to forget the powerful agency of the wind, which often has been proved to carry, to a prodigious distance, sand and dust, and the ashes and scoriæ which have been thrown up during the eruption of volcanoes. Whirlwinds and waterspouts are often powerful agents of transport, and we are not altogether to discredit the marvellous "showers of fishes," &c. which are sometimes reported.

Signs of Rain.—We conclude our observations on rain by enumerating a few of those prognostications of approaching rain, which, admitting of explanation, are most interesting. When the moon is of a pure silvery colour, good weather is indicated; but when it has a brown or chestnut-coloured tint, rain may be expected. This is owing to the effect of the vapour in the atmosphere in refracting the moon's light. For the same reason, when stars are surrounded by coloured halos, the approach of rain is indicated.

When mountain ranges or distant objects appear nearer to us than usual—when sounds are heard more clearly from a distance—when the odour of plants is more than usually powerful, rain may be prognosticated. The first of these signs arises from the effect of an excess of moisture in reflecting and refracting the rays of light—the two last from sounds as well as odours being conveyed better through a damp than through a dry air. The low flight of swallows indicates approaching rain. The cause of this is, that they pursue flies, which delight in warm air; and these flies, escaping from the excess of moisture above, descend nearer to the surface of the earth, and are there pursued by these birds.

Ducks, geese, and other water-fowls, before the approach of rain, may be seen to throw water with their bills over their backs, and dive frequently; the cause of which is, that, although so much in the water, they do not like being wet to the skin; to avoid which, when warned by the peculiar sensation preceding rain, they close their plumage together, by throwing a sudden weight of water on their bodies, in the direction of the growth of their feathers.*

Before the fall of rain, cattle may sometimes be observed stretching out their necks, and snuffing in the air with distended nostrils, which, doubtless, is occasioned by the odours of plants being more powerful than usual, when the air is saturated with an excess of moisture.

Man in strong and robust health does not feel his constitution affected by that change in the state of the atmosphere which precedes rain; but persons who are in delicate health are often much affected. Pain of the head, toothache, irritability of temper, pains in old sores which have healed, the aching of corns, and excessive nervousness, are all, in certain habits of body, signs of approaching wet weather.

Dogs closely confined in a room become drowsy and stupid before rain; the same, in a less degree, is observed of cats; horses neigh much; cattle low; the fallow-deer becomes restless; and many other animals, from the uneasiness they feel owing to the altered condition, prognosticate the approach of rain. Insects, being very sensible of every change in the state of the atmosphere, are good weather-guides; hence, fine weather may be predicted when many spiders' webs are seen in the open air; also when bees are found far beyond their hives. On the contrary, when spiders remain hidden, and bees do not range abroad as usual, rain may be expected. Many flowers and plants are excellent prognosticators of the weather. When the flower of the chickweed expands freely, and remains open, no rain will fall for many hours; but when it closes, showery weather or continued rain may be expected. The trefoil, the convolvulus, and many other plants, contract their leaves before the approach of rain, or during dull cloudy weather.

* Luke Howard's Climate of London, notes to vol. I.

FROST—SNOW.

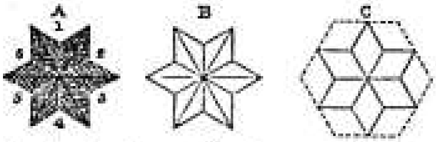
When the temperature of the atmosphere falls to a certain degree of cold (indicated by 32 degrees in our thermometers), which it does principally from the weakness of the sun's rays in winter, the phenomenon of frost or freezing ensues. Freezing is a process of congelation, or, properly, crystallisation, produced by the withdrawal or absence of heat, and by which water assumes the form of ice.

When the temperature of the atmosphere arrives at that low pitch which effects freezing, the watery particles which are upheld in the clouds are frozen in their descent, and coalescing, reach the earth in the form of flakes of snow; and these accumulating on the ground, constitute the appropriate characteristic of the winter season. An intensely cold current of air, mixing with the vapour suspended in a warmer current, occasions, as in the case of hail, this precipitation. Snow, however, is formed in the lower regions of the atmosphere, or might, if commencing in a small nucleus, in higher regions, be converted in its descent into hail. That snow is formed in this manner, there can be no doubt; for a very cold stream of air, admitted into a room in which the contained air is warmer, and loaded with watery particles, will occasion its formation. In the huts of the people in the desolate arctic regions, snow is often so formed; they stop the chinks, yet still the walls are often covered with a thick icy crust; and whenever a cold current from the external air is admitted, snowy flakes are precipitated. Dr Robertson states, that, in a crowded assembly-room at St Petersburg, a stream of cold air was accidentally admitted into the room by a gentleman breaking a pane of glass, on which the vapour in the air was immediately congealed, and fell in the form of snow-flakes. In Siberia, Pallas, Chappe, and others, have seen it formed under similar circumstances; and by the narrative of the Dutchmen who wintered in Nova Zembla, we are informed that a shower of snow fell, from the vapour of expiration, every time there was any communication with the external air. The peculiarities of snow consist in its extreme lightness, and also in its being purely white. Its lightness is occasioned by the excess of its surface exceeding so much in comparison the matter it contains, and its whiteness is owing to the minute particles into which it is divided; hence, when ice is pounded, it is equally white. When snow, however, accumulates in large quantities, its weight becomes very considerable. Snow occurs in all regions of the globe at a certain height above the level of the sea, but falls more abundantly on plains as we proceed from the equator to the poles. In the arctic regions, snow falls nine days out of ten during the months of April, May, and June, and often a depth of two or three inches is deposited in an hour. In these regions, the thickest precipitations are observed to precede the occurrence of storms.

The forms of snow-flakes present an almost endless variety; they are often very regular and beautiful, and reflect with exceeding splendour the rays of the sun. When they are very large, they are said to indicate the approach of thunder. After a copious fall of snow, when the temperature is too low to produce any moisture, its level surface may often be seen sprinkled with thin delicate plates of ice, which refract the light in colours as varied and brilliant as drops of dew. At such times, on the borders of lakes, and on the leaves of trees, groups of feathery icy crystals may be seen, remarkable for the most exquisite delicacy.

Dr Daniel Clarke, in his *Travels in Russia*, mentions that, while at St Petersburg, he observed flakes of snow falling in regular and beautiful forms. "The season," he says, "began to change before we left Petersburg. The cold became daily less intense; and the inhabitants were busied in moving from the Neva large blocks of ice into their cellars. A most interesting and remarkable phenomenon took place the day before our departure; the thermometer of Celsius stood at that time only 5 degrees below the freezing-point, and there was no wind. Snow, in the most regular and beautiful crystals, fell gently on our clothes and on the sledge, as we were driving in the streets. All of them possessed exactly the same figure and the same dimension. Every particle consisted of a wheel or star, with six equal rays, bounded by circumferences of equal diameters: they had all of them the same number of rays branching from a common centre. The size of each of these little stars was equal to the circle presented by dividing a pen into two equal parts. This appearance continued during three hours; in which time no other snow fell, and there was sufficient leisure to examine them with the strictest attention, and to make the representation given in the first figure.

A B C



As water, in its crystallisation, seems to consist of radii diverging from a common centre, by the usual appearances on the surface of ice it might be possible to obtain the theory, and to ascertain the laws, from which this stellar structure results. An equiangular and equilateral plane hexagon is divisible into three equal and similar rhombs: and if the engraved figure A be attentively observed, it will appear that each linear ray of the star is a diagonal (see fig. B) joining the acute angles of a rhomb, whose sides are the loci of the extreme points of the lines of ramification from these diagonals. The rhomb may therefore be the primitive form of water crystallised. This seems the more manifest, because, if equal and similar rhombs be applied between all the rays of the star A, in the spaces 1, 2, 3, 4, 5, and 6, an equilateral and equiangular hexagon will be the result, as represented by the dotted line in fig. C." The same star-like shape of snow-flakes has been seen in Britain. According to a notice in an Edinburgh newspaper, the phenomenon occurred in Lanarkshire in the winter of 1838.

Snow is occasionally seen of a brown colour, which arises from its being impregnated with earthy substances, brought from the mountains by those streams of water which are derived from the thawing of ice or snow. Much oftener has snow been observed of a red colour, which appears generally to have arisen from its intermixture with some vegetable substance. Captain Scoresby informs us, that, in the arctic regions, the redness of the snow may occasionally be attributed to the droppings of the little auk (*Alca alle*), which feeds on shrimps, and congregates in immense numbers.

Snow, which in Britain falls generally most copiously during the months of December, January, and February, seldom occurs so early as October, and is generally, after remaining some time on the ground, dissipated by an increase of temperature, arising from the direct action of the sun's rays or the fall of rain. Occasionally, however, it disappears without any apparent thaw, or so much dissipates as to leave deep furrows on the snowy plain. This arises from the snow itself being evaporated, which will occur even below the freezing-point. "On the night of the 10th of February," says Luke Howard, "I exposed 100 grains of light snow, spread on a dish (which had previously the temperature of the air) of six inches in diameter. In the first hour after dark it lost five grains; in the third it acquired a grain, the wind having changed, and the temperature, which had been falling from 25°, inclining to rise again. In the course of the night the loss was about 60 grains." This very ingenious author adds, that this evaporation from snow probably supplies the water for the formation of those thin mists which appear during intense frost. The air then becomes partially loaded with particles of ice, or of water at so low a temperature as to be ready to become solid the moment they find support. Hence, too, may arise the hoar-frost, which is found to accumulate on the windward side of the twigs and branches of shrubs and trees. Snow seldom remains long, in temperate latitudes, on plains or in valleys, but on the tops of high mountains it occasionally appears throughout the year. The cause of its continuance on these exalted spots, is the thinness of the atmospheric air, which is incapable of holding sufficient heat from the sun's rays to melt the general mass.

Sleet is only a modification of snow. When aqueous globules freeze in the higher regions of the atmosphere, they aggregate together, and form flakes of snow; and when these have partly thawed, and have again become frozen, they constitute sleet, which is thus caused by the variable temperature of the atmosphere. Sleet falls at all seasons, and sometimes changes into rain and sometimes into snow. It occasionally falls, indeed, very heavily, gathering and freezing additional moisture in its descent.

Hail is described by meteorologists as frozen drops of rain, the freezing having taken place while the smaller vesicles of water were assuming the heavier properties of the rain-drop. A cold current of air, blowing suddenly in the direction of a rain-cloud, is understood to be the immediate cause of most hail-showers. Hailstones vary much in shape; they are generally oval or round, but sometimes thin, flat, irregularly globular, angular, pyramidal, occasionally irregular, having a central point whence proceed numerous icy spiculæ, like rays in all directions; and, also, although more rarely, they have appeared as six-sided prisms. Hailstones vary in size from that of a small seed to that of a boy's marble, the smaller generally falling in the more northerly climates, the larger in the south of Europe. In different parts of France and Britain, very large hailstones have occasionally fallen, and done serious damage.

It is calculated that a single drop of water, the diameter of which is only the one-thousandth of an inch, will, in descending through the air, acquire a velocity of nine or ten feet every second; wherefore it is less surprising that hailstones of such magnitude and weight should occasionally prove destructive, not only to delicate plants but even to animals. The large size of hailstones is attributed to an accumulation during the progress of their descent. It is probable that the largest commences its formation with a small nucleus, which receives continual accessions from vapoury particles which it freezes and attaches to itself as it proceeds. Accordingly, hailstones are found to be smaller on the tops of mountains than in the neighbouring plains or valleys; because, not falling so far, they do not augment their size by the addition of successive layers of congealed watery vapour.

Hoar-frost, which appears like a beautiful powdery crystallisation on trees and herbage, is only frozen dew. The conversion of dew into hoar-frost is another wise arrangement in nature, by which plants are protected from the severity of a freezing cold atmosphere.

THUNDER AND LIGHTNING—STORMS.

Independently of the storms of regular occurrence in warm climates, such as monsoons and simooms, there occur sudden and violent atmospheric agitations, both at sea and land, the causes of which are various, though generally depending on rapid transitions of temperature and electrical influence. Two kinds of storms, in particular, are dependent on electrical action in the atmosphere and clouds—the common thunder-storms of temperate climates, and those of a very violent nature occurring in the form of hurricanes in tropical regions.

Thunder-Storms.—Storms of thunder and lightning are simply a case of electrical discharges from one cloud to another, and are a means adopted by nature to restore electrical equilibrium in the atmosphere, and at the same time clear the air from unwholesome vapours or properties. The explanation of thunder-storms given by Professor Thomson, in his Outlines of the Science of Heat and Electricity, being the best we have seen, we shall lay it before the reader:—"Air and all gases are non-conductors; but vapour and clouds, which are composed of it, are conductors. Clouds consist of a kind of bladders of vapour, charged each with the same kind of electricity. It is this electric charge which prevents the vesicles from uniting together, and falling down in the form of rain. Even the vesicular form which the vapour assumes is probably owing to the particles being charged with electricity. The mutual repulsion of the electric particles may be considered as sufficient (since they are prevented from leaving the vesicle by the action of the surrounding air and of the surrounding vesicles) to give the vapour the vesicular form. In what way these clouds come to be charged with electricity, it is not easy to say. But, as electricity is evolved during the act of evaporation, the probability is, that clouds are always charged with electricity, and that they owe their existence, or at least their form, to that fluid. It is very probable that when two currents of dry air are moving different ways, the friction of the two surfaces may evolve electricity. Should these currents be of different temperatures, a portion of the vapour which they always contain will be deposited; the electricity evolved will be taken up by that vapour, and will cause it to assume the vesicular state, constituting a cloud. Thus we can see, in general, how clouds come to be formed, and how they contain electricity. This electricity may be either vitreous or resinous, according to circumstances. And it is conceivable that, by long-continued opposite currents of air, the charge accumulated in a cloud may be considerable. Now, when two clouds, charged, the one with vitreous and the other with resinous electricity, happen to approach within a certain distance, the thickness of the coating of electricity increases on the two sides of the clouds which are nearest each other. This accumulation of thickness soon becomes so great as to overcome the pressure of the atmosphere, and a discharge takes place, which occasions the flash of lightning.

The noise accompanying the discharge constitutes the thunder-clap, the long continuance of which partly depends on the reverberations from neighbouring objects. It is, therefore, loudest and largest, and most tremendous in hilly countries. These electrical discharges obviously dissipate the electricity; the cloud condenses into water, and occasions the sudden and heavy rain which always terminates a thunder-storm. The previous motions of the clouds, which act like electrometers, indicate the electrical state of different parts of the atmosphere. Thunder, then, only takes place when the different strata of air are in different electrical states. The clouds interposed between these strata are also electrical, and owe their vesicular nature to that electricity. They are also conductors. Hence they interpose themselves between strata in different states, and arrange themselves in such a manner as to occasion the mutual discharge of the strata in opposite states. The equilibrium is restored; the clouds, deprived of their electricity, collapse into rain; and the thunder terminates. In thunder-storms, the discharges usually take place between two strata of air, very seldom between the air and the earth. But that they are sometimes also between clouds and the earth cannot be doubted. These discharges sometimes take place without any noise. In that case, the flashes are very bright; but they are single flashes, passing visibly from one cloud to another, and confined usually to a single quarter of the heavens. When they are accompanied by the noise which we call *thunder*, a number of simultaneous flashes of different colours, and constituting an interrupted zigzag line, may generally be observed stretching to an extent of several miles. These seem to be occasioned by a number of successive or almost simultaneous discharges from one cloud to another, these intermediate clouds serving as intermediate conductors, or stepping-stones, for the electrical fluid. It is these simultaneous discharges which occasion the rattling noise which we call *thunder*. Though they are all made at the same time, yet, as their distances are different, they only reach our ear in succession, and thus occasion the lengthened rumbling noise, so different from the snap which accompanies the discharge of a Leyden jar.

If the electricity were confined to the clouds, a single discharge, or a single flash of lightning, would restore the equilibrium. The cloud would collapse, and discharge itself in rain, and the serenity of the heavens would be restored; but this is seldom the case. I have witnessed the most vivid discharges of lightning from one cloud to another, which enlightened the whole horizon, continue for several hours, and amounting to a very considerable number, not fewer certainly than fifty, and terminating at last in a violent thunder-storm. We see that these discharges, though the quantity of electricity must have been immense, did not restore the equilibrium. It is obvious from this, that not only the clouds, but the strata of air themselves, must have been strongly charged with electricity. The clouds, being conductors, served the purpose of discharging the electricity with which they were loaded, when they came within the striking distance. But the electric stratum of air with which the cloud was in contact, being a non-conductor, would not lose its electricity by the discharge of the cloud. It would immediately supply the cloud with which it was in contact with a new charge. And this repeated charging and discharging process would continue to go on till the different strata of excited air were brought to their natural state."

After these explanations, it is only necessary to say, that however awful the noise which thunder usually makes, it is in no shape dangerous. The real danger is from the lightning, which has a tendency to strike high pinnacles of buildings or spires of churches; but if these high places be furnished with metal rods to conduct the lightning to the ground, no injury is likely to occur. Lightning, either silent or accompanied by thunder, is of much rarer occurrence in the British islands than on the continent of Europe.

Law of Storms.—Considerable attention has been bestowed by various men of science on what are supposed to be the regulating principles of storms; for it cannot be doubted that, however irregular their occurrence and apparent action, they are subject to certain fixed laws, and these it is important to discover. As yet, the law of storms has assumed no very distinct or generally recognised form, almost every student of atmospheric phenomena having his own theory on the subject. The question upon which the chief difference exists, is, whether storms blow in direct lines or in circles. The probability is that storms of wind are greatly influenced by the configuration of the localities over which they blow, as well as by the opposition they may meet with in their course: for example, a violent gale of wind, coming in direct force against a lofty mountain, will probably be transformed into a whirlwind; and a similar result will follow the opposing contact of two fierce winds.

At a meeting of the British Association at Newcastle in 1838, Lieut.-Colonel Reid, of the Royal Engineers, laid before that body his views respecting the laws of storms, which have met with general acceptation. From extensive observation on foreign stations and at sea, he was of opinion, with Mr Redfield and Colonel Capper, two persons who had previously investigated the subject, that hurricanes are great whirlwinds, and that these whirlwinds were progressive. "The general phenomena of these storms," he observed, "will be understood, if the storm, as a great whirlwind, be represented by a circle whose centre is made to progress along a curve, or part of a curve, which is in most cases of a form approaching the parabolic, the circles expanding as they advance from the point at which the storm begins to be felt—the rotatory motion, in the northern hemisphere, being in the contrary direction to that in which the hands of a watch go round; while, in the southern hemisphere, the rotation is in the same direction as that in which the hands of a watch revolve. He pointed out how his views were illustrated by the disastrous storm of 1809, experienced by the East India fleet, under the convoy of the *Culloden* line-of-battle ship, and the *Terpsichore* frigate, and four British men-of-war, which left the Cape of Good Hope about the same time, intending to cruise about the Mauritius. Some of these vessels scudded and ran in the storm for days; some, by lying to, got almost immediately out of it; while others, by taking a wrong direction, went into the heart of it, foundered, and were never heard of more; others, by sailing right across the calm space, met the same storm in different parts of its progress, and the wind blowing in opposite directions, and considered and spoke of it as two storms which they encountered; while others, by cruising about within the bend of the curve, but beyond the circle of the great whirl, escaped the storm altogether, which had been for days raging on all sides of them. This led him to draw the very important practical conclusion as to how a ship should act when she encountered a gale, so as to escape from it. By watching the mode of veering of the wind, the portion of a storm into which a ship is falling may be ascertained: if the ship be then so manœuvred as that the wind shall veer aft instead of ahead, and the vessel is made to come up instead of being allowed to break off, she will run out of the storm altogether; but if the contrary course be taken, either through chance or ignorance, she goes right into the whirl, and runs a great risk of being suddenly taken aback, but most assuredly will meet the opposite wind in passing out through the whirl. To accomplish her object, he showed, by a diagram, that it was necessary the ship should be laid on opposite tacks, on opposite sides of a storm, as may be understood by drawing a number of concentric circles to represent the whirl of the hurricane, and then different lines across these, to represent the course of ships entering into or going through the storm."

Mr Espy, an American gentleman, who laid a number of facts on the subject before the British Association in 1840, arrives at the same conclusion as Redfield, Capper, and Reid; but adds, that the whirlwinds blow progressively towards a common centre. This blowing inwards to a centre, Mr Espy conceives to be the consequence of the sudden and powerful ascent of a column of air at that centre, from the atmosphere being there more heated than elsewhere.

If any careful observer of atmospheric phenomena on the ocean, possess facts which tend to throw any light on this exceedingly important branch of science, it is his duty to make them known for the general benefit of mankind.

UNUSUAL METEORIC PHENOMENA.

Among the meteoric phenomena which are of less frequent occurrence than those already noticed, may be included rainbows, figures in the air, luminous meteors, ignis fatui, the aurora borealis, halos, parhelia, and aërolites. As may be seen by referring to the article OPTICS, No. 19, the cause of rainbows is simply the refraction of light through the drops of a shower of rain (or, as may be frequently seen, through the spray of a cataract).

With respect to the appearance of figures in the air, such as representations of landscapes, men, and animals, ships at sea, and so on, it is likewise shown in the article OPTICS, that they are a natural consequence of peculiar refractive powers of the atmosphere at the time of the occurrence. The Mirage of the desert, the Fata Morgana of the Venetians, the Brocken of the Hartz Mountains in Germany, and the armies seen in the air, according to Scottish superstition, all belong to this class of meteoric phenomena.

Luminous Meteors.—These are of various kinds. One of the most familiar is the Will o' the wisp, or *ignis fatuus* (the fire of fools), which appears at night on marshy grounds or places of sepulture. The appearance is that of a small flickering light, struggling in an irregular manner at the height of one or two feet from the ground, and sometimes standing for a few moments over a particular spot. When approached or pursued, the lights are agitated by the motion of the air, and seem to elude investigation. The cause of this species of meteor is well known to men of science; the light being nothing more than phosphureted hydrogen gas, arising from decomposing substances in the ground, spontaneously ignited. The meteors commonly called *falling stars*, which shoot from the upper region of the atmosphere, are ascribed to a similar origin: they are masses of matter inflated with phosphureted hydrogen gas, which, being spontaneously ignited, shoot in a downward direction to the earth. The greatest height whence they come is not above two or three miles, and seldom so much. Electricity, it may be supposed, is also concerned in this class of meteors.

Aurora Borealis.—In extreme northern and southern latitudes, and generally in the coldest season of the year, the sky appears luminous with streams of soft light, called the aurora borealis or the northern lights. This beautiful phenomenon is comparatively seldom seen as far south as the centre of England, but is frequently observed in Scotland, where it is popularly known by the name of *streamers*. In the latter country it appears a little after sunset, and uniformly arises in the north, inclining generally a little to the west; and it occurs more frequently about the time of the equinoxes than at any other season of the year. Its manner of arising, and the general characters it assumes, vary extremely; indeed, so much so as almost to preclude any accurate description. Sometimes, an hour or two after dark, it seems to illumine the northern region of the sky with no more than a gentle and subdued twilight, which gives a soft relief to the surrounding darkness. Sometimes detached masses of light suddenly appear in different parts of the sky, from which silvery and tremulous beams shoot with dazzling and evanescent splendour. Not unfrequently, indeed, from one single spot of light the beams vividly and rapidly extend. Sometimes the phenomenon is first discernible in delicate streaks or threads of light, which enlarge and shift with inconceivable rapidity, until a tremulous arch is formed, which completely spans the azure vault. Very often one general or principal arch is observed, with smaller ones at unequal distances, which frequently move laterally towards each other, and suddenly unite into one broad and brilliant mass. Often, from the horizon, in the north, one limb or segment of the arch streams up into the heavens, and sometimes several of these arise at distances from each other. The varying splendour of the coruscations, and the rapid and playful movements which they display, as they sweep across the heavens, excite alike the wonder and admiration of the spectator.

The height of the aurora has been variously computed to be from 100 to 700 miles above the surface of the earth, and consequently far beyond the sphere of our atmosphere. All the conjectures hazarded with respect to the nature and cause of the aurora have been unsatisfactory: the most feasible conclusion is, that the phenomenon is a demonstration of electric fluid in its passage from the polar to the equatorial regions. Well-digested facts are still required to form an exact and satisfactory theory on the subject.

Halos—Parhelia.—In the colder regions of the globe, and sometimes in temperate climes during cold weather, what are called halos and parhelia, or mock-suns and mock-moons, are sometimes seen. A halo usually consists of two concentric circles of coloured or refracted light, such as that of a rainbow, the one forming an angle of about 23½ degrees, the other an angle of about 47 degrees, with the sun or moon. In different parts of these circles, and chiefly in opposite points at a similar altitude with the sun, bright spots of unrefracted light are seen, which have received the names of mock-suns or mock-moons, according as the light is received from the sun or from the moon during the appearance of the halo. From these bright spots diverging horns of light are occasionally observable. It is generally agreed that a halo is produced by the sun or moon's light being refracted by frozen vapour in the atmosphere. The cause of the parhelia, or bright sun-like spot, is more difficult of definition. Some suppose it to be caused by the frozen vapour being arranged in such a manner at particular points, as allows the light of the sun or moon to be transmitted in a concentrated, instead of a refracted form.

Aërolites.—These are fiery meteors, which, in various forms and sizes, are seen to shoot from the heavens, and, falling to the earth, are found to consist of certain kinds of stones. The chronicles of almost every age and country record the fall of these bodies, which sometimes arrive on the surface of our planet individually, and at other times in what must be called a stream or shower. The celebrated Gassendi informs us that, on the 29th November 1637, about ten o'clock A.M., while the sky was perfectly serene and transparent, he saw a flaming stone, apparently about four feet diameter, fall on Mount Vaision in Provence. This stone was encircled with a zone of various colours, like a rainbow, and accompanied in its fall with a noise resembling the discharge of artillery. It was of a dark metallic colour, extremely hard, and 59 lbs. in weight. In June 1668, two stones, one of which weighed 300, and the other 200 lbs., fell near Verona. The event took place during the night, and when the weather was perfectly serene and mild. They appeared to be all on fire, descending in a sloping direction, and with a tremendous noise. The phenomenon was witnessed by a great number of people, who, when the sounds had ceased, and their courage was sufficiently re-established, ventured to approach these celestial deposits, and found that they had formed a ditch; such had been the force with which they had descended. One of the largest meteoric stones which have ever fallen is now exhibited in a room in the British Museum; it is several feet in diameter, of great weight, shaped like a spheroid, and brown in exterior appearance.

All meteoric stones that have been examined present a similar structure and appearance. The chemical analysis of one which fell in France in 1810 may be taken as a sample of the whole:—Silica, 36·4; alumina, 3·6; lime, 4·2; magnesia, 13·6; iron, 25·0; nickel, 6; manganese, 0·6; sulphur, 5; chrome, 1·5: total, 90·7. The velocity with which the stones are shot through the atmosphere renders them red hot, and some time elapses after their fall before they cool and can be handled.

With respect to the origin of aërolites, there are four theories, each having its supporters. According to Laplace, Poisson, Dr Hutton, and others, they are stones projected from volcanoes in the moon; it being demonstrated that an initial velocity of 6000 feet per second would be sufficient to drive them beyond the moon's attraction, and to bring them within the greater attraction of the earth. Another set of philosophers allege they are projected from volcanoes on the earth, which is exceedingly improbable. Playfair and others say it is not unlikely that the stones are formed in the atmosphere by an aggregation of particles of matter, the result of gaseous vapours; this chemical theory is also very unsatisfactory. The fourth and most probable theory is, that the stones are *asteroids*, or diminutive planets, drawn to the earth's surface when our globe, in its annual revolution, arrives at points near which these bodies are performing a circuit round the sun. A series of remarkable phenomena, of recent occurrence, serve to support this theory. On the morning of the 12th, 13th, or 14th of November every year since 1833, there have occurred, at different parts of both Europe and America, showers of meteoric bodies of a most brilliant appearance; and it has thence been conjectured that the earth, in its revolution round the sun, had fallen in with these bodies in the same, or nearly the same, part of its orbit. If such be the true hypothesis, it follows that these meteors are travellers in space, performing circuits like the planets, and have most likely been projected from the sun in the same manner as the earth and other planetary bodies are believed to have been hurled from that luminary. Showers of fiery meteors, sometimes only gaseous, and at other times solid, are, however, found to occur annually in August, December, and other periods of the year. In September 1841, a shower of many millions of meteoric stones, the greater number of which were not larger than small hailstones, occurred in Hungary, their chief ingredients being oxydate of iron, oxide of iron, and oxyhydrate of iron, with flint, lime, clay, and clay earth.

THE WEATHER.

From the preceding account of the various phenomena of the atmosphere, it must be evident that prognostications respecting the weather must be extremely uncertain, if not, for the most part, quite illusory. According to an ancient prejudice, it has been supposed that the moon, on entering its different quarters, exercises an influence over the weather; but this is ascertained by men of science to be without foundation in reality. The moon affects the tides of the ocean, but in no other known manner has it any influence over the ordinary phenomena of our planet.

It has been seen that winds are the grand disturbers of the weather, and that to them we may proximately ascribe the occurrence of clear skies, fogs, clouds, rain, &c. As the winds originate from circumstances frequently far beyond our horizon, and cannot consequently be foreseen, every prognostic of either fine or bad weather is liable to complete derangement. The chance floating of icebergs from the northern polar regions to a temperate latitude in the Atlantic, has been known to shed such a cold over Britain, as to destroy the best hopes of summer. To utter prophecies of the coming weather, in a country exposed to such contingencies, appears ridiculous. It has long been a favourite belief with certain classes of persons that the weather goes in cycles—that after a limited number of years, the same succession of weather in the different seasons of the year recurs, and is repeated periodically. A period or cycle of nine, eighteen, thirty-six, and fifty-four years has been variously fixed upon. In Scotland, nineteen years has been more generally believed to form a cycle, and on that account leases of farms are commonly made out for that period, in order to give the agriculturist the benefit of an entire round of weather. To suit and support these theories, which rest on no solid foundation, almanacs have been put forth, pretending to foretell the weather of the coming year; but, unless when favoured by accidental resemblances between the weather and the prediction, all such oracular prophecies have been disproved by facts.

As far as the records of meteorological phenomena for a long series of years warrant a conclusion, the following principles respecting the weather may be considered settled:—1. The weather of each year stands by itself; 2. The weather differs annually, and is different in different places according to circumstances; 3. The weather in the interior of continents is so regular in its seasonal variations, that these may be foretold with considerable certainty; 4. The weather of the British islands is so irregular, from unforeseen causes, that predictions as to its condition are only warrantable in very general terms at any season of the year; 5. That agricultural improvements, such as draining of lakes and morasses, the cutting down of forests, &c. improves climate, and tends to equalise temperature; and, 6. That the asperities of cold in our winters, and extreme heats of our summers, have been modified in some degree by these causes. Altogether, it may be said of our climate, that though in some respects uncomfortable, it is improved in its salubrious properties; and, by allowing out-of-door exercise and employment for a greater number of days throughout the year than that of most other countries, is highly conducive to health, mental energy, and social advancement.

PHYSICAL GEOGRAPHY.

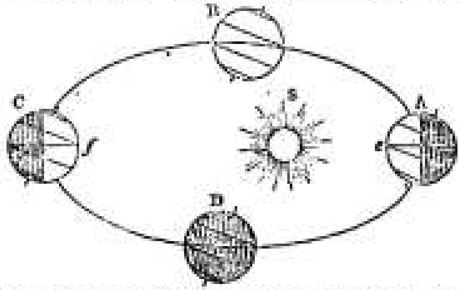
GEOGRAPHY—from *gê*, the earth; and *grapho*, I write—in its simple and literal signification, is that science which describes the superficial appearance and conditions of our globe. It naturally divides itself into two great branches—1. *Physical Geography*, which treats of the earth as a superficies composed of land and water; considers the position, extent, altitude, and general character of the former; and the position, extent, depth, currents, and other motions of the latter. In short, all that relates to the distribution of land and water, variations of surface, temperature and climate, and distribution of plants and animals as dependent thereon, are the legitimate objects of this species of geography. 2. *Political Geography*, which refers merely to the division of the earth's surface by man into territories, empires, kingdoms, and states; treats of their boundaries, the history of their occupation, their produce, commerce, population, laws, religion, and other topics which constitute the fundamental features of human polity. The latter of these branches will form the subject of several subsequent treatises; to an exposition of the former—dwelling more on principles than on mere descriptive details—we intend to devote the present number. Before doing so, however, it will be necessary to advert to the cosmical relations and constitution of our planet as determined by astronomy, geology, chemistry, and meteorology.

GENERAL CONSTITUTION OF THE GLOBE.

Astronomy informs us that the earth we inhabit is one of a number of *planets* which revolve round the sun as a common centre, constituting what is usually denominated the SOLAR SYSTEM. These planets are situated at different distances from the central orb, and differ also in their magnitudes, their densities, and in their periods of revolution. They are nearly spherical in form, are opaque, have no light of their own, but merely reflect that of the sun; and all move from west to east in nearly circular orbits. Several of them serve, in turn, as centres for other bodies of revolution, which are known by the name of *satellites*—as the moon, for example, which is the satellite or attendant of the earth. Besides the planets and their satellites, there is a third and numerous class of bodies belonging to the solar system, namely, *comets*, which revolve round the sun in regular periods, but in orbits so elliptical, that in parts of their course they approach nearer to the great orb than any of the planets, and in others recede so far into the regions of space, as to be entirely beyond the reach of our most powerful telescopes. The *stars* belong to other systems of revolution, and have, so far as has yet been determined, no perceptible effect upon the conditions of our globe, though undoubtedly bearing, like everything in nature, a universal harmonious relationship.

The earth, as an individual planet, is situated at the distance of 95,173,000 miles from the sun; has a mean diameter of 7912 miles; performs a revolution round the sun in 365 days 5 hours 48 minutes and 49 seconds, which constitute the space of time called a year; rotates on its own axis once in 23 hours 56 minutes and 4 seconds—that is, in one day; and in these movements is attended by the moon, which is distant 237,000 miles, is 2160 miles in diameter, and which completes her revolution in 27 days 8 hours, or in one lunar month. We have spoken here of the mean diameter of the earth, because, upon accurate measurement, it has been found to be not a perfect sphere, but an *oblate spheroid*, whose greater diameter is 7925·648, and whose lesser is only 7899·170 miles. This gives a difference of 26·478 miles between the two diameters, or a flattening at each pole of about 13¼ miles—a result that may be artificially illustrated by twirling with rapidity a ball of any yielding material, such as putty, round a spit thrust through it as an axis, when a bulging at the outer circumference will take place, causing the ball to lose its original spherical form. This bulging takes place through what is called the law of centrifugal force, and from what we know of this law, it is concluded that the earth was in a soft or yielding state at the time when it assumed its present form. Besides the bulk, revolutions, and configuration of our globe, science has also determined its *density* with considerable accuracy. By weighing the most prevalent rocks, it has been found that the solid crust composed of them is about two and a half times heavier than water; but from experiments made on the attraction of mountains of known bulk, compared with the attraction and bulk of the globe, it has been inferred that the density of the whole mass is five times that of water: in other words, the earth, as at present constituted, is five times heavier than a globe of water of similar dimensions, and twice the weight of one composed of such rocky substances as those with which we are acquainted. In addition to what may be called its own proper material, the earth is surrounded by a gaseous envelope or atmosphere. This *atmosphere* or air is peculiar to, and inseparable from, our globe—it rotates with the solid mass upon its axis, and does not, as may at first be supposed, occupy the space in which the rest of the heavenly bodies revolve. Like all aëriform and liquid masses whose particles press upon each other equally in every direction, the portions or strata next the earth are more pressed upon than those in higher regions; and continuing this conception, a height must be arrived at where the air becomes so attenuated, as to be inappreciable. Thus it has been determined that the atmosphere does not extend beyond forty-five miles from the mean level of the ocean.

From its planetary relations, as a part of the solar system, the earth derives its figure and motions, its light and heat, and consequently the changes of season, and the alternation of day and night; the phases of the moon, and the rising and falling of the tides; the vicissitudes of wind and weather, and all the varied results and phenomena that flow therefrom. Thus, while its figure is preserved by the laws of centripetal and centrifugal force, its motions are determined and influenced by the attraction and gravitation of the sun and other planets. From its situation with respect to



the sun, it necessarily follows that only one-half of its surface can be exposed at a time to the light and heat diffused from that orb, thereby causing day in the one part, and night in the other. The *seasons*, again, are caused by the fact, that the orbit or path of the earth round the sun is not a perfect circle, but an ellipse; and that, in performing this path, its axis preserves a slanting or oblique position, to the extent of 23° 28′

from the perpendicular. The preceding engraving illustrates the consequences of this elliptical orbit and obliquity of axis. S is the sun, with the earth represented at four different points in its annual course. At B and D, the heat and light of the sun hit at the equator or middle line, and make day and night of equal duration. At any intermediate position, day and night are respectively lengthened and shortened; when at A, the upper or north pole is in darkness; and when at C, the south part of the globe is in the same state. When the point presented towards the sun is at *e*—which is on the 22d of December—it is midsummer to all the southern parts of the earth, and winter to all the north; but as the exposed part advances towards the point *f*, the northern regions gradually enjoy more and more heat, till, on the 21st of June, it becomes their midsummer. In like manner, did our limits allow, might be explained the phases and influences of the moon, and the fluctuations of heat and cold, with their myriad consequences to animal and vegetable existence. So indissolubly connected is the whole scheme of creation, that not a shower that falls, not a particle of sand that crumbles away from its parent rock, or a spikelet of grass that turns sunward, but may be traced to the one great law which originally set the sun and its attendant orbs in motion.

The solar system, however, vast as it seems, is but a unit in space, which is peopled with other systems and orbs circling and encircling beyond the bounds of human conception. What we term *fixed stars* are but suns and centres of revolution; and the solar system, as a whole, may revolve in space round some vast centre, just as its individual planets have their motions round the sun. From such a revolution may arise cycles of heat or cold, life or death, exuberance of certain living forms, and annihilation of others—cycles which meet with a faint analogy in the recurrences of our summers and winters. We know nothing of the constitution of what we call space, or of the ethereal essences which pervade it; and it is not unlikely, that as the solar system passes through successive regions, that causes may operate on a scale sufficiently vast to impress new conditions upon the whole of the planets which constitute that system. But whether our earth be or be not affected by causes so remote and universal, we know for certain that its history, from the beginning of time, has been one of incessant mutation and progress.

The materials of which the earth is composed present a history not less curious than that of its planetary relations. Superficially speaking, the globe consists of land and water; the water occupying the extreme depressions of the land, and this land composed of solid or rocky materials. That the same kind of rocks which appear at the surface do not constitute the interior or central portions, we have evidence from the mean density of the earth; for were the law of gravitation to exert itself uniformly towards the centre, the lightest substance at the surface would be so compressed at the depth of a few hundred miles, as to give to the whole a greater density than astronomical calculations will allow. The interior, therefore, must consist of very different material from the exterior, and this has led geologists to speak of the earth's *crust*, whose composition we know, in contradistinction to the central portion, concerning which we can only form conjectures. This crust, or external shell of solid matter, consists of rocks, differing not only in their appearance and arrangement, but in their mineral and chemical characters; some being compact and crystalline, as marble, others soft and dull, as chalk; some lying in layers or strata, others occurring in huge irregular masses; while, mineralogically and chemically speaking, we have such rocks as granite, quartz, slate, lime, coal, rock-salt, chalk, and clay. But the crust so composed, compact and solid as it may seem, is far from being permanent and stable; in other words, the dry land, which now appears with all its irregularities of hill and valley, plain and ravine, lake and river, is not the dry land which existed many thousands of years ago. Strictly speaking, indeed, the aspect of the globe is ever changing. Here the sea encroaches on the land, there the debris borne down by rivers silts up bays and estuaries; here earthquakes sink, and volcanoes elevate the surface; lakes are dried up, and rivers change their course; and, greater than all of these, vast regions gradually subside, and are covered by the ocean, while others as gradually emerge from the waters, and become dry land. All these changes, past and present, form the subject of geological consideration.

Geology, in its aim to decipher the physical history of our globe, has determined that all the known rocks may be ranked under two great sections—the *stratified* and the *unstratified*. The former appear in layers or beds, and have evidently been deposited in water, hence said to be *aqueous* or *sedimentary;* the latter appear in vast irregular masses, generally disrupting the stratified

rocks, and have all the appearance of having been formed like the lavas of the present day, hence they are called *igneous* or *volcanic*. Of the sedimentary rocks, sandstone, limestone, slate, and coal may be taken as illustrative examples; of the igneous, granite, basalt, greenstone, and lava are the most familiar. As at present, so in all time past, the surface of the earth has been subjected to atmospheric, aqueous, and other influences, the effects of which are to wear down the exposed material; and this, borne away by floods and rivers, is deposited in the ocean, where, consolidated by pressure, heat, and chemical agency, it forms new strata of rocks, which in time are brought to the surface by volcanic and other elevatory forces. Thus, then, one set of agencies degrade, and another reconstruct and elevate; and in proportion as either of these preponderate, so will any portion of the earth be low and level, or high and precipitous. Such, then, is the origin of the stratified and unstratified rocks—the one but the reconsolidated matter of pre-existing rocks, which have been worn and battered down by rains, frosts, waves, and rivers; the other the cooled and hardened material sent forth from the interior of the earth by volcanic agency. But while rivers and floods bear down mud, sand, and the like, they also carry such vegetable and animal remains as lie in their course; and in this manner plants and animals are entombed in the newly-formed layers or strata. As at present, so in former eras, such remains have been enclosed in the stratified rocks, where, subjected to certain chemical agencies, they have become petrified, and are thus preserved as records of the former Flora and Fauna which peopled the globe. Geologists have accordingly found that the earth has not always been occupied by the same kinds of plants and animals that now exist; but that different eras, in its onward history, have had very different Flora and Fauna, and that at present not one, perhaps, of its former genera is in existence.

Aided by the mineral composition of the rocks themselves, and by these fossil organisms which are found in them, geologists have arranged the strata composing the accessible crust into *formations;* that is, into series of strata which seem to have been deposited under the same terrestrial conditions. Thus the *primary* formation includes the hard crystalline and slaty strata, as gneiss, mica-schist, clay-slate, &c. in none of which organic remains have yet been found, and whose material has evidently been derived from the granitic rocks on which they rest as a basis or foundation. Next in succession above the primary are the *transition* rocks, so called from their containing remains of vegetable and animal life, and as indicating the transition of the globe from an unpeopled to a peopled condition. This formation consists of hard quartzose sandstone, certain indurated slates and limestones, and of the marls, shales, and sandstones known by the name of the "old red sandstone." Its fossils consist chiefly of infusory animalcules, corals, shell-fish and fishes, and of sea-weeds, and of few lowly-organised terrestrial vegetables. Then comes the *secondary* formation, subdivided into the older and younger; the former comprehending the mountain limestone, coal, bituminous shales, ironstone, clays, and soft thick-bedded sandstones; and the latter the new red sandstone, magnesian limestone, and those calcareous groups known as the lias, oolite, and chalk. In the older secondary, corals, shell-fish, and fishes are exceedingly prevalent, and vegetation during that era was so prolific, as to furnish the material of which coal is formed; in the younger secondary, vegetation is less abundant, but shell-fish, fishes, and strange gigantic fish-like reptiles are everywhere to be found, and of forms not now in existence. Next in ascending order lie the beds of the *tertiary* formation, consisting of clays, marls, soft sandstones, limestones, and gypsum; and in which the remains of birds, mammalia, and vegetables somewhat like existing genera are for the first time discovered. Above all these formations are scattered the clays, gravels, sands, peat-mosses, and marls which constitute the *superficial accumulations* of the current era; and in these are found the remains of existing races of plants and animals, some species of which, however, have already become extinct in several regions. Intermingled with these formations — now throwing them up in hills, or depressing them in valleys; now overlying them in mountain masses, or breaking and contorting them in the form of veins and dikes —are the igneous rocks, the granites, basalts, and traps of past ages, and the lavas of the present era.

All this succession and accumulation of strata, this appearance and disappearance of different races of plants and animals, indicate the lapse of innumerable ages—ages through which the earth has progressed from phase after phase to that which it now presents. What a strange and chequered history! Nor does it yet present, in any of its physical relations, a single aspect of rest or stability. The conditions of its constitution forbid this; and while we write, rocks are wearing down, rivers are laden with debris, new strata are being deposited, volcanoes are elevating, earthquakes are depressing, and land and sea are gradually changing places, as they have done in all times bygone. All the stratified rocks which we have enumerated have been deposited in the ocean, in estuaries, or in fresh-water lakes; and could we accurately map out the sites and limits of these deposits, we should find that, at no two periods in its history, has our planet presented the same distribution of land and water. All that we know for certain is, that, from the earliest dawn of the stratified formations up to the current moment, there has been sea and dry land, rains, springs, rivers, and all those degrading and transporting agents which are in incessant operation around us. What the altitude and irregularities of this dry land, what the depth and constitution of this ocean, we may never ascertain. We know, however, that the same rocky material has undergone successive rounds of disintegration and reformation; that this material is essentially made up of siliceous, calcareous, argillaceous, bituminous, metallic, and saline constituents; and that these constituents, as well as those of plants and animals, are compounded of *fifty-four* elementary substances; of which, at the ordinary pressure and temperature of the atmosphere — five are *gaseous*, seven *non-metallic* liquids and solids, thirteen *solid metalloids*, and twenty-nine *metals*.

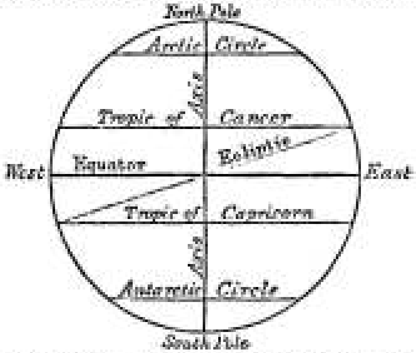
Of the constitution of the ocean, or watery portion of the earth's superficies, chemical research affords us equally accurate data. When pure, water is composed of 1 hydrogen and 8 oxygen by weight, or of 2 hydrogen and 1 oxygen by volume. In motion, however, water is generally found to contain many impurities—such as clay, sand, animal and vegetable matter, &c.—which, if left at rest, by their own weight soon fall to the bottom. Such substances are said to be *mechanically suspended*, and when deposited at the bottom, form sediment. Besides impurities of this description, water may contain matter which will not fall down, and which is said to be held in *chemical solution*. Sea water of the Atlantic, according to Dr Marcet, contains $4\frac{4}{10}$th grains of saline matter in every hundred; while, according to Dr Murray, the water of the German Ocean contains only $3\frac{4}{10}$ths. This saline matter consists chiefly of chloride of sodium (common salt), sulphate of soda, muriate of lime, and muriate of magnesia. It has been also ascertained that the Southern Ocean contains more salt than the Northern; that this saltness is greater towards the tropics than at the equator, and less towards the poles; that small inland seas, though communicating with the ocean, are less salt than the ocean; that the Mediterranean contains a greater proportion of saline matter than the Atlantic; and though the saltness of the sea be pretty uniform at great depths, still, at the surface, owing to the admixture of rain, river, and iceberg water, it is not quite so salt. A knowledge of the constitution of the ocean is necessary to the explanation of numerous facts in geology and biology. The saline constituents must influence more or less all chemical changes, rock deposits, and animal and vegetable life, which take place in the ocean. From these constituents shell-fish and coral animalcules obtain the material of which shell-beds and coral-reefs are constructed; and by this same constitution marine plants and animals are made to assume a character which distinguishes them from the inhabitants of fresh waters.

The atmosphere, the next great constituent of the globe, plays an equally important part in the organic and inorganic economy. Pressing with a weight of about fifteen pounds upon every square inch at the ordinary sea level, and diminishing in density in the duplicate ratio of the altitude, it is evident that animals and plants fitted to live at small elevations will die if removed to great heights—a circumstance corroborated by the fact, that travellers experience difficulty in respiration on very high mountains, and that blood has been known to start from their ears and other tender parts under the diminished pressure. Calculating from data afforded by its density, a limit has been assigned to the atmosphere at the altitude of forty-five miles—or about forty miles above the top of the highest mountains. Notwithstanding its transparency, the air intercepts and reflects the sun's rays, multiplies and propagates them by an infinity of repercussions; and were it not for this property, objects would never be illuminated unless exposed to the direct light of the sun. It is also the recipient and retainer of the solar heat reflected from the earth; and were it not so constituted, the solar rays would be returned to space, and an excessive cold continually prevail. Besides, according to the general physical law, that the capacity of gases for heat increases with their rarity, bodies placed in the upper regions of the atmosphere have their heat so rapidly abstracted, that they are ever beneath the freezing point; hence the perpetual snows and glaciers of the higher mountains. Chemically speaking, it is a gaseous admixture—every hundred parts of which are composed of 79 nitrogen, and 21 oxygen—with about one part in a thousand of carbonic acid. In addition to these, which are the permanent constituents of the atmosphere, there is always a certain amount of aqueous vapour, amounting from 1 to 1·8 per cent.; and in certain localities, traces of ammonia, sulphurous acid, muriatic acid, and other ingredients are to be occasionally detected. The atmosphere may therefore be regarded as the laboratory in which clouds, rain, snow, and other vapours are formed—the medium through which the light and heat of the sun are diffused and equalised—an element without which animal and vegetable life could not exist, for both incessantly inhale and exhale its elements; and an agent indispensable to those innumerable physical operations which constitute the progressive history of our planet.

Thus assisted by the determinations of astronomy, geology, chemistry, and meteorology, as regards the general constitution of the globe, physical geography proceeds to describe and account for its superficial appearance and conditions, and these, again, as influencing the life and distribution of the plants and animals by which it is peopled. Before entering, however, upon these interesting but complicated details, it will be necessary to explain the principal terms and technicalities usually employed by geographers.

GEOGRAPHICAL TERMS.

The direction from which the earth moves, in its daily rotation, is called the *West;* that towards which it moves the *East;* the point which is on the right hand of one standing with his back to the east is called the *North;* that on the left hand the *South.* The imaginary line on which the earth turns is called the *Axis;* its termination towards the north is known as the *North Pole;* that towards the south the *South Pole.* The early cultivators of geography dwelling on a part of the earth nearer the north than the south pole, supposed the former to be uppermost, though, in reality, such ideas as upper and under do not belong to astronomy; and it is for this reason that in globes and maps the northern part is always placed at the top, the east being towards the right, and the west towards the left hand, with the south at the bottom. Exactly between the two poles, and consequently dividing the earth into two equal portions, is a line called the *Equator;* all north and south of which are respectively



called Northern and Southern Hemispheres or Half-spheres. In the same way, an encircling line, at right angles to the Equator, divides it into Eastern and Western Hemispheres. The circuit of the earth, both in its girth between east and west, and between north and south, is divided into 360 parts, called *degrees,* each degree being equal to about 69½ British miles. At the distance of 23½ of these degrees from the Equator, in both directions, are two parallel lines called the *Tropics,* in reference to the sun's declination; known respectively as that of *Cancer* and *Capricorn,* from these constellations being situated in a corresponding part of the sky. At the same distance from each pole is a parallel line—that on the north being styled the *Arctic,* and that on the south the *Antarctic Circle.* The spaces between the tropics are called *Torrid Zones,* because the sun, being always vertical in some part of that space, produces a greater degree of heat than is felt in regions where his rays strike more obliquely. The spaces between the tropics and the Arctic and Antarctic Circles are styled the *Temperate,* and the spaces within these latter circles the *Frigid Zones.* Lastly, a line, which cuts the Equator obliquely, touching upon opposite points of the tropics, is called the *Ecliptic.* The points where the Ecliptic cuts the Equator are termed *Equinoctial Points* or *Nodes;* and when the sun is in that part of his course, the day and night are of equal length. These equinoxes of course occur twice during the year—namely, the 21st March and 21st September. The Ecliptic and Equator are sometimes called *Greater Circles,* because they encircle the earth at the thickest parts; the others above enumerated are all *Lesser Circles.* A series of lines drawn from pole to pole over the earth's surface, and cutting the Equator at right angles, are called *Meridians,* from the Latin *meridies,* mid-day. Every place upon the earth is supposed to have one of these passing through it, although it is usual to describe only twenty-four upon the surface of the terrestrial globe. When any of these is opposite the sun, it is then mid-day, or twelve o'clock, with all the places situated on that meridian, and consequently midnight with those on the opposite meridian, on the other side of the earth. Thus, when it is twelve o'clock at noon in any particular part in Britain, it will be twelve o'clock at midnight in a corresponding part on the opposite side of the globe—that is, with our *Antipodes*—near New South Wales; and the intermediate hours, sooner or later, will all lie in the countries between these two points, exactly according to their position or degrees of longitude.

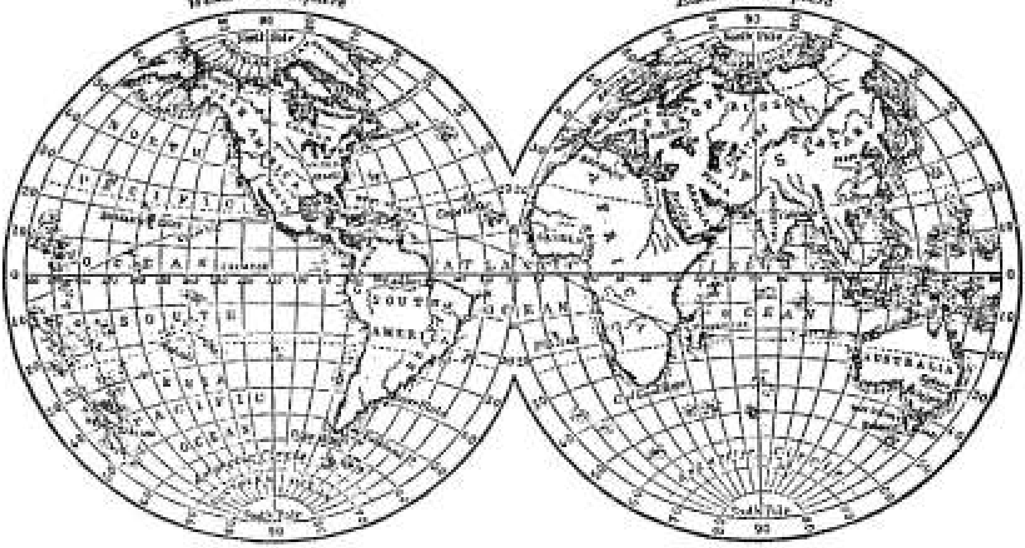
The exact situation of a place upon the earth, or its latitude and longitude, is determined by means of these circles. They are all divided, as already stated, into 360 parts, which parts are called *degrees;* these degrees again into 60 equal parts, called *minutes;* the minute into 60 others, called *seconds;* and so on. They are usually indicated by certain signs—thus, 8° 5′ 7″ is 8 degrees 5 minutes 7 seconds. The *latitude* of a place is its distance measured in that manner from the Equator. If it lies north of that line, it is in north latitude; if south of it, in south latitude. There being only 360 degrees in the circumference of the earth, and the distance from the Equator to either of the poles being only a fourth part of it, a place can never have more than 90 degrees of north or south latitude. The *longitude* of a place is the distance of its meridian from another, which is called the *first meridian.* The first meridian is quite arbitrary, and it is a matter of indifference through what point we draw it, provided it be settled and well known which one we adopt, so as to prevent mistakes. Foreigners fix upon the principal observatories of their respective countries. In Germany, the island of Ferro is generally adopted; in France, the observatory of Paris; and in England, that of Greenwich. Longitude is reckoned either east or west of the first meridian; and 180 is therefore the utmost degree of longitude. Some geographers, however, reckon longitude all the way round the globe. From the meridians all tending to a point at either pole, the degrees of longitude decrease as we approach these points from the equator.

Besides these terms and technicalities, which refer to the earth as a whole, there are others employed to designate its separate portions of land and water. Thus, of the land, a *continent* is any vast region uninterrupted by seas; an *island,* any smaller portion surrounded by water; a *peninsula,* a portion nearly surrounded by water; an *isthmus,* the narrow neck which connects a peninsula with the mainland; a *cape, promontory,* or *headland,* a point of land jutting out into the sea. As to the water, a large uninterrupted extent of sea is called an *ocean;* smaller portions are known as *seas;* a bend of the sea into the land, a *bay;* a deeper indentation, a *gulf;* a narrow stripe of sea, a *strait* or *channel;* and where the sea stretches inland to receive the waters of some large river, it is termed a *firth* or *estuary.* Referring to the surface of the land, without any reference to water, extensive flats are known as *plains, steppes, pampas,* &c.; smaller ones as *valleys, straths,* and *dales;* elevated land is spoken of as rising into *hills,* or, still higher, into *mountains;* and level elevated tracts are known by the name of *table-lands* or *plateaux.* Running water makes its appearance in *springs,* many of which conjoined form *streams,* and streams *rivers;* and where these become stagnant, and spread out into inland sheets, they take the name of *lakes.* The bounding-line of land and water is termed the *shore,* and the land bordering on the sea in any place is generally spoken of as the *coast* or *sea-board,*

DISTRIBUTION OF LAND AND WATER.

To exhibit the earth's surface at one view, it is usual to map it into two halves or hemispheres—the Eastern, comprehending the one great continent of the *Old* World, or that known to the ancients; and the Western, or *New* World, discovered and explored since the close of the fifteenth century. To these modern geographers add a third—namely, *Oceania*, or the Maritime World, partly situated in both hemispheres, and comprising Australia and the vast group of islands which stud the Pacific Ocean. It will be seen at one glance that the sea and land are very unequally distributed—that they preserve no regularity of outline or form—and that either is placed indifferently as to position on the earth's surface. Many fanciful conjectures have been offered to account for the configuration of the existing continents, but none of them seem to have any foundation in fact. The elevating and depressing causes mentioned under the head of GEOLOGY, are too violent and

Western Hemisphere — *Eastern Hemisphere*



capricious, to leave anything like regularity in their results, while it is a matter of indifference as to the planetary relations and equilibrium of the globe what portion of its surface be land or water. And yet, seeing that everything in nature is regulated with such order and harmony, there may be, though beyond our present means of detection, a progression as to the time and manner in which the various portions of the solid crust shall be elevated into dry land, or submerged beneath the ocean. It has been already stated, on geological authority, that the land and water have frequently changed places—and this changing implies vast revolutions in the kind and amount of the vegetables and animals which people the earth. Did the greater portion of the dry land exist between the tropics, for example, the Fauna and Flora of the world would be essentially different from what obtains at present, and still more so from that which could flourish were that land distributed chiefly in the polar regions. The distribution of land and water, therefore, though unimportant as regards the physical relations of the globe, is all-essential to the character of its life and humanity.

Though we are thus unable to account for the present relative arrangement of sea and land, there is one determining principle sufficiently clear—namely, that so long as the same quantity of water remains on the globe, a fixed amount of space will be required to contain it. If the difference between the elevations and depressions of the solid crust be small—in other words, if the hollows in which lakes and seas are spread out be shallow—their waters must extend over a greater space; and if these hollows be deep, the waters will occupy less extensive areas. The operation of this principle should be borne in mind; for if the elevation of the land were less general, the waters would occupy larger spaces, and this more extended area of shallow water would act in various ways. It would render the climate more genial and uniform; and, extending a greater surface to the evaporating power of the sun, rains and atmospheric moisture would be more prevalent. These, again, would influence the amount and kind of animal and vegetable life on dry land; while the shallow waters themselves would be more productive of life—it being a well-known fact, that marine plants and animals flourish only at limited depths. Of terraqueous distribution at any former period of the world, we can only infer from the appearances which the surface and rocky strata present; but of the present distribution we have pretty accurate information, with the exception of those inhospitable regions surrounding either pole.

The proportion of dry land to water, as at present known, is about one to three—that is, two-thirds of the whole surface of the globe may be assigned to water. Estimating the entire superficies to contain 196,943,750 square miles, nearly 147,000,000 are occupied by water, and only 51,000,000 by dry land. Others, reckoning the entire area of the globe at 197,000,000 of square miles, assign seven-tenths as the proportion of space occupied by the ocean—that is, about 136,000,000 of liquid superficies, and somewhat less than 60,000,000 of solid dry land. Of this land, the greater portion lies in the northern hemisphere, or north of the equator; while south of that line, the ocean spreads for thousands of leagues unbroken by a single islet. It will no doubt greatly alter this estimate should the indications of land within the antarctic circle hereafter prove to be portions of one great polar continent. The following is given as an approximation to the amount of land (in square miles) in the different latitudinal zones of the earth's surface:—

Northern Hemisphere.		*Southern Hemisphere.*	
Arctic Zone, -	2,250,000	Antarctic Zone,	—
Temperate Zone,	28,530,000	Temperate Zone,	3,830,000
Torrid Zone, -	11,620,000	Torrid Zone,	12,210,000
Total,	42,400,000	Total,	16,040,000

The relative configuration of land and sea, we have said, is so extremely irregular, that no conception can be formed of it unless from the study of a well-constructed map; but whatever the character of this configuration, it exercises a most important influence on the physical operations of the globe, by determining the direction of oceanic and tidal currents, and by modifying the direction and force of waves. Oceanic currents influence the temperature, and consequently the life of the ocean; they carry along with them every species of floating debris—and this they deposit wherever the configuration of the land presents an obstruction. Tides also exercise a powerful transporting influence; they rise to greater or less heights, according as they are obstructed by the outline of the land; and while they sweep headlands and promontories bare, they lay down sand and gravel in sheltered bays. Waves also wear away the land, according as the line of coast obstructs or favours the violence of their progress. Since, therefore, these oceanic agents are wearing away dry land in one quarter, and filling up shallow bays and creeks in another; since rains and rivers are wearing down inland regions, and carrying the material to the sea; and since, moreover, earthquakes and volcanoes are here submerging land, and there elevating the bottom of the ocean—the relative distribution of land and water must be continually fluctuating. However imperceptible this shifting may be—little affected as the existing continents may have been within the historic period, or even within the era, of man—still the change goes forward; and we are no more entitled to regard the present distribution as a thing fixed and enduring, than an inhabitant of the old red sandstone era (had any such existed) would have been to declare the then arrangement of land and sea as a thing immutable.

CONTINENTS AND ISLANDS.

The quarters or continents (though, strictly speaking, there are only the two great continents already mentioned) into which it is usual to divide the dry land, are *Europe*, *Asia*, and *Africa* in the Eastern Hemisphere; North and South *America* in the Western; and *Oceania* (including Australia, Malaysia, and Polynesia), situated partly in both hemispheres. By referring to the map, it will be perceived that there are traces of land still unexplored both in the arctic and antarctic regions; but whether these may be islands or masses worthy to be ranked as new continents, we have yet few means of conjecture. At present, the comparative areas (in square miles) of the established quarters—including their respective islands—are calculated as follows:—

Old World, or eastern continent,		31,230,000
Europe,	3,724,000	
Asia,	16,152,000	
Africa,	11,354,000	
New World, or western continent,		15,000,000
North America,	8,200,000	
South America,	6,800,000	
Maritime World, or Oceania,		4,632,000

The superficies of this vast expanse presents an amazing diversity of character; some portions being little elevated above the sea-level, others rising into mountains of more than five miles in height; some tracks swampy, others arid; certain regions tame and flat, others diversified by the wildest irregularities; districts teeming, under tropical influences, with life and growth, others buried in the perpetual solitude of ice and snow. This diversity of character forms the especial object of our arrangement and description.

Although the above division into "quarters" be convenient, and even justifiable enough, yet so much do these sections run into each other, so largely do portions of one or more of them lie within the same parallels, and so frequently are their other conditions akin, that it is not very easy to draw a series of broad and well-marked physical and vital distinctions between them. And yet there is something peculiar in the external conditions of Africa—for example, something in its climate and superficies, its river-systems, its Fauna and Flora—that serve to distinguish it as a whole from any of the other continents. The same may be said of South America, of North America, and of Oceania; and in a less degree of Asia and Europe, which are separated by no great natural boundary. Retaining, therefore, these generally-acknowledged divisions, let us glance at their respective positions and superficial characteristics as influencing the vitality of our planet.

Europe—lying almost wholly within the northern temperate zone, diversified by a happy blending of mountain and plain, marked by no geographical feature on a scale so large as to give to its surface the character of monotony, and surrounded and intersected by seas which greatly influence its climate—affords, in proportion to its area, a habitat to a more varied and highly-developed existence than any other quarter. Widely connected, however, with Asia on the east, as much of the two continents as lie within the same parallels present considerable similarity, at the same time that every facility to the dispersion of species is afforded by a land communication. Asia, situated partly within the torrid, temperate, and frozen zones, and presenting an area almost five times that of Europe, exhibits every species of geographical diversity—vast mountain-chains and elevated table-lands, broad level steppes and sand deserts, luxuriant plains watered by the largest rivers, tracts doomed to everlasting snow or to scorching sterility, salubrious valleys of incessant verdure, and noisome jungles of the grossest growth. With such a variety of character, it is impossible to treat of it as a whole, and consequently geographers divide it into five well-marked regions—namely, *Central* Asia, consisting of a series of ascending plateaux, diversified by mountain ridges of stupendous height, and intersected by narrow valleys; *Northern*, including the whole of the continent north of the Altai Mountains—a flattish region traversed by large rivers, bleak and barren, suffering under an intense cold, thinly peopled, and almost physically incapable of improvement; *Eastern*—upon the whole a low-lying and somewhat arid region, though traversed by several of the largest rivers in the world, and occasionally diversified by spurs from the central table heights; *Southern*, including the two peninsular projections of India within and without the Ganges—decidedly the finest region of the continent, diversified by minor hill-ranges and well-watered valleys, enjoying a high though not an oppressive temperature, having only a rainy season for its winter, and, except during long drought, presenting in every district an unfailing verdure; and lastly, *Western* Asia (from the Indus westward and north to the Caspian), which, with a few minor exceptions, may be said to consist of high sandy plains, studded with salt lakes, very inadequately watered by rivers, and on the whole a hot and arid region. A continent marked by such a diversity of surface and climate, presents an appropriate field for the exhibition of almost every form of vitality known in the other continents, and thus has belief ever pointed to it as the cradle of organic existence. Africa, the next great division of the old world, is almost entirely insular, the isthmus connecting it with Asia being only 72 miles across, of no great elevation above the sea-level, and even in part occupied by lakes and salt marshes. Respecting the physical appearance and construction of Africa, our information is extremely limited; all that is known with any degree of certainty being some patches along the sea-board, and a few tracks or lines across the Sahara, or Great Desert, of the north. Little known, however, as it is, its isolation, its intertropical position, and its general configuration, must stamp it with *vital* peculiarities; and yet its connection with Asia on the one hand, and its proximity to Europe on the other (the Straits of Gibraltar being only about 8 miles in width), offer numerous facilities to the interchange of vegetable and animal species. Thus the southern and northern sea-board of the Mediterranean present many similar forms; the Flora and Fauna of Egypt and Nubia are identical in many instances with those of the adjoining tracts of Arabia; while the intertropical regions offer numerous genera allied to those of Birmah and Hindoostan.

Turning now to the new world, we find too the two Americas, so slenderly attached by the narrow, rocky Isthmus of Panama, which at one part is little more than 16 miles across, that they may safely be regarded as separate and distinct continents. This separation is rendered still more decided by the irregular character of the isthmus and the adjoining high tableland of Mexico, which form an almost impassable barrier to the migration either of animal or of vegetable races. South America lies chiefly within the tropics, a third part or less stretching southward into the temperate zone; its superficies is broadly marked by mountain and plain, exhibiting along the entire western coast a flat arid region, from fifty to one hundred miles in breadth; then rising boldly up into the Andes, which stretch along its whole length, and present a rugged irregular region of variable breadth; and ultimately falling away to the north and east in the *llanos* of the Orinoco, the *plains* of the Amazon, and the *pampas* of La Plata. Nor are its physical features more broadly marked than the plants and animals by which it is peopled, these exhibiting typical peculiarities only next in degree above those of the somewhat anomalous continent of Australia. Respecting the entire configuration and extent of North America, we have as yet no determinate knowledge. If we adopt the opinion of Mr Simpson—who traversed the coast from Point Barrow to Point Turn-again—that the waters of Melville Sound are connected with the Gulf of Bothnia, then is North America distinct from the arctic regions of Cumberland Island, N. Georgia, and Greenland, which will require to be erected into a new geographical division. Following, however, the usual course of including these regions, and leaving the "north-west passage" as still problematical, the area of the known continent may be stated at 8,500,000 square miles—the great mass of which lies within the northern temperate zone. The general physical characteristics of the continent are remarkable for the magnitude of the scale upon which they are presented—the plains, lakes, and rivers being superior to those of all other countries. Though lying chiefly within the temperate zone, its southern and northern regions are respectively placed under tropical and arctic influences, and thus it presents in some measure the threefold variety of Fauna and Flora which characterises the greater continent of Asia. This greater diversity of climate renders it less peculiar in its living forms than the sister continent, at the same time that its proximity to Asia—being separated by Behring's Straits, which are only 36 miles broad, and annually frozen over—renders the immigration of old-world species by no means improbable.

The insular portions of the globe are not less worthy of notice than the continents themselves, though these, in reality, are but islands of greater extent, washed on all sides by the ocean. Meaning, however, by the term *island*, those smaller masses of land lying in the midst of seas and lakes, we find them sometimes solitary, oftener collected into groups or *archipelagos:* in some cases they are little more than low sand-banks, ledges of rocks, or coral reefs; and in others—rising to a considerable elevation above the surface of the water, and spreading to a considerable extent—they present in miniature all the features of the continents to which they belong. They are often the summits of submarine mountain chains, and, as such, are intimately connected with each other, and with the neighbouring mainland. Many of them are evidently the production of volcanic forces—the dawn of new continents emerging from the waters, as others are the gradually-submerging relics of former terrestrial regions. The most important island-groups are the British, Japan, Philippine, and East Indian, in the eastern hemisphere; and the West Indian and Polynesian in the western. The largest individual islands (regarding Australia as a continent) are—Borneo, with an area of about 300,000 square miles; Madagascar, 234,000; New Guinea, whose outline is yet imperfectly known; Sumatra, 128,000 square miles; Niphon, 109,000; Great Britain, 83,020; Nova Zembla, yet imperfectly known; Newfoundland, 57,000; Cuba, 43,400; and Iceland, 30,000 square miles.

Islands, we have said, are either connected with existing continents, are portions of former continents now submerged, or are new and independent elevations. Thus, if an island is of the same geological formation with the adjoining mainland, we must regard it either as a portion separated by depression, or as a belated portion only rising into dry land. In either case, we are bound to consider it in all its relations—vital as well as physical—as belonging to the adjacent continent. Again, islands of totally different formation from that of the nearest continent, may in most cases be regarded either as relics of former lands, or as new lands rising into day; and we are not to be startled at the fact of their exhibiting (like Australia) races of plants and animals altogether peculiar. Lastly, with respect to far distant and solitary islets, whether of volcanic origin or not, we must view them as indices of operations past or future, and as proofs of the fact, that the sea bottom presents the same irregularities as the surface of the land—these islets towering above the general configuration like lofty peaks of existing mountain ranges.

Such is a brief glance at the partition of the dry land (so far as it is known) into continents and islands—a partition which exercises an all-important influence over organic existence, and which, after all, is dependent on very minute geological operations. A general elevation of the solid crust in the eastern hemisphere, for example, would connect Britain with the continent of Europe, the Loffoden islands with the Scandinavian peninsula, enlarge the connection between Asia and Africa, elevate the Sunderbunds of the Ganges into a vast plain, the Laccadive and Maldive reefs into extensive islands, and the bed of the Yellow Sea into an alluvial plain. A depression to the same amount, on the other hand, would sever Scandinavia from Europe, lay the Netherlands and part of Central Europe under water, sever Africa from Asia, convert a large portion of Arabia, Egypt, and Northern Africa into an extension of the Mediterranean; in fact, totally overturn the existing relationship of the dry land in the old world. Similar phenomena would be presented under similar circumstances in the new world; and more strikingly still in connection with the island-groups of the Pacific. Equally important results depend upon the relative positions of the continents and islands. Had South America, unaltered in a single square yard, lain parallel with, instead of crossing, the equator, or had Africa been intersected by seas as Europe is, it requires no stretch of imagination to conceive the radical difference which their Flora and Fauna would have presented. Whether the present arrangement of continent and island is that which admits of the greatest amount and variety of vital development, is what we have not yet sufficient data to determine; but this we know, that the existing irregularity and varied subjection to arctic, temperate, and tropical influences, is much more favourable to these results than any single influence, however gigantic its operation. Nay, more, as regards man, and the highest aim of creation—the civilisation of man—the present arrangement is of the first importance. The theatre of his operations all arctic, and he would never have risen above the condition of the Laplander or Esquimaux; all antarctic, and behold his condition in that of the miserable Fuegian; all tropical, and see him in a state of languid, enervated, semi-civilisation; while balanced as conditions are, see his progress mainly in one broad zone, where Chinese, Indian, Persian, Chaldean, Syrian, Egyptian, Greek, Roman, Frank, and Anglo-Saxon have successively, or simultaneously, figured in the march of improvement.

MOUNTAINS AND TABLE-LANDS.

As elevation above the waters of the ocean is the origin of the dry land, so its most prominent features are those peculiar upheavals known by the name of *hills* and *mountains*. They are the framework, so to speak, upon which the solid crust is built and compacted; they are the immediate results of the elevating forces mentioned under GEOLOGY, and according to their character, so is that of the regions to which they belong, generally speaking, determined. They subserve numerous and important purposes in nature. Rising into regions of perpetual ice, they serve, in hot climates, to temper the air with the breezes generated around their heights; they are the reservoirs of rivers, supplying the shrinking streams, in the dry seasons of the lower countries, with copious torrents from their melting snows; they are, in most instances, the storehouses of the richest minerals; they increase and diversify the surface of the earth; and, by presenting impassable barriers between opposite regions, they give variety and richness to animal and vegetable life: we say impassable barriers, for the broadest seas are not half so effective in obstructing the dispersion of vegetable and animal life, as lofty snow-clad mountains. Seas have their tides, and currents, and drifting winds, and waves—even the polar seas have their firm ice-fields and drifting ice-floes, on which plants and animals may be borne; but the snow-clad summit is enduringly inapproachable to all that partakes of vitality.

Isolated mountains of great height are of rare occurrence, and when they do appear, are usually active or recent volcanoes. Hills and mountains, whether rising to the height of one thousand or twenty thousand feet, generally appear in chains or ranges, consisting either of one central chain, with branches running off at right angles, or of several chains or ridges running parallel to each other; and in both cases often accompanied by subordinate chains of minor elevation. Several chains constitute what is called a *group*; and several groups a *system*. Geology views these systems as so many axes of elevation, necessary to the rise of certain formations from the bottom of the ocean; ascertains the direction and centre of the elevating force; explains the phenomenon of "crag and tail;" speculates on the cause of the steep side being generally turned towards the older formations, while the gradual slope looks towards the newer; and further determines the respective eras when they rose into existence, by examining the nature of the stratified deposits broken through and carried up with the elevatory masses. Thus the Grampians, flanked and crested by no secondary rocks, long preceded the Pyrenees; the Pyrenees the Alps, which displaced the youngest secondary strata; and the Alps, again, had risen into form while the site of Ætna was a shallow sea of tertiary deposit. The relative ages of mountain chains appertains more especially to the province of the geologist; but with their epochs is connected their physiognomy or contour, a subject eminently interesting to the geographer. So persistent is the contour of mountains, whether associated with the primitive, secondary, or more recent formations, that the practised eye of the geologist can generally determine at a glance the era of their upheaval. The bold, but bald and massive heights of a granitic mountain, differ widely in aspect from the abrupt and splintery crags and pinnacles of a primitive; while the rounded, undulating, and terraced outline of the secondary trap-hills distinguish them at once from the conical crateriform heights of the tertiary era. Nor is it in appearance alone that these distinctions are interesting; the cold barren subsoil of a granitic district, altogether independent of elevation, differs as widely in its vegetable exhibitions from those of a fertile and congenial trap as a cultured garden does from a moorland wild.

Respecting the classification of mountains, various plans have been adopted by continental writers; but most of them are objectionable as involving geological theories: we shall adhere to that simpler arrangement which takes into account merely their geographical position and connection:—Those of Europe have been classified into a number of systems, some of which are continental, others insular. Laying aside minutiæ, the following seem to be distinct and natural:—1. The *Hesperian*, embracing the mountain ridges of the Spanish peninsula—all of which maintain a wonderful parallelism in position, as well as unity of character, and whose extreme culminating point is Maladetta in the Pyrenees, 11,424 feet. 2. The *Gallo-Francian* system, including all the hilly eminences in France which lie to the north of the Garonne, west of the Rhone, and south of the Rhine. None of these are of great age, or of great elevation, the highest being a peak of the Plomb de Cantal in Auvergne, 6113 feet. 3. The *Alpine* system, embracing all those ridges and branches which radiate from the great Alpine range of Switzerland, such as the Maritime, Cottian, Pennine, Rhotian, Noric, and other Alps; the Apennines in Italy, and the Balkan or Hæmus group in Turkey. This is the great mountain development of Europe, under which, as one system, geographers used to comprehend the whole of the southern groups and chains: the highest or culminating point is Mont Blanc in Switzerland, 15,732 feet. 4. The *Hercynio-Carpathian* system, including all the mountains and eminences comprehended between the Rhine, Dnieper, and Danube, the plains of Northern Germany and Western Poland. The highest point in this system is Ruska-Poyana in the Eastern Carpathians, 9912 feet. 5. The *Scandinavian*, a system of the highest antiquity, embracing the well-defined chains of Norway, Sweden, and Lapland, the extreme height of which does not exceed 8350 feet. 6. The *Ural* system or chain, which forms the boundary-line between Europe and Asia, and rises in its highest part to between 5000 and 6000 feet. Lastly, the *Britannic system*, consisting of a number of detached chains, as the Grampians, Cheviots, and Welsh mountains, the highest point of which is Ben MacDhui in Aberdeenshire, 4390 feet. All of these systems, as axes of elevation, have long ago become fixed and permanent; none of them has for the last two thousand years shown symptoms of volcanic activity: Hecla, Vesuvius, and Ætna, the only active volcanoes in Europe, seem to point to future upheavals.

The mountains of Asia may be all traced from that vast central plateau already adverted to, which forms, as it were, the nucleus of the continent. Omitting ranges of minor altitude, we may enumerate—the *Altai*, forming the boundary between the Chinese empire and Siberia, one of the bleakest ranges in the world, stretching unbroken for 500 miles in length, and reaching an extreme altitude of 11,500 feet; the *Iablonnoi* and *Stanovoi*, which may be regarded as prolongations of the Altai, stretching onwards to Behring's Straits, and attaining a height probably not exceeding 6600 feet; the *Khing-khan* range, bounding the Desert of Kobi, extending about 600 miles in length, but of unknown altitude; the *Chang-pe-shan*, skirting the east coast of Mandshuria, and rising abruptly from the sea to a height of 5000 feet; the *Pe-ling* and *Yun-ling* ranges, on the west of China Proper, ramifying variously, probably attaining a culminating height of 11,000 or 11,500 feet, and branching southward through Birmah and Annam in several parallel ridges which fall to 4000 and 3000 feet; the great *Himaleh* mass, extending about 1300 miles in length, and from 200 to 250 across, rising from the Indian side by stages of 4000, 8000, and 11,000 feet, then swelling generally to 14,000, in about 200 points reaching a height of 18,000 feet, and in Dhwalagari and Chumulari to 20,000 feet—the greatest known altitude of the terrestrial surface; the *Hindoo Koosh*, with their southern ramifications, which may be regarded as prolongations of the Himaleh; the *Thian-chan*, in Central Tartary, rising to an absolute height of 11,000 or 12,000 feet, but only from 3000 to 4000 above the surrounding table-land; and lastly, the *Tauro-Caucasian system*, diversifying the west of Asia with numerous ridges and peaks, the highest of which is Elburz, 17,786 feet. In connection with these systems and ridges are active volcanoes, as in Kamtchatka, Japan, the Thian-chan ranges, the plateau of Mongolia, &c.; and we are therefore not entitled to regard those so connected as having yet attained their ultimate elevation.

Of the mountain-systems of Africa we know nothing with certainty; a few detached facts are all that geography can offer. The hills of Cape Colony rise from Table Mount 3582 feet, to the Sneeuveldt, 7400 feet, and thence to the Nieuveldt, 10,000 feet, the intervening spaces being shrubby *kloofs* or valleys, and broad grassy terraces or *karoos*. Of the *Lupata* chain, or "Backbone of the World," as it is called by the older geographers, nothing is known, save that it skirts, almost unbroken, the entire eastern sea-board of the continent; and information is equally deficient respecting the clustering ridges of Abyssinia and Nubia, and the more linear ranges of Kong, Donga, and Cameroon. The last, it has been ascertained, rise to an elevation of more than 13,000 feet; but whether this be the maximum, or whether the whole may not belong to one system, further exploration can alone determine. On the north, between the Sahara and the Mediterranean, the *Atlas* system is well-defined, and here an elevation of 11,400 feet has been ascertained; but some peaks in the chain rise much higher, and, according to recent accounts, seem to be permanently covered with snow—a fact which would seem to indicate an altitude of more than 15,000 feet.

The mountains which traverse South America may be ranked under two systems—the *Cordilleras* or *Andes* proper, and the Brazilian Andes. The former, in several parallel chains, extend from the Straits of Magellan to the Caribbean Sea, in many places spreading out over a breadth of several hundred miles, embracing lofty table-lands, containing mountain lakes, and everywhere intersected by steep narrow ravines, passes, and lofty waterfalls. At Popayan, the main chain divides into three ridges, one of which, shooting off to the north-west, passes into the Isthmus of Panama; a second separates the valleys of the Cauca and Magdalena; and a third, passing off to the north-east, separates the valley of the Magdalena from the plains of the Meta. The highest summits of the system are between 15 and 17 degrees south, where Sorata reaches the elevation of 25,350, and Illimani that of 24,200 feet; throughout Chili and Peru they range from 15,000 to 23,000 feet; in Columbia, from 14,000 to 16,000 feet; and in Patagonia, from 4000 to 6500. Altogether, the Andes present a most magnificent spectacle to the voyager on the Pacific; the snow, which permanently covers their lofty summits, even under the burning sun of the equator, contrasting beautifully with the deep blue of the sky beyond; while occasionally another contrast is exhibited in vast volumes of smoke and fire, emitted from some of the numerous volcanoes which stud the entire range. The Brazilian Andes occupy a great breadth of country, but seldom exceed an elevation of 6000 feet.

The mountains of North America are scarcely in proportion to the other physical features of that continent, either in point of continuity or of altitude. Regarding the Cordilleras of Panama and Mexico, the Californian or Maritime range, and the Rocky Mountains, as portions of the great system of the *Andes* proper, we have in Guatemala a culminating point of 14,900 feet; in the Mexican volcano of Popocatepetl, of 17,735; in the table-land of Mexico, a general height from 4000 to 8000 feet; and in the Californian range, an average altitude of 8000 or 10,000 feet, which suddenly rises to 12,630 in Mount St Elias. The *Rocky Mountains*—the greatest and most continuous of the North American chains—rise from 8000 to 10,000, occasionally to 12,000, and only between 52 and 53 degrees north, to 16,000 feet; while the *Alleghanies* reach their extreme height at 6470 feet, and sink down in their branches to 3000 and 2000 feet.

In Oceania we have several minor groups and ranges; but the principal elevations are in detached volcanic heights, the index-fingers, as it were, to future mountain systems. In Malaysia, the highest known point is Mount Ophir in Sumatra, 130,50 feet; Australia has no eminences of importance; but Polynesia has the verdant and wooded heights of Tahiti, rising to 10,000 feet; and the active craters of Owhyhee, respectively 13,000, 14,000, and 16,000 feet above the sea level.

Such are the more prominent mountain systems as known to geography. Those who regard them as mere ridges, rising on one side, and descending as abruptly on the other, and at most intersected by a few narrow passes, gorges, and ravines, form a very erroneous conception of the physical contour of the globe; for, so far from this being the case, most of these systems are but the escarpments or ramparts of elevated expanses known as *plateaux* or *table-lands*, which form in some instances the nucleus of continents, and the source from which the rivers of such continents flow. Thus, on examining the map of Asia, it will be seen that all the rivers flow—north, east, south, and west—from the central region, which, in reality, forms a succession of remarkable plateaux. These plateaux may be termed the Persian, which ranges from 3000 to 6000 feet above the sea; the Mongolian, at an elevation of from 8000 to 12,000 feet; and that of Thibet, which is still more elevated. There are some masses of this kind in Europe, but of comparatively small extent—as the central part of Spain, which is about 2200 feet in height; and the Swiss table-land, between 3000 and 4000 feet. We know too little of Africa to speak of its interior; but a large part of New Granada and Ecuador, in South America, is situated at an elevation of from 5000 to 9000 feet, and contains populous cities, such as Quito, Bogota, &c. One of the most noted of these table-lands is that of Mexico, not less remarkable for its elevation than for its extent. "On the eastern and western coasts are low countries, from which, on journeying into the interior, you immediately begin to ascend, climbing, to all appearance, a succession of lofty mountains. But the whole interior is, in fact, thus raised into the air from 4000 to 8000 feet. The conformation of the country has most important moral and physical results; for while it gives to the table-land, on which the population is chiefly concentrated, a mild, temperate, and healthy climate, unknown in the burning and deadly tracts of low country into which a day's journey may carry the traveller, it also shuts out the former from an easy communication with the sea, and thus deprives it of a ready access to a market for its agricultural productions." As with the Mexican, so with all other table-lands, according to their latitude and elevation. Under the tropics they become theatres for the exhibition of temperate or even of arctic species; while under a temperate zone they are inhabited solely by boreal forms.

EARTHQUAKES AND VOLCANOES.

These are rather agents than effects—rather the cause of geographical diversity than geographical features themselves; and in this respect belong more properly to the province of geology: still, as by far the greater portion of superficial irregularity is the direct result of their operations, and as it is often impossible to separate cause from effect, it will be necessary here to give them some further consideration. An earthquake may produce a momentary undulation of the ground, followed by no perceptible result; it may simply elevate one region or depress another; it may be attended by a vast destruction of animal life, and the submergence of forests; it may alter the course of rivers, and produce new shores and beaches; it may create vast tidal waves, which give rise to accumulations of debris; open new springs and fissures, from which issue various products differing from those hitherto known in the district. Innumerable instances of such changes could be cited; a few, however, will suffice to convince the reader of the importance of this class of physical agencies:—By the great Chili earthquake of 1822, an immense tract of ground—not less than 100,000 square miles—was permanently elevated from two to six feet above its former level; and part of the bottom of the sea remained bare and dry at high water, with beds of oysters, mussels, and other shells adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia. By an earthquake in 1819, a tract—the Ullah Bund—in the delta of the Indus, extending nearly 50 miles in length, and 16 in breadth, was upheaved ten feet; while adjoining districts were depressed, and the features of the delta completely altered. The earthquakes of Calabria, which lasted for nearly four years—from 1783 to the end of 1786—produced numerous fissures, landslips, new lakes, ravines, currents of mud, falls of the sea-cliffs, and other changes, which, taken in conjunction, afford one of the finest examples of the complicated alterations which may result from a single series of subterranean movements, even though of no great violence. In 1743, the town of Guatemala, in Mexico, with all its riches, and eight thousand families, was swallowed up, and every vestige of its former existence obliterated; the spot being now indicated by a frightful desert, four leagues distant from the present town. In 1692, a similar calamity overtook the town of Port-Royal in Jamaica, when the whole island was frightfully convulsed, and about 1000 acres in the vicinity of the town submerged to the depth of fifty feet.

Volcanic forces act in a similar manner, in as far as they elevate, depress, and break asunder portions of the earth's crust; indeed earthquakes and volcanic throes, considered as subterranean movements merely, produce precisely the same results. But volcanoes, properly so called, act in another and equally important manner in producing geographical changes. They elevate the crust into long continuous ridges or mountain chains, form isolated cones, and discharge accumulations of lava, scoriæ, ashes, loose stones, and other igneous debris. Geologists and geographers often amuse themselves by enumerating volcanic vents to the amount of 300 or thereby; but this is of little moment compared with the determination of the centres of elevation to which they belong. In Europe, there appears to be three centres of volcanic action—namely, that of the Levant, to which Ætna and Vesuvius belong; that of Iceland, represented by Hecla and the craters of Jan Meyen; and that of the Azores in the Atlantic. In Asia there is abundant evidence of volcanic action on the borders of the Mediterranean, the Black Sea, the Caspian, and the Persian Gulf; while along the eastern borders of that continent there is a range not less than 5000 miles in length and 250 in breadth, including Sumatra, Java, the Eastern Moluccas, and the Philippine Islands; the same range bearing farther northward, though less distinctly, for several thousand miles, and terminating in the volcanic cones of the Aleutian isles. The whole extent of the two Americas is also traversed by a volcanic range, manifesting itself by eruptions along the whole line, from the Rocky Mountains through Mexico and the Andes, onward to Patagonia and Terra del Fuego. The islands of the Pacific further attest the presence of similar forces, as in the New Zealand, Sandwich, and other groups; as do those —namely, the Canaries, Cape de Verd, Ascension, St Helena, Madagascar, Bourbon, &c.—which surround the continent of Africa. In these centres of igneous action many of the volcanoes are *extinct*, others are merely *dormant*, while many are incessantly *active*.

The cause of volcanoes, earthquakes, and other subterranean movements, has been the subject of several theories, but is yet by no means very satisfactorily determined. The most prevalent opinion is that which connects them with one great source of central heat—the residue of that incandescent state in which our globe originally appeared. By this hypothesis it is assumed that the crust of the earth is of various thickness, that it contains vast caverns, and is extensively fissured—primarily by unequal contraction from cooling, and subsequently by subterranean agitations. Through these fissures water finds its way to the heated mass within; this generates steam and other gases, and these exploding, and struggling to expand, produce earthquakes and agitations, which are rendered more alarming by the cavernous and broken structure of the crust, and the yielding material upon which it rests. Occasionally these vapours make their way through fissures and other apertures as gaseous exhalations, or as hot springs and jets of steam and water, like the geysers of Iceland. On the other hand, when the expansive forces within become so powerful as to break through the earth's crust, discharges of lava, red-hot stones, ashes, dust, steam, and other vapours follow; and repeated discharges of solid material gradually form volcanic cones and mountain ranges. It does not follow, however, that volcanic discharges must always take place at the point where the greatest internal pressure is exerted, for volumes of expansive vapour press equally upon the crust and upon the fluid mass within, so that the latter will be propelled towards whatever craters or fissures do already exist. This theory of central heat is further supported by the occurrence of igneous phenomena in all regions of the globe, and by the fact, that most volcanic centres are in intimate connection with each other—a commotion in one district being usually accompanied by similar disturbances in another. The only other hypothesis which has met with countenance from geologists, is that which supposes the internal heat to be the result of chemical action among the materials composing the earth's crust. Some of the metallic bases of the alkalies and earths, as potassium, the moment they touch water, explode, burn, melt, and become converted into red-hot matter, not unlike certain lavas. This fact has given rise to the supposition that such bases may exist within the globe, where, water finding its way to them, they explode and burn, fusing the rocks among which they occur, creating various gases, and producing caverns, fissures, eruptions, and other phenomena attendant upon earthquakes and volcanoes. As yet, our knowledge of the earth's crust at great depths is excessively limited; we know little of the chemical and magnetic operations which may be going forward among its strata; and we are equally ignorant of the transpositions which may take place among its metallic and earthy materials; but judging from what we do know, this theory, however ingenious, seems by no means adequate to the results produced. It is true that there occurs nothing among the products of volcanoes at variance with its assumptions; but the magnitude, the universality, and the perpetuity of volcanic action, point to a more stable and uniform source—that source being the internal heat or residue of that igneous condition in which our planets originally appeared.

PLAINS—VALLEYS—AND OTHER DEPRESSIONS.

The plains, or level portions of the earth's surface, form a feature in its physical aspect equally important with that presented by its mountain systems. The name is given to extensive tracts, whose surface, in the main, is level, or but slightly broken by elevations and depressions. They are found at all elevations above the sea, and of every degree of fertility; from the exuberant tropical delta just emerging from the water, to the irreclaimable sterility of the desert of ever-shifting sand. In the economy of nature, they constitute the chief theatres of vitality: there plants, from the lowliest herbage to the most gigantic timber trees, flourish in greatest perfection and abundance; there animals, governed by food instincts, congregate most densely; and there man, led by similar instincts, and by the higher purposes of social life, has chiefly planted his habitation.

The noblest of these expanses are the river plains of the new world, drained by such waters as the Mississippi, the Amazon, and La Plata. In North America, the basin or drainage of the Mississippi is estimated at 1,300,000 square miles, and that of the St Lawrence at 600,000; while northward of the 50th parallel, extends an inhospitable flat of perhaps still greater dimensions. Much of the former expanse is rolling or undulating in its surface, well watered by minor rivers, exhibiting broad grassy *prairies* and extensive pine forests; the second is more irregular in surface, largely occupied by lakes, and cumbered with forest growth; while the last is a bleak and desolate waste, overspread with innumerable lakes, and resembling Siberia in the physical character of its surface and the rigour of its climate. In South America, we have first the low belt of country skirting the shores of the Pacific, from 50 to 100 miles in width, and about 4000 in length, fertile at its extremities, but in the middle sandy and arid; next the basin of the Orinoco, consisting of extensive plains called *llanos*, either destitute of wood, or merely dotted with trees, but covered during part of the year with tall herbage; then the basin of the Amazon, a vast plain, embracing a surface of nearly 2,000,000 square miles, possessing a rich soil and humid climate, and almost entirely covered with dense forests and impenetrable jungle marshes by the river sides; and lastly, the great valley of the Plata, occupied chiefly by open plains called *pampas*, in some parts saline and barren, but in general clothed with weeds, thistles, and tall grasses. Next in order of importance is that section of Europe extending from the German Sea, through Prussia, Poland, and Russia, towards the Ural Mountains, presenting indifferently tracts of heath, sand, and open pasture, and regarded by geographers as one vast plain. So flat is the general profile of this region, that it has been remarked "it is possible to draw a line from London to Moscow, which would not perceptibly vary from a dead level!" Passing the Ural ridge, a plain of still greater dimensions stretches onward through Siberia, towards the shores of the Pacific. This region is of no great elevation, and though diversified by occasional heights, consists chiefly of gravelly steppes, covered with coarse herbage, lakes, and morasses. In Africa, the northern and central portion, so far as explored, appears to be a vast expanse of Sahara, or sandy desert, broken at scanty intervals by oases of life and verdure.

Besides these wide expanses, which may be said to counterbalance the mountain systems, there are plains of minor extent, which often stamp the countries to which they belong with a peculiar character. These are the verdant *prairies* of North America, already noticed, the *pampas* and *llanos* of South America, the *steppes* of Asia and Northern Europe, the *tundras* or bog-marshes of Siberia, the grassy *karoos* of Southern Africa, the tangled *jungle* of India, the alluvial *straths* or *dales* of our island, and the low muddy, but gradually-increasing *deltas* of such rivers as the Ganges, Nile, Niger, and Mississippi. To lesser flats and depressions—as valleys, glens, ravines, &c.—which give character to the landscape of minor districts, our space will not permit us to refer. Physically, they produce results akin to those of larger depressions; and whether they be the subsidences occasioned by earthquakes, the sites of silted-up lakes, valleys of erosion, or ravines of volcanic rupture, it is the province of geology, not of geography, to determine.

Under this head it is usual to describe *fissures*, *caverns*, and other *subterranean* openings; but as these are interesting more on account of their curious structures, than from any effect they produce on the aspect or conditions of the globe, we shall leave them to be noticed, as occasion may offer, under the respective countries in which they occur. This only we may observe, that they owe their formation either to earthquakes and volcanic convulsions, to the erosion of subterranean springs and streams, or to the action of waves and tides, when the cliffs in which they are situated formed the shores of the ocean. They become indices, in this way, to bygone operations; and are not unfrequently the catacombs, as it were, of animals long ago extinct, whose remains had either been drifted thither, or who, while alive, had fled there for a last shelter during some of nature's extraordinary convulsions.

THE OCEAN.

The ocean, though in fact a single mass of fluid resting in the hollows of the solid crust, surrounding the dry land on all sides, and indenting it with numerous bays and gulfs, is generally divided by geographers into the following great basins:—The *Pacific* Ocean, 11,000 miles in length from east to west, and 8000 in breadth, covering an area of 50,000,000 square miles; the *Atlantic*, 8600 miles in length from north to south, and from 1800 to 5400 in breadth, covering about 25,000,000 square miles; the *Indian* Ocean, lying between 40 degrees south and 25 degrees north latitude, is about 4500 miles in length, and as many in breadth, covering a surface of 17,000,000 square miles; the *Antarctic* Ocean, lying round the South Pole, and joining the Indian Ocean in the latitude of 40 degrees south, and the Pacific in 50 degrees, embraces an area (inclusive of whatever land it may contain) of 30,000,000 square miles; and the *Arctic* Ocean, which surrounds the North Pole, and lies to the north of Asia and America, having a circuit of about 6400 miles. Besides these great basins, there are other *seas* of considerable extent, as the Mediterranean, covering an area of 1,000,000 square miles; the German Ocean, 153,700; the Baltic, 134,000; the Black Sea, with its subordinate gulfs and branches, 181,000; but these and other minor sections will be more appropriately described when we come to treat of the respective countries with which they are politically as well as physically associated.

Respecting the *depth* of the ocean we have no very definite knowledge; but this we may assume, *a priori*, that it possesses great irregularity of depth and shallowness, just as the terrestrial surface presents diversity of hill and plain, and that, as the loftiest mountains rise about five miles in height, so the extreme depth of the ocean may not greatly exceed that measure. In the North Atlantic, Lord Mulgrave did not touch the ground with a sounding line of 4680 feet, and Mr Scoresby was equally unsuccessful with one of 7200 feet; while in latitude 15° 3' S., and longitude 23° 14' W., Sir James Ross tried, but did not obtain soundings, with a line of 27,000 feet! Having nearly ascertained its superficies, and assuming average depths, many have amused themselves with calculating the probable quantity of water in the ocean; but all such calculations, in the absence of anything like data, are worse than worthless. This only we know, that the quantity, whatever it may be, remains, by the unalterable laws of evaporation and condensation, always at a fixed point, there being neither increase nor decrease. It has been remarked by La Place, a French astronomer, that if the existing waters of the ocean were increased only one-fourth, the earth would be drowned, with the exception of some of the highest mountains; and that if, on the other hand, the waters were diminished in the same proportion, the largest rivers would dwindle to the capacity of brooks, and some of the principal arms of the sea would entirely disappear, while at the same time the earth would be deprived of its due proportion of humidity, and the face of nature be dried up and rendered desolate. The *pressure* of the ocean (which depends on its depth) exerts an important influence, inasmuch as it renders it impossible for plants or animals to exist beyond a comparatively limited distance from the shore or depth from the surface. Teeming as the ocean is with life, its greater depths seem to be as void and desolate as the peaks of the snow-clad mountains.

Water being a slow conductor of heat, the *temperature* of the ocean is less affected by seasonal influences, and much more uniform, than that of the atmosphere, while the action of currents and counter-currents tends to equalise its heat in all latitudes. Within the tropics, the surface temperature ranges between 77 and 84 degrees Fahrenheit; but at the depth of 300 feet or thereby, the solar influence is unfelt. In the torrid zone, the temperature diminishes with the depth; in the polar seas, it increases with the depth; and about the latitude of 70 degrees, it is nearly constant at all depths. Taking the month of March as one of those during which the heat of the sun must be equally determined in both directions by latitude, we find that in that month the sea has been found, at 11° 32′ S., of 80·6 Fahrenheit; at 31° 34′ S., of 75·7; at 40° 30′ S., of 59·9; though in some instances it has been found several degrees more or less at the same season, and under nearly the same latitude. A small difference is discovered between the observations on temperature in the two hemispheres. For the first 25 degrees towards the south, the decrease of heat is slower, and after that more rapid, than towards the north. It must be evident to every one who considers the great mass of waters composing the ocean, and the interchange of position which must always be taking place, to a greater or less extent, between the warmer and colder portions, that this comparative equability of temperature is unavoidable, even if there were no other causes to account for it. The uses of that equability are still more obvious: by it the natural result of high latitude is more or less corrected. A milder air breathing from the sea softens the climate all over the adjacent land, and produces a congeniality which is of the greatest service. On the other hand, in those torrid regions where both animated and vegetable nature is apt to sink beneath the vertical rays of the sun, the cooling breath of the ocean comes, generally at fixed times, communicating freshness and vigour to all around.

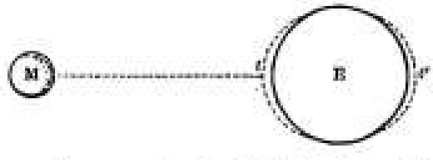
The *saline property* of the ocean, to which we have already adverted in general terms (p. 51), has never been scientifically accounted for; it baffles all human investigation. Some have alleged that it is caused by fossil or rock salt at the bottom; others that the saline constituents are carried down by springs and rivers from the land; but neither hypothesis will account for all the phenomena, while, if the latter were true, the ocean would be gradually becoming salter in consequence of incessant contributions. The most reasonable conclusion is, that the sea is a homogeneous salt body, that its waters were created, and have continued, and ever will continue, in this saline condition, in the same manner that the atmosphere has been created and exists as a compound body. The inquiry, therefore, why the sea is salt, is just as needless as why the atmosphere is composed of two or three gases. The two questions are equally shrouded in mystery. All that we know for certain is, that the ocean is not of uniform saltness; that the Southern Ocean, for example, contains more than the Northern; that inland seas are generally more saline than the open ocean; and that the surface water is somewhat fresher than that obtained from considerable depths. The gravity conferred on the water of the ocean by its saline property is 1·027, reckoning distilled water at 60° Fahr. equal to 1; and to this density it owes its superior buoyant powers. Again, fresh water, under ordinary circumstances, freezes at 32 degrees Fahrenheit, whereas the water of the ocean requires a degree of cold equal to 28 degrees; and the ice then formed is irregular, porous, and charged with vesicles of a dense briny liquid.

The *colour* and *phosphorescence* of the ocean are the next sensible properties requiring attention. When examined in small quantities, sea-water is colourless; but when viewed in the mass in the wide ocean, it appears to be of an azure or blue tint. The cause of this generally blue colour has not been as yet clearly explained; but it seems to be in some degree accounted for by reference to certain principles connected with the science of optics. Probably most are aware that light consists of the set of colours which we see so beautifully displayed in the rainbow. Now it is a law of light, that when it enters any body, and is either reflected or transmitted to the eye, a certain portion of it, consisting of more or less of its colours, is lost in the body. The remainder, being reflected, strikes our vision, and whatever colour that may be, the object seems of that colour. Now it chances that the portion of light most apt to be reflected from masses of transparent fluid is the blue; hence it is, or supposed to be, that the air and sea both appear of this colour. While there can be no doubt that the ocean is generally of a blue colour, it is equally certain that there are many portions of sea in which a different hue appears. The causes of these exceptions from the rule seem to be of various kinds. Frequently, the ordinary colour of the sea is affected by the admixture of foreign substances, these being sometimes of a living and organic nature, and sometimes the reverse. The most simple example of the latter class of cases is the common flooding of any stream, when quantities of mud and earthy particles are introduced into the river, and emptied into the sea. What is thus strikingly seen on every coast, on a small scale, will readily be conceived to be of infinitely wider extent in the mighty rivers of the principal continents of the globe. Some seas are coloured *yellow* from a similar cause. Vegetable matter is known to have a colouring effect; but more usually the peculiar tint, whether red, green, &c. of the sea, results from the presence of infusorial animalcules. Another class of cases in which the ocean appears to be tinged with a peculiar colour, is referable to the reflection of rays of light from the bed or bottom; and hence, in shallow and clear seas, the colour of the ground is a main cause of any particular tint which the water may assume.

The phosphorescence of the ocean, described in such glowing terms by almost every voyager in tropical seas, is now satisfactorily ascertained to arise sometimes from the presence of zoophytes and infusorial animalcules, and at others from the decomposition of vegetable and animal matter. Similar phenomena, arising from similar causes, exist on land—the glow-worm, firefly, certain fungi, putrid fish, &c.—and their appearance in the one element need not excite greater surprise than their exhibition in the other.

TIDES—CURRENTS—WAVES.

The waters of the ocean are subject to various motions and fluctuations, such as tides, currents, whirlpools, waves. That regular ebb and flow known by the name of *tides*, and which confers on the ocean one of its most interesting features, is caused by the attraction of the sun and moon. By the universal law of gravitation, all masses of matter have a tendency to be attracted or drawn towards each other. The moon, therefore, as a mass of matter, in passing round the earth, has a tendency to draw the earth after it, or out of its natural relative position, and it really does so to a small extent. As it passes round, it draws up the waters in a protuberance, or, in common language,



draws a huge wave after it. But it also draws the land beneath the protuberance, and so causes the opposite side of the globe to be drawn away from the ocean, leaving the waters there to form a similar protuberance or high wave. In the one case, the water is drawn directly up or towards the moon (M); in the other, the water is in some shape left behind by the land being pulled away from it. In both a similar effect is produced; two tides (*t t′*) are caused at opposite extremities of the earth. Where the higher part of either of these great billows strikes our coasts, we have the phenomenon of high water; and when the lower touches us, it is low water. Each of the waves is brought over any given place in the circumference of the earth in twenty-four hours, so as to cause high water twice a day. The sun is also known to have a certain attractive influence on the waters of the ocean; but from the great distance of that luminary, the effect is comparatively small. But when this minor influence of the sun coincides with that of the moon, or acts in the same line of attraction (*Mt*), we perceive a marked increase in the tides; on such occasions we have what are called *spring*, or *large* tides. When the solar and lunar attractions act in opposition, we have *neap*, or *small* tides. The spring tides happen twice a month, when the moon is at full and change; and the neap when the moon is in the middle of its orbit between those two points. A tide requires six hours to rise, which it does by small impulses or ripplings of the water on the shore, and six hours to ebb or fall; but every successive high water is from twenty to twenty-seven minutes later than the preceding, or, on an average, about fifty minutes for two tides, in consequence of the earth requiring that time above the twenty-four hours to bring any given point again beneath the moon. The tides are thus retarded by the same reason that the moon rises fifty minutes later every day. It is evident that the tides will be greatest at that point of the earth's surface which is nearest to the moon, or where the latter is vertical. She is so between the tropics; and accordingly the tides are there greatest, and they diminish as we approach either poles. It is further to be remarked, that the moon does not anywhere draw up the tides immediately. Three hours elapse before the waters are raised, in consequence of the law of inertia, or a disposition which every body has to continue in the condition of rest or motion in which it happens to be placed. This stubbornness to resist the moon's influence is only overcome by a three hours' action upon the waters; and thus the tidal wave is always three hours behind the moon in its passage. Twice a year—namely, in March and September—the tides are higher than at other times, because then the attraction of the sun and moon is strongest. In some of the firths or arms of the sea on the east coast of Scotland, it has been occasionally noticed that there have been four high waters in the twenty-four hours. These, however, are not simple tides. The double risings are caused by the irregular passage of the tidal wave from the Atlantic round the north and south points of the island of Great Britain. When that portion of the wave which proceeds by the south reaches the east coast sooner than that by the north, or *vice versa*, there will be two risings of the water instead of one. Moreover, in consequence of all the great seas and oceans forming, as we have seen, only one sheet of water variously distributed, the ebb and flow in each depend not on its own proper tide, but are the result of the combination of that tide with currents mingling with it from tides of other seas—a result depending upon inequalities of sea-bottom, the configuration of its coasts, their inclination under water, the size and direction of the channel which connects it with other seas, and occasionally upon winds and currents which are not tidal. So much do these circumstances affect the astronomical or *primary* tidal wave, that while it rises in the expanse of the Pacific to one or two feet only, the *derived* wave often rises in confined or obstructed seas to elevations of thirty, forty, or even seventy feet! This circumstance has given rise to the determination of *cotidal* lines, or lines which mark the contemporaneous position of the various points of the great wave which carries high water from shore to shore. Inland expanses of water, like the Baltic, Mediterranean, and Caspian Seas, and the lakes of North America, have no perceptible tides.

Besides being affected by the regular motion of the tides, the ocean, in many parts of its extended bounds, is influenced by currents, which act continually in particular directions. Currents are the result of various causes—such as temperature, winds, peculiar construction of coasts and inlets—but chiefly, as is believed, of the rotatory motion of the earth. The globe in its diurnal motion leaves, as it were, the fluid behind; and hence there is a perpetual flow of the sea from the western coasts of Europe and Africa towards the eastern *land-board*, as it is called, of America, and from the west of America to the eastern coast of Asia. This movement is chiefly confined to the tropics, unless where the sea is turned aside by the land, and caused to diverge towards the north or south. If we start in a survey of this motion from the western coast of America, we find it producing a constant current across the vast expanse of the Pacific, till it is turned off by Asia and Australia. A great division of its force is directed through the seas on both sides of the latter continent, and so on through the Indian Ocean, and round the Cape of Good Hope, till it reaches the free expanse of the Atlantic, across which it proceeds in the same manner as across the Pacific. The current of the Atlantic strikes the coast of Brazil, and breaks at Cape St Augustine into two divisions, one of which proceeds round Cape Horn into the Pacific, while the other advances through the Caribbean Sea, and so on into the Gulf of Mexico. This latter branch conspires, with the vast issue of fresh waters which pours into the Gulf of Mexico, to raise the level of that sea above that of the neighbouring ocean; and causing the surplus to force its way out between Florida and Cuba, produces the celebrated *Gulf Stream*, which is by far the most powerful marine current known.

Besides the grand equatorial or tropical current, there is one of a less decided character from the poles to the equator. The sea under the tropics evaporates to a greater extent than elsewhere, by the influence of a vertical sun. The vapours are apt to proceed towards the north and south, where they descend in rain. A surplus of water is thus produced in the high latitudes, which naturally flows back towards the equator. Hence a constant but comparatively slight flow from the north and south towards that warmer region of the earth. Under the influence of this stream, large masses of ice are constantly becoming detached from the polar stores, and drifted to the tropics. In some of the bays on the north side of Iceland this frigid substance comes in vast quantities, insomuch as to choke them up to the depth of 500 feet. What is still more strange, these masses of ice are sometimes mixed up with trees, some of which are known to be the produce of the torrid zone in America; this is accounted for by the action of the northern division of the great current which parts at Cape St Augustine. That northern division, after rushing into and out of the Gulf of Mexico, proceeds northward to Newfoundland, and thence at a high latitude returns athwart the Atlantic, finally sweeping along the western coasts of Europe, and rejoining the current which gave it its first impulse.

The operation of the tides is less observable in the great currents we have alluded to, than in those which prevail in the more secluded seas. The abstraction of water from a secluded sea by the recess of the tide, and the rush inwards produced by its flow, are sufficient of themselves to cause very impetuous currents, more particularly in the narrow channels by which the inland seas are connected with the ocean. We find it stated, in a pamphlet respecting the condition of the Orkney Islands, that the Pentland Firth, which separates the continent of Great Britain from Orkney, "has no fewer than four-and-twenty contrary currents of the tide at the flood of spring, besides numerous sets and eddies, which, under the local names of *wells*, *swelchies*, and *roosts*, boil more madly on the Orcadian shore than ever did witch's caldron on the kindred coast of Norway, if we may believe old tradition and Bishop Pontoppidan. 'The Boar of Papa,' at the opposite extreme of Orkney, is another terrible tide; when he gets a vessel in his tusks, he shakes the masts out—an operation which, in the country phrase, goes by the name of *hackling*." The contrariety of influences which are sometimes brought into play by polar and equatorial currents, and those produced by the tides, occasion many phenomena extremely perplexing, and sometimes very dangerous, to the navigator. In the Cattegat, by which the Baltic is connected with the German Ocean, one current always goes in by the side next Jutland, while another issues forth by that nearest to Sweden. In like manner, a current seems to proceed along the eastern coast of Britain towards the south; while another, flowing in an opposite direction, advances along the coast of Holland. What is still more curious, under-currents are sometimes found going in a contrary direction to those upon the surface. At the Straits of Gibraltar, it is said there is always a surface current setting in, as if to supply a want in the Mediterranean, while at a certain depth there is another flowing outwards to the Atlantic.

Two currents of equal force, but of different directions, meeting in a narrow passage or gut, will cause a *whirlpool*, a phenomenon which has ignorantly been said to be produced by subterranean rivers, gulfs, chasms, &c. but essentially is only an eddy, produced by the contact of two currents meeting on a centre. The whirlpool named the Euripides, near the coast of Greece, alternately absorbs and rejects the water seven times in twenty-four hours. Charybdis, in the Straits of Sicily, absorbs and rejects the water thrice in twenty-four hours: and the Maelstroem, on the coast of Norway, which is considerably the largest, absorbs, every six hours, water, ships, whales—in short, everything that approaches its malignant influence—and the next six hours is employed in casting them up again. These eddies are sometimes augmented by the force of contending tides, or by the action of the winds.

Being an elastic and mobile fluid, water is readily acted upon by winds; and thus *waves* are produced, varying in height and velocity according to the force and continuity of the wind, extent of uninterrupted surface, depth of the ocean, contending currents, and the like. "The common cause of waves," says Dr Arnott, "is the friction of the wind upon the surface of the water. Little ridges or elevations first appear, which, by continuance of the force, gradually increase, until they become the rolling mountains seen where the winds sweep over a great extent of water. In rounding the Cape of Good Hope, waves are met with, or rather a swell, so vast, that a few ridges and a few depressions occupy the extent of a mile. But these are not so dangerous to ships as a *shorter* sea, as it is termed, with more perpendicular waves. The slope in the former is so gentle, that the rising and falling are scarcely felt; while the latter, by the sudden tossing of the vessel, is often destructive. When a ship is sailing before the wind, and riding over the *long swell*, she advances as if by leaps; for while each wave passes, she is first descending headlong on its front, acquiring a velocity so wild, that she can scarcely be steered; and soon after, when the wave has glided under her, she is climbing on its back, and her motion is slackened almost to rest before the following wave arrives. The velocity of waves has relation to their magnitude. The large waves just spoken of proceed at the rate of from thirty to forty miles an hour. It is a vulgar belief that the water itself advances with the speed of the wave; but in fact the *form* only advances, while the *substance*, except a little spray above, remains rising and falling in the same place with the regularity of a pendulum. A wave of water, in this respect, is exactly imitated by the wave running along a stretched rope when one end is shaken; or by the mimic waves of our theatres, which are generally undulations of long pieces of carpet, moved by attendants. But when a wave reaches a shallow bank or beach, the water becomes really progressive; for then, as it cannot sink directly downwards, it falls over and forwards, seeking the level." Sailors and others speak of waves running "mountains high;" but it is questionable if, even in the dreaded Bay of Biscay, they ever attain an altitude of thirty feet, measuring from the trough of the sea to the crest of the succeeding wave.

LAKES AND RIVERS.

Lakes are inland bodies of water not connected with the ocean or any of its branches: they are generally fresh, but are occasionally brackish, or even decidedly salt. They are classified according as they are fresh or saline, and according to the manner in which they receive and discharge their waters—namely, those that both receive and discharge running water; those that receive waters, but have no visible outlet, as the Caspian Sea; those which receive no running water (being fed by springs), but have an outlet; and such as neither receive nor discharge running water. Lakes are distributed over the globe according to the inequalities of surface; and all tend to annihilation, partly by silting up their basins, and partly by deepening their outlets, thereby effecting an entire drainage of their waters. By far the most gigantic are those of North America—such as Superior, Huron, Michigan, Erie, and Ontario, which respectively occupy 35,000, 20,000, 10,000, 10,000, and 7200 square miles. Next in order are the lakes of Asia, of which the largest are Aral and Baikal; the surface of the former is estimated at 9930, and the latter at 7540 square miles. Of the African lakes we have no definite information; but Europe can boast of a vast number, which, though generally small, give beauty and diversity to her landscapes. Those of Ladoga and Onega, in Russia, are the largest; the former having a surface of 6330, and the latter of 3280 square miles. A comparative estimate of the extent of these vast sheets may be formed, when we mention that the area of lake Geneva does not exceed 340 square miles.

Lakes subserve important purposes in the economy of nature. They serve as reservoirs for the waters which rivers would too speedily carry away from the land; they are the tanks, as it were, in which the impurities of streams subside; they refresh, irrigate, and enliven the landscape; and as they all tend to silt up their own sites, these sites become in time tracts of the most fertile alluvium, and such has been the origin of some of our finest plains. They are also the scenes of extensive and varied vital operations. The plants which spring from their bottoms, or flourish by their margins, differ widely from true terrestrial and maritime vegetation; and the animals which people their waters exhibit structural peculiarities not less distinct and characteristic.

Rivers, streams, springs—whether flowing with a volume several miles in breadth, or trickling in a tiny rill which a child's hand might obstruct—constitute a class of the most valuable agencies in the physical history of our globe. They are the irrigators of its surface, adding alike to the beauty of the landscape and the fertility of the soil; they carry off impurities and every sort of waste debris, to be deposited in the ocean as the strata of future continents; and when of sufficient volume, they form the most available of all channels of communication with the interior of continents. Man has ever located himself by their banks—using their waters for his domestic purposes, making their bosoms the highway of his commerce, and applying the force of their currents to the abridgment of his toil. They have ever been things of vitality and beauty to the poet, silent monitors to the moralist, and agents of comfort and civilisation to all mankind. The manner of their origin is this:—The sun's heat, acting upon the ocean and other exposed surfaces of water, converts that element into vapour; this vapour, invisible, and of less specific gravity than the atmosphere, ascends, and forms clouds, mists, &c.; and when condensed by cold or electric agency, as described under METEOROLOGY, falls by its specific gravity to the surface in the form of dew, rain, hail, and snow. Falling on the surface indiscriminately, these percolate the soil, find their way through the rents, fissures, and pores of the rocky strata, and ultimately escape at some lower level in the form of *springs*. Some of these springs are perennial, others temporary or intermittent; some are limpid, and almost absolutely pure; others are impregnated with metallic, earthy, and saline ingredients, according to the nature of the strata through which they have percolated: some are cold, others tepid; while many issue, with bubbling and steam, near the ordinary boiling point of water. Springs, naturally tending to lower levels, unite, and form *streams;* and these again falling still lower, conjoin in valleys, and form *rivers*—creating in their course rapids, cataracts, and waterfalls, ravines and dells, lakes, swamps, and marshes, alluvial plains, and low terminating deltas. The valley in which a river flows is usually termed its *basin;* and its *drainage* is that portion of country drained by its streams or tributaries. It is the custom of geographers to compare rivers by their lengths; but this does not always convey a correct idea either of their physical or economical importance; for some main trunks, of limited length, may drain a vast extent of country, and others of great length may offer few or no facilities for commercial transport. The following is an approximation to the proportional length, area of basin, and quantity of water discharged per annum by some of the principal rivers, reckoning the Thames as 1:—

	Rivers.	Length.	Basin.	Discharge.
EUROPE.	Thames,	1	1	1
	Rhine,	4½	12½	13
	Loire,	4	8½	10
	Elbe,	4½	9	8
	Vistula,	4½	13½	12
	Danube,	9¾	86	65
	Dnieper,	7¼	36	36
	Don,	7½	37	37
	Wolga,	14	94	89
ASIA.	Euphrates,	9¼	42	66
	Indus,	11½	72½	123
	Ganges,	10	70	148
	Yang-tse-Kiang,	15½	138	226
	Amour,	16	164	162
	Obi,	15	236	170
AFRICA.	Nile,	18¾	90	250
AMERICA.	St Lawrence,	22½	109	112
	Mississippi,	19	249	338
	La Plata,	13½	225	490
	Amazon,	22½	365	1210

CLIMATOLOGY.

The climatology of the globe relates to the degree of heat and cold to which its respective countries are subject, the dryness and moisture of the air, and its salubrity or insalubrity as influenced by these and other causes. As yet the minutiæ of climate are but imperfectly determined; the following general causes, however, have been sufficiently ascertained:—1. The action of the sun upon the atmosphere; 2. The internal heat of the globe; 3. The height of the place above the sea; 4. The general exposure of the region; 5. The direction of its mountains relatively to the cardinal points; 6. The neighbourhood of the sea, and its relative position; 7. The geological character of the soil; 8. The degree of cultivation which it has received, and the density of the population collected upon it; and 9. The prevalent winds. These causes, acting together or separately, determine the character of a climate as moist and warm, moist and cold, dry and warm, dry and cold, &c.; and this climateric character is the main influence which determines the nature and amount of vegetable and animal development.

The torrid zone has two seasons—the wet and the dry. The latter is considered as the summer, and the former as the winter of the regions within this zone; but they are in direct opposition to the astronomical seasons, as the rains follow the sun. In some districts there are two rainy and two dry seasons every year. In the temperate zones, the year is divided into the four seasons whose changes are so agreeable and salubrious. This regular succession of the annual changes, however, can hardly be considered as extending farther than from 35 to 60 degrees of latitude. In the frigid zones two seasons only are known—a long and severe winter, and a short but fervid summer. This abrupt and harsh transition is occasioned by the great length of the day in summer, when the sun never sets, and by the total absence of that luminary in winter. The decrease of heat as we recede from the equator is greater in the southern than in the northern hemisphere. According to Humboldt, continents and large islands are warmer on their western than on their eastern sides. The extremes of temperature are more felt in large inland tracts than in islands and situations near the coast. The sea absorbs and radiates heat more slowly than the land; and thus, after the land has given out its last particle of caloric, the ocean is radiating its tempering influences. For these reasons, climatologists have found it necessary to construct *isothermal lines* round the globe; that is, lines along which the annual mean temperature is the same. Again, places which have the same mean annual temperature vary considerably in their mean summer and winter temperature; hence *isocheimal* lines, or lines of equal winter temperature, and *isotheral* lines, or those which show equal summer over points upon different isothermal curves. Another set of lines or curves, called *isogeothermal*, connect points where the temperature of the soil is equal at or beneath the surface.

Since the temperature of the atmosphere diminishes with the altitude, a limit must be reached where water will remain in perpetual congelation, independent of all seasonal influences. This limit is called the *snow-line*, and is found at various heights, according to latitude, proximity to the sea, and other causes, which affect the general climate of the region. In the Himaleh and Andes, it is found at an elevation of about 17,000 feet; in the Swiss Alps, at 8500 feet; and in the Scandinavian range, at 3500 feet. Generally, in those countries which are near the equator, the snow-line is found about 16,000 feet, or three miles, above the sea-level: about the 45th parallel in either hemisphere, it occurs at an elevation of 9000 feet; under 60 degrees of latitude, at 5000 feet or thereby; under 70 degrees latitude, at 1000 feet; and under 80 degrees, the snow-line comes down to the mean sea-level, for countries which are 10 degrees distant from the poles are covered with snow all the year round. From snow and glacier-clad mountains cold breezes rush down to cool the adjacent plains; and similar winds blow from the arctic to the tropical regions. Indeed, wherever the air of one region becomes heated or rarefied, the colder and heavier air of the surrounding regions will rush in to restore the balance. Such is the cause of all aërial currents, and in particular of those blowing within the 25th degree of latitude on either side the equator, known as the *trade-winds*. *Monsoons* are merely the trade-winds diverted north or south by the land that lies within these parallels. The *simoom*, *harmattan*, *sirocco*, and other local winds, *sea and land breezes*, and in fact every species of aërial current, may be traced to similar causes.—See METEOROLOGY.

The amount of rain which falls on the earth's surface is exceedingly varied, ranging from twenty or thirty inches to several feet per annum; but the moisture of a climate does not wholly depend upon the amount of rain registered by a rain-gauge; for some climates are humid, and yet not rainy; others dry, and yet subject to periodical torrents. These torrents give rise to inundations; hence the peculiar seasonal floodings of such rivers as the Nile and Ganges.

DISTRIBUTION OF PLANTS AND ANIMALS.

The *life* of the globe—that is, its vegetable and animal productions—constitutes its most important and exalted feature as a creation. All the varied materials of which it is composed, all the complicated actions, reactions, and mutations to which they are subject, are humble phenomena compared with the production of the lowliest organism. This life is everywhere: the waters teem with it, the dry land from pole to pole is clad with it; nay, there is life within life, and perhaps there exists not a single plant or animal but becomes in turn an abode for others of more diminutive dimensions. Speculations as to the origin and generic classification of vegetable and animal life belong not to our subject. Geography views them simply as they exist, and endeavours to determine the laws which regulate their distribution.

Vegetables—of which about 100,000 species have been described—are regulated in their terrestrial distribution by conditions of soil, heat, moisture, light, height of situation, and various other causes; *in the waters* by depth, heat, light, nature of bottom, and the presence of mineral and saline ingredients. Were it not for these causes, there is no reason why the tribes and genera of one region should not be identical with those of another—why the palms of India should not flourish alongside the oaks of England, the oaks of England with the pines of Norway, or these again with the dwarf birches of the arctic regions. As it is, the tropics have genera unknown to the temperate zone, and every advance poleward brings us in contact with new and peculiar species. Temperature in this case seems to be the grand regulating condition; and as this is effected by elevation, as well as by increase of latitude, we find the mountain ranges near the equator presenting all the features of a tropical, temperate, and even arctic vegetation. Thus, palms and plantains may luxuriate at their bases; then appear oranges and limes; next succeed fields of maize and wheat; and still higher commences the series of plants peculiar to temperate regions. In temperate latitudes, though the variety of vegetation be less, similar phenomena present themselves. "We may begin the ascent of the Alps, for instance, in the midst of warm vineyards, and pass through a succession of oaks, sweet chestnuts, and beeches, till we gain the elevation of the more hardy pines and stunted birches, and tread on pastures fringed by borders of perpetual snow. At the elevation of 1950 feet the vine disappears; and at 1000 feet higher the sweet chestnuts cease to thrive; 1000 feet further, and the oak is unable to maintain itself; the birch ceases to grow at an elevation of 4680, and the spruce fir at the height of 5900 feet, beyond which no tree appears. The rhododendron ferrugineum then covers immense tracts to the height of 7800 feet, and the herbaceous willow creeps two or three hundred feet higher, accompanied by a few saxifrages, gentians, and grasses, while lichens and mosses struggle up to the imperishable barrier of eternal snow." Besides these great climatic effects, there are others depending on soil, moisture, light, &c. which, though limited, are not less imperative. Thus the southern slope of a hill is generally clothed with species distinct from those on the north; a limestone district presents a carpet of vegetation widely different from that of the clayey moorland: some tribes flourish in the moist valley, which would die on the open plain; some tribes thrive in the marsh, others on the dry upland; some luxuriate under the influence of the sea spray, which would be instant destruction to others. But whilst most species are subject to these laws, there exists in the constitution of many a certain degree of elasticity which admits of their adaptation to a wider range—a beneficent arrangement, which permits man to extend through cultivation those grains and fruits upon which his subsistence so essentially depends. [For further and more minute information respecting the laws which regulate the dispersion and distribution of plants, see VEGETABLE PHYSIOLOGY.]

The animals which people the globe are subjected to somewhat similar laws of distribution. Some are strictly tropical, others confined to the temperate zone; while not a few are destined to find their subsistence wholly within the polar circles. Besides this general distribution, we find a more particular restriction to certain continents and tracts where peculiarities of soil, climate, and food, seem to be the governing conditions. Thus, the elephant roams only in India, Birmah, and Africa; the ostrich in Africa; the rhea in the pampas of South America: the kangaroo in New Holland; the reindeer within the arctic circle; the polar bear amid the snows of Greenland and Labrador; and so on, as will be more minutely shown under ZOOLOGY. Similar laws are impressed on the life of the ocean. The whale of the Greenland seas is not the same with the whale of the Pacific; the herring finds its chosen habitat in the Northern Sea; the oyster clings to a peculiar bottom, at a certain depth; the cod inhabits the same banks and shoals for ages; and a few fathoms of greater or less depth would be more fatal to many species of shell-fish than the dredge of the fisherman. As on plants, so on animals altitude exerts a very decided influence; and we do not exaggerate when we affirm that a lofty mountain range presents a more impassable barrier to vital distribution than the widest expanse of ocean. Though presenting a close analogy in the manner of their distribution, plants and animals differ in this respect, that many tribes of the latter—birds, fishes, and mammalia—make periodical migrations of vast extent; food and proper breeding-places being the objects of their search. These migrations must not be confounded with that adaptability of constitution which fits the horse, the dog, the ox, the sheep, the pig, and other domestic animals, to be the companions and supports of man in his onward possession of the globe. The one is but a change of place in search of food, under a congenial temperature; the other amounts to a constitutional change, irrespective of climateric influence.

Man, of all animals, has the widest geographical distribution. This he enjoys not only from the greater adaptability of his constitution, but from that superior intelligence which enables him to counteract the effects of climate by clothing, houses, fire, and the storing of provisions. It may be justly affirmed, therefore, that there is no region where man may not exist and carry on the purposes of life, in a higher or lower degree of civilisation. Though generally regarded as a single species of a single genus, naturalists have divided mankind into several varieties, according to their more prominent physical features; and ethnologists, extending the subject according to minor features, language, and so forth, have subdivided these varieties into branches, types, tribes, and families. That the external conditions to which man, like all other animals, is subjected, may in the course of ages have stamped the inhabitants of certain regions with certain physical characteristics, is nothing more than what may be expected; but that every little difference of dialect, every tint of skin or colour of hair, every mould of nose or contour of skull, is warrant sufficient for a new subdivision, is an absurdity not to be tolerated. At present, *five* great divisions are admitted by ethnologists, and these we shall merely enumerate—premising that the branches, types, tribes, and families into which mankind have split in their dispersion over the globe, the causes and modes of that dispersion, and other kindred particulars, will be fully treated in a separate sheet, devoted to the PHYSICAL HISTORY OF MAN:—1. The *Caucasian* variety, inhabiting Turkey, Arabia, Persia, part of Tartary, Affghanistan, and Hindoostan in *Asia*; Egypt and Abyssinia in *Africa*; and the whole of Europe. 2. The *Mongolian* variety, spread over the north and central parts of Asia, China, Japan, Birmah, Annam, Siam, Cochin-China, and, according to some ethnologists, comprising the Esquimaux both of the Asiatic and American continents. 3. The *American* variety, comprising all the aboriginal races which peopled the new world before its discovery by Columbus. 4. The *Ethiopian* race, inhabiting the whole of Africa, with the exception of Egypt, Abyssinia, and the northern coasts. And 5. The *Malay* race, which is made to include the inhabitants of the Malaysia, Polynesia, and Australasia.

Such are the recognised *varieties* of the human race; and here it may be remarked, that in whatever stage of civilisation they now appear, the time seems to be approaching when some of them will altogether vanish, their place being occupied by the higher and more intelligent—a result quite in consonance with the whole scheme of creation, whether in its physical or social progress.

VEGETABLE PHYSIOLOGY.

Every one is acquainted with the common forms of vegetation—herbs, shrubs, trees—for they exist in all situations suitable to their growth, and constitute not only a highly ornamental covering to the surface of the earth, but, as is well-known, afford an inexhaustible supply of nourishment to the animal races. The science which embraces the study and investigation of the vegetable kingdom is known by the name of Botany, from the Greek word *Botané*, a plant. That department of the subject which explains the organisation and vital functions of plants we call *Vegetable Physiology*, and that which recognises their arrangement into orders, tribes, genera, and species, according to their respective forms and qualities, *Systematic Botany*. The one relates to functions which are common to all vegetables, the other takes notice only of such peculiarities and attributes as serve to distinguish one individual from another, or one family from another family. It is to the former of these departments that we now direct the attention of the reader.

GENERAL ECONOMY OF VEGETATION.

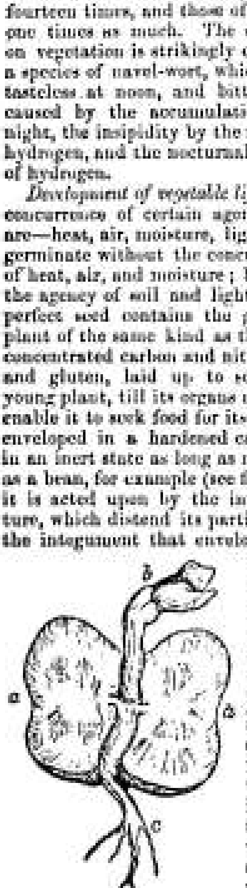
Nature and functions of plants.—Minerals, plants, and animals are all formed by the chemical combination of certain elements. In minerals these elements combine by the force of chemical affinity only, but in plants and animals they are held in combination by vital action. Of the nature of life, or the vital principle, science does not attempt to explain the cause, but restricts itself to a mere exposition of its phenomena. Vitality enables plants and animals to absorb and assimilate food, consisting of the elements necessary for their increase, and also to reproduce beings of their own kind, by means of certain organs: hence they are said to be *organised*, and the substances of which they are composed are known by the general name of *organic matter*. Minerals not possessing vitality have no organs, and consist only of *inorganic matter*. Animals feed partly on other animals, and partly on plants; and plants feed partly on organic matter when decomposed, and partly on inorganic. Thus mineral substances, by the beautiful economy of nature, contribute towards the support of animals through the medium of vegetation.

The simplest forms of life are observable in certain plants and animals, whose economy is limited to the absorption and assimilation of nutriment, and the power of reproduction; and the difference between these inferior plants and animals is so trifling, that in them the animal and vegetable kingdoms seem to pass into each other. Thus, certain tribes of zoophytes, and some kinds of algæ, or sea-weed, are so very nearly allied both in appearance and habits, that they can scarcely be distinguished from each other scientifically; and, indeed, the same object has been occasionally classed as a plant by one naturalist, and as an animal by another. The scientific differences between plants and animals are indeed difficult to define, when they are to be applied to all plants and to all animals. Few plants possess the power of locomotion; but the aquatic plant called the Fresh-water Sailor detaches itself from the mud in which it grows originally, and rises to the surface of the water to expand its flowers. Plants are propagated by division, which most animals are not; but the polypes of the coral-reef grow united like the buds of a plant clustering round a common stem from which they receive their nutriment, and, when separated, become each perfect individuals. Plants are said to have no stomach; but the lobe-like leaves of Venus's fly-trap possess the power of digesting the flies they catch; and though plants are said to be without feeling, the leaves of the sensitive plant shrink from the slightest touch. In like manner the pith of young trees and shrubs has been compared to the spinal marrow of animals; the upward current of the sap in spring, and its descent in summer or autumn, to the circulation of the blood; and the exhalation of oxygen, and absorption of carbonic acid gas in the leaves, to respiration; but beyond a faint analogy, there is nothing like identity between the respective functions of plants and animals. Indeed, all the vital functions of plants are performed in a manner different from those of animals; the instances of locomotion, sensitiveness, and power of digestion in the former being very rare and imperfect, while the power of propagating by division in the latter is equally so. On the whole, the two lines or systems of life seem to start, as it were, from a common point at the base, the inferior forms bearing a certain similarity in structure and functions, which gradually disappears as we ascend in the scale of development.

Plants derive their food partly from the soil and partly from the air; and whatever they take must either be reduced to a liquid, or to a gaseous state. The elements of which plants are composed are—carbon, oxygen, hydrogen, and nitrogen. Of these, carbon, which is a solid substance, is the principal; and as it is insoluble in water, it must be combined with oxygen, so as to form *carbonic acid gas*, before it can be taken up by plants. Oxygen is the next in abundance, and it is absorbed principally when combined with nitrogen, in the form of atmospheric air. Hydrogen is not found in a free state in the atmosphere, and therefore it can only be taken up by plants when combined with oxygen, in the form of water, or with nitrogen, as ammonia, in which last form it exists in animal manure. Nitrogen, though found in very small quantities in plants, is an important element, as it constitutes the principal ingredient in the *gluten*, which is the most nutritive part of corn and other seeds, and which is essential to the germination and nourishment of young seedling plants. Nitrogen also appears to be a principal agent in the production of colour in leaves and flowers, especially when they first expand. As oxygen is imbibed by plants in combination with all the other elements of which they are composed, it is not surprising that the plant takes up more of this gas than it requires; and consequently, it has been furnished with a remarkable apparatus in the leaves, to enable it to decompose the carbonic acid and other gases which it has absorbed, and to part with the superfluous oxygen. Plants are thus found to improve the air by the removal of carbonic acid, which is injurious to animal life, and by the restoration of oxygen, which is favourable to it; and so to maintain a necessary equilibrium in the atmosphere, as animals are continually absorbing oxygen, and giving out carbonic acid. In hot swampy countries, however, where vegetation is extremely rapid, and the soil surcharged with decaying vegetable matter, plants absorb more carbonic acid than they want, and give out the superfluity through their leaves; hence warm moist climates, such as those of some of the West India islands, though extremely favourable to vegetation, are highly injurious to human life.

Light being essential to the decomposition of carbonic acid gas in the leaves, oxygen is not exhaled by plants during the night; but, on the contrary, a small quantity of carbonic acid gas escapes, and oxygen is absorbed. These processes have been called the respiration of plants; but they are very different from the respiration of animals, the first being mechanical, and the second chemical, and both totally unconnected with the assimilation of food. When the soil abounds in carbonic acid gas and in moisture, the roots of a plant must continue constantly absorbing that moisture mixed with the carbonic acid; and this carbonic acid rising to the leaves, escapes in its original state when there is no light to decompose it. The absorption of oxygen is a chemical process, which appears to go on whenever the process of assimilation has ceased—in dead plants as well as in living ones. When leaves have ceased to act in decomposing carbonic acid, and assimilating or fixing the carbon in autumn, oxygen is absorbed so rapidly as to change their colour to some shade of red; fruit, when fully swelled, ceases to assimilate carbon, and becomes intensely acid by the absorption of oxygen; and, finally, the decay of all vegetable texture is hastened by the absorption of the same element. Thus, as the assimilation of carbon ceases during the night, oxygen is absorbed at that period in quantities that vary according to the nature of the plant; those plants which have acid, or highly-flavoured juices, absorbing most. Baron Liebig tells us that the tasteless leaves of the American aloe, if kept in the dark twenty-four hours, absorb only 0·3 of their volume of oxygen in that time; while the leaves of the spruce fir, which contain volatile and resinous oils, absorb ten times, those of the common oak, which abound in tannin, fourteen times, and those of the balsam poplar, twenty-one times as much. The chemical action of oxygen on vegetation is strikingly exemplified in the leaves of a species of navel-wort, which are acid in the morning, tasteless at noon, and bitter at night. The acid is caused by the accumulation of oxygen during the night, the insipidity by the mixture of the oxygen with hydrogen, and the nocturnal bitter flavour by an excess of hydrogen.

Development of vegetable life.—This depends upon the concurrence of certain agents, the principal of which are—heat, air, moisture, light, and soil. No seed can germinate without the concurrence of the three agents of heat, air, and moisture; but in the *growth* of plants, the agency of soil and light is also necessary. Every perfect seed contains the germ or embryo of a new plant of the same kind as the parent, and a portion of concentrated carbon and nitrogen, in the form of starch and gluten, laid up to serve as nutriment for the young plant, till its organs are sufficiently developed to enable it to seek food for itself. The seed is generally enveloped in a hardened case, in order to preserve it in an inert state as long as may be necessary. As soon as a bean, for example (see fig.), is put into the ground, it is acted upon by the influence of heat and moisture, which distend its particles, and make them burst the integument that envelopes them. The agency of the air is next required to combine with the store of nutriment laid up in the seed (*a a*), and to fit it for the purposes of vegetation. The first organ which expands in the embryo of a young plant is the root *c*; and nature has provided a small opening in the covering of a seed, towards which the point of the root is always turned, in order that it may be protruded without injuring its soft and delicate texture. The root takes up water and air, and transmits the liquid thus formed to the seed-leaves *b*, in which it is exposed to the influence of light. The nutritive substances laid up in the seed become quite changed during the process of germination. The starch, which is insoluble in water, is rendered soluble by the action of a peculiar substance called *diastase*, derived from the gluten. This substance has so powerful an effect upon the starch, as to render it instantly soluble in the sap, and thus the nutriment is gradually prepared for the use of the infant plant. As the sap ascends, it becomes sweet; the starch is changed into sugar, and this sugar, again, into woody fibre as the tip of the plant emerges into light. When the store of starch and gluten has been exhausted, the plant is able to live by its own assimilating powers, at the expense of the air and the soil.



Heat, though essential to germination, is injurious, unless it be combined with moisture. A high degree of dry heat will parch seeds, and destroy their vitality; hence, when they are to be kept for food, it is not unusual to dry them in an oven, to prevent them from germinating. When combined with moisture, a very high temperature is not injurious to vegetation; and, indeed, some kinds of moss have been found growing near hot springs in Cochin China, where they must have vegetated in a heat equal to 166 degrees; on the other hand, in cold climates, mosses, some kinds of grass, and chickweed, are found to vegetate at 35 degrees, or even only just above the freezing point. Warmth is not only necessary for the germination of the seed, but also for the growth and after-development of the plant. The sap will not rise without a certain degree of heat; and it is well known that frost stops its current. Cold will also check the development of the flowers and fruit, and even of the leaves, and will prevent the full flavour being attained by the fruit. The secretions of plants are diminished by cold. The fruit of the walnut and the beech produce oil in the south of Europe, which it will not do in Britain; and the leaves of the mulberry grown in this country will not afford the same quantity of caoutchouc to the silkworm as in France and Italy.

Moisture must be combined with heat and air to render it useful to vegetation. An excess of moisture without heat, and combined with air, induces decay in seeds, instead of exciting them to germinate; and an excess of moisture is injurious even to growing plants, as it destroys the delicate tissue of the spongioles of their roots. When trees are grown in situations where they have abundance of heat and moisture, but where the roots are beyond the reach of air, they have a tendency to produce leaves instead of fruit and seeds, and all their secretions are weakened. On the other hand, too little moisture prevents the leaves and fruit from attaining their proper size and form.

Air is essential both to the germination of the seed and the development of the plant. Without oxygen from the atmosphere, the carbon laid up in the seed cannot be made available for the use of the infant plant, as carbon in its concentrated state is insoluble in water, and requires to be combined with oxygen to convert it into carbonic acid gas, before it can be absorbed by the vessels. In like manner, air is essential through all the processes of vegetation; no wood can be formed, no seed ripened, and no secretions produced, without abundance of carbon; and this cannot enter the plant, even from the soil, without a constant supply of oxygen from the air. The greater part of the carbon in plants is indeed derived directly from the air by the leaves, in the shape of carbonic acid gas—a minute quantity of which is always found in combination with the atmosphere.

Light is not required for the germination of seeds, but it is essential to the development of plants, as it occasions the decomposition of the carbonic acid contained in the vessels of all the parts exposed to its influence; without which the plant could not assimilate the carbon to its own use. Colour also appears to depend partly on light. Plants grown in darkness are most deficient in colours which contain blue. The leaves and other parts, which should be green, are frequently reddish, from the retention of oxygen, or yellowish, from the superabundance of nitrogen, while the flowers and fruit are whitish. Frequently, the whole plant appears whitish, and of a sickly aspect, in which case it is said to be *etiolated*, or blanched.

The soil serves not only as a bed for plants to grow in, but also contributes to their nourishment. In addition to the elements of which they are principally composed, there is always found in their substance a small quantity of inorganic matter, which differs according to the nature of the plant, and which appears to be derived solely from the soil. The proportion which this matter bears to the whole will be found by burning part of the plant in the open air; when the inorganic matter, being indestructible by fire, will be left in the form of ashes. Soils are of various kinds, and they are produced principally by pulverised particles of rocks, being disengaged by the action of heat, air, and water, and mixed with decaying animal and vegetable substances. There are four primitive earths, called *clay*, *sand*, *lime*, and *magnesia*; the first three of which are found more or less in almost every soil, and generally with only a very small proportion of the latter. Clay, which is also called *alumina*, or *argillaceous earth*, or *earth of alum*, predominates in some soils, and these are generally unfertile, as the particles of clay are too adhesive to allow the free passage of either air or water to the roots of plants. A soil of this kind also offers obstacles to the expansion of fibrous roots; and when it admits water, it retains it so long as to be injurious. Sand, which is also called *silex*, *silica*, or *siliceous earth*, consists, on the other hand, of particles which have generally too little adhesion to each other; and it is injurious to plants, partly from its incapability of retaining sufficient water for their nourishment, and partly because it admits too much solar heat to their roots. Lime is never found in a pure state in nature, but always combined with some acid. The common carbonate of lime, or limestone, is of no use in vegetation till it has been burned—that is, till the carbonic acid, water, and other matters it may contain, have been driven off by heat. In this state it is called caustic lime, and is used as a manure, as it has a great affinity for carbonic acid, which it is continually drawing into the soil from the atmosphere or other sources. Chalk, or the earthy carbonate of lime, is well adapted for vegetation, but it is generally cold, as, from its whiteness, it reflects the solar rays instead of absorbing them. Magnesia is very similar to lime, but is less abundant. It generally occurs in combination with lime, in what is called magnesian limestone. Notwithstanding the whiteness of chalk, calcareous soils—that is, soils containing some form of lime—are generally black, from the quantity of vegetable matter which they contain in proportion to the depth of the soil. All soils containing a great proportion of decayed vegetable matter are black; and black soils, though generally warm, from the power they possess of absorbing solar heat, are seldom productive, unless they be dry. Thus, black peat, or bog earth, which is moist, is unproductive; while heath mould, mixed with sand, which is dry, is very useful for many kinds of crops. The reason is, that decayed vegetable matter, or *humus*, is insoluble in water, and consequently cannot be taken up by plants until the carbon it contains is combined with oxygen, so as to form carbonic acid gas, which can only be done when the humus is kept sufficiently dry to allow of its particles being exposed to the free action of the atmosphere.

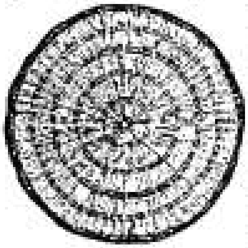
It must be observed, that no soil consists of any one of the primitive earths alone, and that most soils contain all of them combined in different proportions, and mixed with other ingredients. These are saline particles of various kinds, potash, soda, and other alkalies, iron, and several other minerals, in combination with the different acids—all of which are designated, when speaking of the food of plants, by the general name of *inorganic matter*. Plants require different kinds of inorganic matter, according to their nature, and appear to possess the power of selection, as they only take the kind they need, though it may form but a very small portion of the soil in which they grow. Thus, it is evident that any particular crop must in time exhaust the soil in which it grows of the requisite inorganic matters, unless they should be renewed by the addition of what are called mineral manures (see AGRICULTURE); and it is also clear that crops requiring another kind of earth may succeed in the same soil, after it has become unproductive for the first kind of crop. This, according to modern doctrines, explains the necessity which is known to exist for what is called *the rotation of crops*—that is, for letting crops of a different nature succeed each other in fields and gardens. The necessity for this rotation was supposed by Decandolle and others to arise from plants' poisoning the soil with the excrementitious matter which they were supposed to eject by their roots; but while this hypothesis was believed, it appeared difficult to account for the well-known fact, that the same crops may be grown perfectly well in any soil for an indefinite number of years, provided that soil be frequently and properly manured; that is, supplied afresh with the ingredients of which it has been exhausted by the plants. As to the matter which is discharged from the roots, it is generally of the same nature as the peculiar secretions of the plant—as, for example, the matter exuded by the roots of the poppy has the properties of opium—and can exercise no deleterious effect upon its growth in the manner Decandolle supposed.

Nature, when unassisted, invariably makes an effort to change the crops of plants. When a forest in North America is burnt down by accidental fires in the summer season, trees of quite a different kind spring up from long concealed seeds in place of those which have been destroyed. When, in ordinary circumstances, one kind of plant has exhausted the soil in its neighbourhood, it pushes its roots to as great a distance as possible in quest of food, and there sends up shoots, while a new race of plants grows upon the spot which it has vacated. In these, as in a thousand other circumstances, we find that one of nature's great primary laws is that of perpetual change—an alteration from one condition and appearance to another, in endless succession and variety. In the artificial cropping of the ground, the farmer, for his own sake, is impelled to take a lesson from nature, and to study what species of plants he can most advantageously produce in succession from his fields. (See AGRICULTURE.)

Term of vegetable existence.—The longevity of plants differs according to their nature and the circumstances in which they are placed. Thus, herbaceous plants, the stems of which are succulent and full of juice, are either *annuals*, that grow only one season, and die as soon as they have ripened their seed; *biennials*, which generally last for two years; or *perennials*, which last for several years. Trees and shrubs, which have ligneous or woody stems, are destined to remain undecayed for years. Shrubs are those ligneous plants which have several stems springing from the same root, all nearly of the same thickness. They seldom last above thirty or forty years, and frequently not half that time; but trees which have only one stem or trunk proceeding from the root to a considerable height before it divides into branches, generally endure for a long period of time—in several instances even for centuries. The length of time which trees live depends in a great measure on the situations in which they grow. If a tree which is a native of mountains be placed in a valley, it grows more rapidly, but the term of its existence is shortened, and its timber becomes softer and of less value. In like manner, if the tree of a valley be grown on a mountain, the term of its existence is lengthened, and its trunk, though of slow growth and small dimensions, produces timber remarkable for its toughness and durability; as, for example, the Highland oak.

The age of trees was formerly calculated by their diameter, or by the number of concentric circles or layers in the trunk; but both these modes are now found to be fallacious. According to the first, it was supposed that if a tree attained the diameter of a foot in fifty years, fifty years should be counted for every foot it measured in diameter; and thus it was supposed that the great baobab tree, found by Adanson on the banks of the Senegal, which measured nearly thirty feet in diameter, must have been about six thousand years old, or coeval with the world itself

It is now found, however, that the baobab, like all soft-wooded trees, grows rapidly, and attains an enormous diameter in less than a hundred years. The mode of counting by concentric circles only applies to exogenous trees, and even with them is very uncertain. A warm spring, which sets the sap early in motion, followed by weather cold enough to check vegetation, will give the appearance of two layers in one year, as the recommencement of vegetation will have the same appearance as a new layer in spring. In many trees, such as the oak, for example, a second growth often takes place after midsummer; so that even a third layer is occasionally formed in the course of six months. On the other hand, a moist warm winter, by keeping the tree growing the whole year without any check to vegetation, will give the appearance of only one layer to the growth of two years. Notwithstanding these anomalies, practical men find counting the concentric circles of a tree the best mode which has yet been discovered of ascertaining its age, as in ordinary cases only one growth is made in the course of a year. The accompanying figure represents a section of a stem five years old, having the pith in the centre, a cylindrical layer for every year of the growth, and the bark on the outside.



The natural decay and death of plants appear to follow the same laws as the natural decay and death of animals. When a tree approaches the term of its existence, the sap flows more feebly through its vessels, and it is no longer propelled through every part. As this takes place, the parts no longer visited by the sap die; and as soon as life has fled, the opposite principle of chemical affinity begins to act, and the various elements that composed the plant fly off, to combine with other elements, so as to form new substances. This is the natural process which takes place invariably with every organised being; the fall of the leaf, and the dropping of the ripe fruit, are but the death of both when fully matured; and in the like manner death is followed in both instances by its natural attendant—decomposition.

DISTRIBUTION OF PLANTS.

The geographical arrangement of the vegetable world is influenced by conditions of soil, heat, moisture, light, altitude of situation, and various other causes; for, did they flourish independently of those conditions, then there were no reason why the vegetation of one part of the globe should differ from that of another. We know, however, that the flowers, shrubs, and trees which adorn the plains of India are not the same with those which clothe the valleys of Britain; and that these, again, are totally different from the scanty vegetation of Iceland or Spitzbergen. Each order is, nevertheless, perfectly adapted to the conditions under which it exists, and finds in its *habitat*, or native situation, all the elements which administer to its growth and perfection. Obvious, however, as are the effects of these external conditions, the mode in which they operate is but imperfectly known. The same elements enter into the composition of the vegetation of the tropics as those which form the vegetation of temperate regions; the same organs, tissues, modes of growth, and inflorescence, are observable; and yet, without the conditions above enumerated, a plant which has been transferred from the one region to the other will speedily languish and die. Even one which flourishes under the influence of the sea-breeze, if removed far inland, will perish; and no art can retain in healthy perfection a native of the mountain which has been transplanted to the warm and humid valley.

Certain plants, like animals, may, however, be acclimatised; that is, may be made to grow and propagate their kind in a region in which they do not naturally occur. Many of our cultivated and most useful plants are of this kind; as, for example, the potato. This plant, which is a native of tropical America, flourishes luxuriously, and is of the highest utility, in northern Europe; but this it does by a special adaptation. In South America, the warm climate enables it to propagate by the seed; hence in that region its tubers are small and insignificant; but in Europe, where the climate is unfavourable to the production of the plant from seed, it propagates by the tubers, which are consequently enlarged, so as to contain a store of nutriment for the young plant, before its stem and leaves be sufficiently developed. The acclimatising of plants does not permanently change their character, for, in being restored to their native habitats, they assume their original forms and qualities.

The habitats of plants—that is, the situations in which they naturally thrive best—are generally distinguished as follow:—*Marine* when the plants float upon, or are immersed in, salt-water, such as sea-weeds; and *maritime* when they grow by the sea-shore, or in places exposed to the influence of the sea-breeze. *Aquatic* is the general term for fresh-water habitats; and these may be either *lacustrine* when growing in lakes, *fluviatile* when in rivers, or *palustrine* when in marshes or wet meadow-lands. Plants growing in open pastures are said to be *pratensise*, in cultivated lands *arvensise*, in woods *sylvan*, in mountainous parts *alpine*, and in caves, mines, and other underground excavations, *subterranean*. The station of a plant is said to be *epiphyte* when it grows upon others, living or dead, without deriving from them the elements of nutrition; and *parasitic* when it adheres to their surface, and directly extracts its nourishment. The range of habitat is that extent of the earth's surface over which a plant is distributed by nature. The terms maritime and alpine, for example, are general in their application, and refer to all plants which grow by the sea-side or on mountains; but the plants which flourish on the sea-shores of Great Britain are not the same with those on the coast of Africa; nor are these, again, allied to the maritime vegetation of Chili. The geographical range of any plant conveys a more specific idea, and embraces only that particular spot in which the plant rejoices. This range is circumscribed by conditions of temperature, light, and elevation above the sea, and does not, as might be supposed, depend very closely upon belts of longitude, by which temperature is generally indicated. Thus, nearly all the beautiful pelargoniums and mesembryanthemums which adorn our greenhouses, are natives of a limited space near the Cape of Good Hope, as are also many of our most beautiful bulbs. The curious stapelias, that smell so much like carrion, are found wild only in South Africa. The different kinds of eucalyptus and epacris are restricted to Australia; and the trees bearing balsam grow principally in Arabia, and on the banks of the Red Sea. The umbelliferous and cruciferous plants spread across Europe and Asia; the cacti are found in tropical America; and the labiatæ and cariophyllaceæ are seldom discovered but in Europe. The peculiar ranges and centres of vegetation, as they are termed, cannot be well understood without a knowledge of the different tribes and classes of plants, the consideration of which forms the subject of SYSTEMATIC BOTANY.

Soil exercises less influence on the distribution of plants than is usually ascribed to it, though there can be no doubt that on its power of absorbing and retaining heat and moisture much of the luxurious growth of vegetables depends. They will grow to some degree in almost any soil, as the bulkier ingredients (clay, lime, and sand) always predominate; but a proper proportion of these earths is necessary to perfect vegetation; and many plants will not continue healthy and propagate, unless supplied with other elements, such as potash, soda, and various metallic salts. For this reason the natural vegetation of a limestone country differs from that of a retentive clay; while the plants which cover all sandy downs are totally different in kind and character from those of the alluvial valley. Moisture, which is indispensable to the existence of vegetation, also exercises some influence in its natural distribution. The plant which roots in the parched sand is furnished with leaf-organs to absorb moisture from the atmosphere, and retain it, while in a wet situation these organs would become diseased, and rot away; so, in like manner, a marsh plant, whose spongioles are its main organs of sustenance, would perish were it removed to an arid soil. The organic structure of such plants forms a limit to their distribution; and the same may be said of the salicorniæ, arenaria, peploides, &c. which live only when exposed to the salt spray of the ocean. Another circumstance connected with the air, and one which is worthy of notice, is whether it be more generally stagnant or in motion. It is perfectly evident that the action of stagnant air upon a plant must be every way less than that of moving air, whether we suppose the action to be of one kind or another; and therefore, up to a certain point, motion in the air must be favourable to the growth of vegetables. Of this we have abundant proofs in the variety, luxuriance, and activity of the vegetation of those regions which, like the Brazils, Oriental isles, and Malay peninsula, are constantly exposed to the steady currents of the trade-winds.

Heat and light are perhaps the most manifest agents in the distribution of vegetable life. The luxurious growth of the tropical jungle is the direct result of warmth and moisture, just as the barrenness of Nova Zembla is the effect of piercing cold; yet both situations are inhabited by plants which enjoy the conditions peculiar to their existence. No conditions of mere soil, or light, or moisture, could make the palms, tree-ferns, and jungle-flowers of India flourish in Great Britain; so neither would our oaks or pines flourish in Iceland, unless we could provide for them that temperature and seasonal influence necessary to their healthy existence. Light, though it acts most powerfully on the colours and blossoms of plants, is also an essential element in their geographical arrangement. The southern slopes of our hills and mountain ranges are always clothed with a more elaborated and more fully developed race of plants than the northern slopes; and this depends wholly upon the greater degree of light which the former enjoy. The northern side may sometimes be as green, but it never will be so flowery as the southern exposure; and the attentive observer may detect new tribes on either side almost as soon as he has passed the summit. The more free the exposure, the more readily will most plants also blossom, and yield a rich fruit. So well is this understood in the grape countries on the Rhine, that the right bank of that river, which faces the sun, is reckoned to be much more valuable than the left, and commands a higher price for its wines.

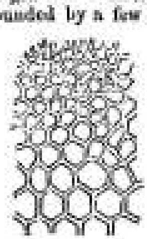
Altitude, or elevation above the ordinary sea-level, also exerts an obvious influence on the distribution of vegetable life: it is equivalent to removal from a tropical to a temperate region, or from temperate latitudes to the arctic circle. For every hundred feet of ascent, there is a proportional fall of the thermometer; so that, at the height of 5000 feet in Britain, and 16,000 at the equator, we arrive at the region of perpetual snow; in other words, to heights as destitute of vegetation as the frozen zone. This intimate relation between altitude and decrease of temperature accounts for the fact, why the base of a mountain may be clothed with the vegetation of tropical India, the sides with that of temperate England, and the summit with the mosses and lichens of icy Labrador. "We may begin the ascent of the Alps, for instance, in the midst of warm vineyards, and pass through a succession of oaks, sweet chestnuts, and beeches, till we gain the elevation of the more hardy pines and stunted birches, and tread on pastures fringed by borders of perpetual snow. At the elevation of 1950 feet the vine disappears; and at 1000 feet higher the sweet chestnuts cease to thrive; 1000 feet further, and the oak is unable to maintain itself; the birch ceases to grow at an elevation of 4000, and the spruce fir at the height of 5000 feet, beyond which no tree appears. The rhododendron ferrugineum then covers immense tracts to the height of 7800 feet, and the herbaceous willow creeps two or three hundred feet higher, accompanied by a few saxifrages, gentians, and grasses, while lichens and mosses struggle up to the imperishable barrier of eternal snow."

The circumstances which facilitate the dispersion or migration of plants are unconnected with the causes which limit their geographical distribution. Many seeds drop from the parent stalk, spring up into new series of stems, which in turn give birth to another race of seeds, and these, again, to another circle of vegetation. Thus, any tribe of plants would spread from a common centre till arrested by the influences which limit its range of habitat; and this mode of dispersion no doubt occasionally occurs. In most plants, however, the seeds are small and light, and easily borne about by the winds; some are downy, and furnished with wings; others have tufts and filaments; and many are ejected from their carpels with considerable force. All these appendages and peculiarities are evidently intended to facilitate their dispersion, which is further assisted by rivers, lakes, and tidal currents, by the wool of animals, the droppings of birds, and the economical pursuits of man, whether accidental or intentional. The seeds are arrested in their progression by various causes: some are furnished with barbs and hooks, which lay hold of objects; others become entangled amid herbage, the mud of rivers, or the softened soil of winter; while many, towards spring, are acted upon so as to emit an adhesive substance, or their fleshy pericarps melt down into the soil, carrying the embryo along with them.

STRUCTURE OF PLANTS—SIMPLE ORGANS.

The organs with which both plants and animals are gifted to enable them to carry on the functions of life, are of two kinds—namely, *simple organs*, such as the flesh of animals and the cellular tissue of plants; and *compound organs*, such as the leaves of plants and the limbs of animals; the latter always consisting of certain arrangements or combinations of the former. The principal substance of which plants are composed is known by the general name of *tissue*; but of this there are three distinct kinds, distinguished as *cellular*, *woody*, and *vascular*, which have been compared to the flesh, bones, and veins of animals.

Cellular tissue is the fleshy or succulent part of plants, of which familiar examples may be given in the pulp of leaves and fruits. It consists of a great number of cells of irregular shape, which adhere together, sometimes quite loosely, as in the pulp of an over-ripe orange; and at other times—as, for example, in the cuticle or outer skin—so closely, as to seem to form a homogeneous mass, unless examined by a powerful microscope. Each cell consists of a small bag or bladder, filled apparently with liquid; but intermixed with this liquid, which consists of hydrogen and oxygen nearly in the same proportions as in water, there are some grains of starch and some of colouring matter, surrounded by a few particles of gluten. The starch,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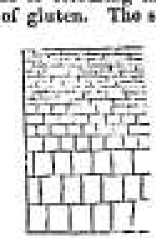
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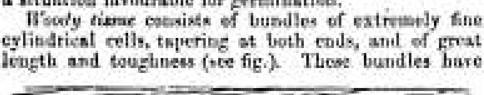
which has been compared to the fat of animals, consists principally of carbon, and the gluten of nitrogen. The cells of cellular tissue vary very much both in size and shape. They generally, however, present the appearance of a honeycomb when sections are cut of the pulp of the leaves, pith, or fruit (*a*); but in sections of the bark and sapwood, they take a parallelogram form, and resemble the bricks of a wall (*b*). The cells are generally small when they are first formed, but they increase in size as they become older. Thus, in the tissue of a leaf, they are at first very small; but as fresh cells are formed close to the veins, those towards the margin of the leaf dilate; and a similar process takes place in every part of the plant, the newly-formed tissue always consisting of cellules, which enlarge as they get older.

In the pulp of leaves and fruit, and in the cellular tissue of the bark, there are frequently cavities found among the cells, which are of several kinds. Those called *receptacles of secretion* are formed for the reception of the oils and other fluids secreted by plants; as, for example, the fragrant oil in the myrtle and the orange, and the turpentine in the pine and fir tribe. Other similar cavities, called *air cells*, contain oxygen nearly in a pure state; and others, which are called *intercellular passages*, are generally filled with watery fluid, and communicate with the open air by means of pores in the epidermis. All these cavities have no distinct membrane to enclose them, but are surrounded by what may be called a wall of small cells, which form part of the cellular tissue. The shape and size of these cavities vary exceedingly; the receptacles of secretion, and the air cells, are generally larger than the common cells, but the intercellular passages in very dry plants are so small as to be scarcely perceptible; though in succulent plants—as, for example, in the stem of the garden Nasturtium—they are nearly as large as the cells.

Cellular tissue readily decays when the parts composed of it fall from the tree. The carbon it contains is liberated so soon as the vital force by which it was retained has fled, and escapes with the oxygen in the form of carbonic acid gas; whilst the hydrogen, which then forms its principal remaining element, attracts fresh oxygen from the atmosphere, and becoming thus changed into water, rapidly melts away, leaving the inorganic portion to mix with the soil. In leaves, the pulpy parts disappear first, leaving behind the outer cuticle and the nerves or veins, which are of firmer texture; the latter, indeed, being composed principally of woody fibre, the tubes of which have been filled with earthy matter during the process of vegetation, decay very slowly. Those parts of a plant which nature seems to have intended not to be of long duration, such as the fleshy parts of the leaves, the flowers, and the fruit, are composed entirely of cellular tissue of very loose texture. In the stones of fruit, however, which are also composed of cellular tissue, a portion of earthy matter is deposited, which partially lines the cells, and gives them a temporary firmness, without destroying their facility of decay; so that the seeds contained in them may be preserved as long as they are kept in a dry state, and yet liberated so soon as they are placed in a situation favourable for germination.

Woody tissue consists of bundles of extremely fine cylindrical cells, tapering at both ends, and of great length and toughness (see fig.). These bundles have



Woody Tissue.

so much the appearance of fibres, that their true nature was not suspected by the elder botanists; and it was supposed that they retained their fibrous appearance even when subjected to the most minute division. It is now found, however, that the fibres of woody tissue cannot be divided beyond a certain point, and that, though they may be made so small as to take seven or eight of them to equal the thickness of a fine hair, each of these exceedingly slender fibres is, in fact, a hollow tube tapering at both ends, and adhering to other hollow tubes of a similar nature. The tubes of woody fibre, when young, serve as channels for the passage of the ascending sap; but afterwards they become filled with particles of inorganic matter, which give solidity and durability to the wood. Woody fibre is found mixed with cellular tissue in the wood and inner bark of trees; it also forms part of the veins or nerves of leaves; and in general is found in all organs which require strength, toughness, and durability.

Vascular tissue has been divided by modern botanists into three varieties—namely, *vascular proper*, *pitted*, and *lactiferous*. Vascular tissue, properly so called, consists of cylindrical cells of great delicacy and thinness, called *spiral vessels* and *ducts*. *Spiral vessels* consist of hair-like tubes coiled round and round in a spiral manner, and enclosed in tubes of transparent membrane. They are of a light elastic nature, and though coiled up naturally like a cork-screw (see fig.), they may be unrolled to a considerable extent. If a leaf of the spider-wort (*Tradescantia*), or of any kind of bulb, be doubled down first on one side, and

Spiral Vessel.

then on the other, so as to break through the outer skin on both sides, and if the two pieces of the leaf be then carefully and gently drawn asunder, the transparent membrane will break, and the spiral vessels will unrol, so as to appear, when seen with the naked eye, like fine hairs between two portions of the leaf. Spiral vessels prevail in leaves and flowers, and are found, though more sparingly, in the young green wood of trees and shrubs; but never in the old solid wood, and very rarely in the roots or in the bark. They are very few and small in coniferous trees; but they are abundant in palms and their allies. In ferns and the club mosses they occur occasionally; but the other cryptogamous or flowerless plants are entirely without them. These vessels are sometimes called *air vessels*, because their slender spiral tubes are always found filled with a kind of air, which contains seven or eight times more oxygen than the common air we breathe. *Ducts* are cylindrical tubes closely resembling those which enclose the air vessels; only the spiral vessels they contain appear to have been broken into rings, or short corkscrew-like curves, which sometimes cross each other in a reticulated manner. These rings and curves are, however, quite different from the true spiral vessels, as they have no power of unrolling, and appear only intended to keep the slender membrane which forms the duct distended. Similar rings are found in the windpipe of animals, which appear also only intended to keep that membrane distended.

Pitted tissue, sometimes called *dotted ducts*, consists of tubes which, when held up to the light, appear full of holes, from the numerous dots in the lining of their sides. The mouths of these tubes are very conspicuous in the wood of the rattan when cut across; they are also to be seen in sections of the oak and the vine; and, indeed, in most other kinds of wood, as well as in the stems of herbaceous plants. Being the channels through which the ascending sap is conveyed, the dotted ducts are larger than the vessels of the other tissues, and are distinctly visible in many kinds of wood, even when dry. Modern botanists consider them as belonging to cellular tissue, and as consisting only of elongated cells placed end to end, and opening into each other so as to form a kind of tube. Lactiferous tissue, which is the same as the proper vessels of the older botanists, consist of tubes, which are distinguished from all other kinds of tissue by being branched. They are filled with a mucilaginous fluid called the *latex*, which is, in fact, the descending sap, and is full of numerous small specks, like that which is the germ of the future chicken in the egg of a hen. These specks are always in motion while they remain in the vessels of the latex, and whenever they are deposited, they expand into cells of different kinds of tissue. From the latex, also, is formed gum, sugar, tannin, or other secretions, according to the nature of the plant. The vessels of the latex are found on the under sides of leaves, and within the inner bark, which they may be said to line: hence the peculiar secretions of a tree are generally strongest in the bark.

COMPOUND ORGANS AND THEIR FUNCTIONS.

The compound organs of plants are composed of several of the simple ones; as, for example, a leaf has woody and vascular tissue in its veins, and cellular tissue in its pulpy part; and in like manner, these elementary organs are found in the stem, flower, fruit, and, in fact, in every part of the plant. The compound organs are divided into three kinds—namely, the *general organs*, which are common to every part of a plant, such as the *epidermis* or skin, and the hairs; *the organs of nutrition*, through which the plant takes and digests its food, such as the root, stem, and leaves; and *the organs of reproduction*, which are the flowers, fruit, and seeds.

General organs.—The epidermis or skin is a thin membrane, which covers every part of a terrestrial plant, except the stigma and the spongioles, but which is sometimes entirely or partly wanting in plants which live under water. It is composed of a kind of cellular tissue; but the cells are pressed so closely together, as to make it appear homogeneous to the naked eye; and they are filled with air instead of water. The use of the epidermis is to retain a sufficiency of moisture in plants; for should the delicate membrane of which the cells of their tissue are composed become so dry as to lose its elasticity, the different organs would be unable to perform their proper functions. On this account its thickness is curiously adapted to the conditions under which a plant grows. In ordinary cases, the epidermis consists of two layers, the outer one of which, called the *cuticle*, is extremely thin, and consists of cells of oblong shape and large size, pressed closely together, and filled with air; while the secondary layer is formed of cells of a different shape and size, but still closely pressed together. In the plants of very hot countries, it consists of three, or even four layers, in order that the moisture may be retained, notwithstanding the excessive heat and dryness of the climate. Those plants which have numerous pores, or *stomata*, in their epidermis, require watering oftener than others, and are more easily affected by the heat of the sun. Thus we often see the leaves of the common lilac droop, as though the plant were suffering from want of water; while those of the apple or pear tree which grows beside it are perfectly unaffected by the heat—the latter tree not having above twenty thousand pores in the square inch, while the lilac has one hundred and sixty thousand in the same space. The epidermis of aquatic plants is extremely thin, and is entirely wanting on the under side of floating leaves.

Hairs are minute expansions of the epidermis, and are found almost upon every part of a plant. Sometimes they cover the whole of the leaf, and at others they are only found on the lower surface. They are of two kinds—namely, *lymphatic* and *glandular*; and are described as downy, silky, hirsute, bristly, ciliate, stellate, &c. according to their aspect and mode of arrangement. The use of lymphatic hairs is partly to protect the surface of the leaf from the heat of the sun and from drying winds, and partly to collect moisture from the atmosphere. It is now known that plants take in nourishment from the atmosphere as well as from the soil; and it is supposed that part of this nourishment is absorbed through the lymphatic hairs. It has been observed, that the hairs, when they do not cover the entire surface of the leaf, always grow either upon the veins or in the angles where the veins cross each other. It is thus evident that they have a direct communication with the vessels containing the sap. Glandular hairs are hollow, generally open at the point, and with a receptacle of secretion at the base. Of this nature are the stings of the nettle, and the hairs of the sweetbrier, &c. which are filled with a fragrant volatile oil. In both these cases, glandular hairs seem to act as organs of excretion, through which the plant is enabled to exude certain fluids.

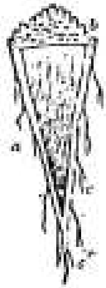
Glands are organs of secretion, or cells containing liquid different from that in the cells of the common tissue of the plant, as in the flowers of the *Hypericum*, or St John's wort, which give out a red liquid when pressed. Sometimes glands assume a wart-like appearance; thence the stems or leaves on which they appear are said to be *verrucose*; and sometimes they take the form of little watery blisters, in which case the plant is said to be *papillose*.

Besides the above-mentioned organs, there are prickles, thorns, and spines, which seem closely analogous, though much less common. *Prickles* may be called hardened hairs, as they are merely indurated expansions of the epidermis, without any woody fibre; and they may be detached from the branch which bears them without laceration. *Thorns* differ from prickles, in being formed partly of woody fibre; and they cannot be detached from the branch which bears them without lacerating its vessels. They are, in fact, abortive, or imperfectly-developed buds, and are formed instead of leaves and branches. *Spines* resemble thorns in every respect, except in being found on the leaves and stems of herbaceous plants, while thorns only grow on the trunk and branches of woody plants. When spines grow on leaves, they are always found on the veins, which are extensions of the woody fibre.

ORGANS OF NUTRITION.

The organs of nutrition are the root, the stem and branches, and the leaves; and of these organs, the root and the leaves, or some modification of them, must exist in every flowering plant, as the vital functions could not be carried on without them.

The root (*radix* in Latin) is commonly defined to be that part of a plant which attaches itself to the soil where it grows, or to the substance on which it feeds, and is the principal organ of nutrition. Exceptions to this definition occur, as in the case of some vegetables which grow floating loosely in water, as duckweed and others, having no root at all. As the nourishment of a plant is derived from the earth, the root is that part which grows in an opposite direction to the stem, and is buried in the ground. A root consists of several parts (see section), which have been called the body or *caudex* (*a*); the collar or life-knot (*b*); the branches or radicles, when such exist; and the rootlets or small fibres (*c c*), which seem to be indispensable in all roots. The body of the root assumes various forms; it may be globe-shaped, as in the turnip; conical, or tapering gradually from the collar to the attenuated fibre, as in the carrot; fusiform, or tapering at both ends, as in the radish; this latter may be abrupt—that is, as if the lower end had been cut off, exemplified in the devil's bit scabious; fibrous, or consisting of small threadlike fibres, which proceed directly from the collar, as may be seen in most grasses; tuberous, when the fibres bear globe-shaped bodies filled with starchy matter, as in the potato; fasciculated, when the fibres swell slightly in the middle; bulbous, when the round lobe consists of coats or layers, such as may be seen on cutting an onion across. A corm is similar in form to a bulb, but is not composed of layers; a palmated root consists of a number of oblong tubers proceeding from the collar, like the fingers from the body of the hand, as in the dahlia. Tuberous roots, such as the potato, are considered by some modern botanists as merely underground stems, from the circumstance of their having eyes, or buds, from which branches will spring.

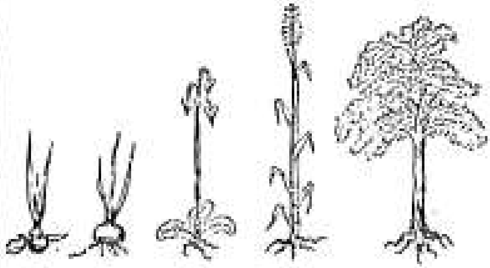


The crown, collar, or life-knot, as it is variously called, is that part which lies between the stem and the root. It is the most essential portion of the whole; for if it be removed, or seriously injured, the plant will inevitably die; whilst the small fibres or rootlets, although an essential part of a plant, may be destroyed at pleasure so long as the crown remains, for it readily reproduces them. When it is of a slender make, as the seeds form, it dries up, and the plant soon dies, as the poppy, mignionette, and other annuals. The crown, however, in some cases, by proper treatment, may be rendered so strong, that annuals can be brought to grow for two or more years. The fibrous root consists of a quantity of long thin fibres, of different lengths and thicknesses, and having still finer ones springing from them, as in the case of wheat, barley, and most grasses. These small fibres or rootlets bear a resemblance to the branches and leaves of the stem. Fibrils consist of a central fasciculus of vessels, enclosed by a cellular cortex and cuticle. Like the leaves of trees that are not evergreen, they are annually produced; in some cases dying and falling off like leaves, in others becoming thicker, harder, and forming radicles or root-branches. The spongelets, as they are called, which take up nourishment from the soil, are situated at the extremity of these rootlets. They are minute spongy bodies, of an oblong shape. We have an instance of rootlets falling off like leaves in those arising from bulbs—such as the lily, the onion, the tulip, &c. which are pushed off and perish like leaves by buds containing the rudiments of the rootlets to be evolved next season of growth.

Roots have a remarkable tendency to grow downwards, or in the direction of the earth's centre, and, from experiments, it seems not unlikely that this tendency is an effect of gravitation. The precise direction, however, is very much influenced by the condition of the soil. Both root and rootlets extend as if in quest of food, and this will penetrate sideways or obliquely to great distances. When plants are by any means prevented from fructifying by seeds, they almost invariably increase by extending their roots, from distant points of which new plants will spring up. Roots thus perform the functions of stems, and though the two differ in many respects, yet there are cases where it becomes difficult to distinguish between them. Some species of palms send down aërial roots for the purpose of strengthening their stems—these shoots partaking of the character of both stem and root. The roots sent out by cabbages and cauliflowers from above the collar, when they are transplanted to a rich soil, are of the same kind. Many herbaceous plants send out roots in a similar manner when they are earthed up; and trees which grow in unnatural situations, as on a wall or bare rock, send down roots in quest of soil and moisture, which afterwards take the appearance of stems. The maple, the gooseberry, and some others, may have their roots converted into stems by reversing the plants, and burying the tips of the shoots in the earth, so as to leave the roots in the air. In this case, the branches will soon send out fibrous roots from the joints which have been buried in the earth, and the fibrous part of the old roots withering, the roots themselves will gradually assume the character of branches.

The stem or stalk.—When a plant shows itself above the ground, it evidently manifests a strong tendency to the light. Light, in fact, is essential in bringing it to maturity, and in giving the green colour to its leaves. The stem, with a few exceptions, is always above ground, and is furnished with joints or nodes at regular distances, where the fibres and vessels take a curved direction, so as to form a little recess, plainly discernible when the branch is split in two, in the centre of which the bud is formed that afterwards expands into a branch furnished with leaves, and sometimes producing flowers and fruit. "The stem," says Rennie, "is divided from the root by the part called the crown or collar. The space between the collar and the first leaf or bud is termed the bole; but the great body of a stem is called the trunk. The stem of grasses, corn, and reeds, is termed the straw; the stem of palms, ferns, mushrooms, and sea-weeds, is termed the stalk; the stem of such flowers as the primrose, the daisy, the snowdrop, and the lily, is termed the scape, though flower-stalk is certainly better; the running stem, as in the strawberry and cinquefoil, is termed a runner; a shorter runner that does not root, as in the house-leek, is termed an offset; a longer one that does not root, as in the cucumber, a vinelet; and a small stem proceeding laterally from a root or stool, a sucker."

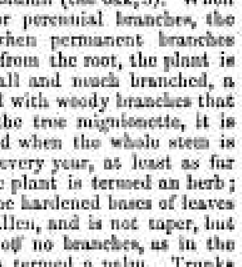
The stem, it will be observed, assumes many forms and characters as to bulk, structure, position, place,



1. 2. 3. 4. 5.

and duration. It appears as a tuber (*Gladiolus*, 1), a bulb (the onion, 2), a scape (*Dodecatheon*, 3), a culm (*Arundo*, 4), or as a woody column (the oak, 5). When a trunk bears permanent or perennial branches, the plant is termed a tree; when permanent branches arise, not from a trunk, but from the root, the plant is termed a shrub; when small and much branched, a copse-shrub; when furnished with woody branches that are not permanent, as in the tree mignionette, it is termed an under-shrub; and when the whole stem is not woody, and dies down every year, at least as far as the crown of the root, the plant is termed an herb; when a trunk is formed of the hardened bases of leaves which have withered and fallen, and is not taper, but all of one thickness, giving off no branches, as in the date and cocoa, the plant is termed a palm. Trunks which increase by successive layers of new wood on the outside of the old, as the ash, are termed *exogenous*; those which increase by the addition of fibrous matter in the centre, as the palms, are styled *endogenous*; and those formed by the adhesion of the leaf-stalks as they spring from the growing-point, as the tree-ferns, are said to be *acrogenous*.

Buds, which have various forms, but are generally oval or roundish, consist of the young shoots either of leaf, flower, or twig, and proceed from what is called the axil of a leaf. They are usually formed either early in summer or in autumn, and are so contrived as to preserve from injury the delicate foliated structure within. The outside is composed of tough scales, which are frequently covered with a gummy resin, and they are internally kept warm by a downy substance interposed between the leaves. To this envelope Linnæus applied the term *hybernaculum*, because it serves for the winter protection of the young and tender portions of the bud (see fig.). The inner scales perform the functions of leaves, until these are perfected and fully expanded, when they drop off; but in some trees, as in the apple and the almond, they are converted into leaves; whilst in others, as the rose, they are converted into the petioles or foot-stalks of the real leaves, which spring out of them. When the central part of a bud contains leaves only, it lengthens upwards as it expands into a branch;



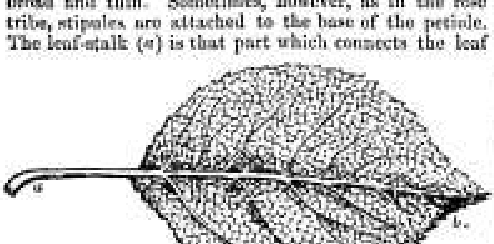
Hybernaculum, or Leaf-Bud.

thus a leaf-bud and a branch-bud may be said to be the same. When it contains a flower, this is situated as in the bulb of the tulip, in which small bulbs are formed on the edges of the crown of the root between the scales, which gradually enlarge at the expense of the scales, are detached, become perfect bulbs, and send up leaves and flower-stalks. With respect to the manner in which the leaves are folded in the bud—they may be plaited, as in the palm and birch; doubled, as in the rose and oak; embracing, as in the iris and the sage; double embracing, as in valerian, teasel, &c.; double compound, as in carrot, mimosa, &c.; rolled inwards, as in grasses; tiled, as in privet, lilac, &c.; rolled outwards, as in rosemary, primrose, &c.; rolled lengthways, breadthways, rolled from the tip to the base, or wrapped round the stalk.

The buds of trees being in a state of great sensibility, and feeling the first warmth of the sun, the vitality of the continued shoot is roused into action; it attracts the moisture contained in the neighbouring cells charged with nourishing matter; the rising sap also enters its vessels; it gradually swells, and bursting the enclosing scales, pushes into the light and air, unfolding its leaves successively as it advances, until the whole tree becomes green.

Leaves.—Leaves are the grand ornament of plants, and from their numbers, position, and delicacy of organisation, they are designed to effect an important office in the vegetable economy. Springing from the branches, and exposed in profusion to the atmosphere, they perform the functions of a breathing apparatus analogous to that of the lungs or gills of animals. A similar purpose at least is designed; for the circulatory sap of plants, like the blood of animals, requires to be exposed to the atmospheric influence, in order that it may be suitable for nutrition. This purpose is accomplished by the agency of the leaves, to which the sap, on rising from the roots through the stem and branches, is propelled or attracted, and there both air and light exercise their beneficial influences. Leaves are thus indispensable to the growth of plants, and care should be taken not to injure them; for defoliation, either naturally or by art or accident, instantly arrests the growth, and the failure or diminished expansion of foliage is a certain sign of debility.

A leaf consists generally of two parts—the petiole, or leaf-stalk; and the lamina, or that part which is broad and thin. Sometimes, however, as in the rose tribe, stipules are attached to the base of the petiole. The leaf-stalk (*a*) is that part which connects the leaf



with the branch, and at the base will be found slightly hollowed, in which a bud rests. Sometimes the leaf-stalk is wanting, as in the sow-thistle and catch-fly, and in this case the leaf is said to be sessile or sitting. The lamina, or broad part of the leaf (*b*), is frequently of a different colour on the under side to what it is on the upper. This is exemplified in the common silver-weed (*Potentilla anserina*), the leaves of which are hoary on the lower side and green on the upper. Leaves are either *caducous*, falling in summer; *deciduous*, falling in autumn; *persistent*, remaining till pushed off in the following spring; or *perennial*, when of still longer duration, as in evergreens. The forms of leaves are exceedingly varied—being *simple* or *compound*; and these again are distinguished as oval, lanceolate, hastate, sagittate, pinnate, cordate, &c.

With regard to the manner in which leaves project from the branches, and their distribution over the woody cylinder to which they are attached, every possible variety may be observed. They may be opposite—that is, two leaves growing on either side of the branch, the one directly opposite to the other; alternate, when one leaf springs out on one side of the branch, and another on the opposite side a little above it, and so on; whorled or *verticillate*, when a number of leaves grow round the stem from a common knot or joint, as in the bed straw. The distribution of alternate and opposite, however, is not regular; for in some instances it will be found that the leaves on the lower part of the stem are alternate, whilst those on the upper are opposite.

There is a numerous description of plants which have few or no leaves, as the torch and melon thistles; but their stems are much dilated, presenting a large superficies of parenchymous exterior to the air and light; or they are profusely covered with spines, which no doubt, conjointly, do the office of leaves. It may be remarked that such plants as the common garden rhubarb, which require much moisture, are provided with very broad leaves, which catch the rain that falls upon them, and also, by their umbrageous quality, preserve the soil from being parched.

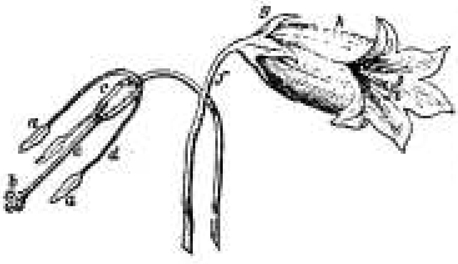
Green is the most general colour of leaves, but some are red, or purple, or yellow; some appear nearly white, in consequence of being clothed with short woolly or silky hair. They differ much in substance and structure: some are immensely thick and fleshy, as those of the genus aloe; others remarkably thin, as those of the beech. The texture of the surface is also very dissimilar; some are rough, prickly, and wrinkled, others smooth and glossy. Whatever be their form or appearance, it is found, by minute microscopic observation, that the interior of the fine membranous substance consists of cells and passages suitable to the due exposure of the sap, the inhaling of air, and the absorption of humidity from the atmosphere.

ORGANS OF REPRODUCTION.

The organs of reproduction are the flowers, the fruit, and the seed; and these, or some modification of them, must exist in every perfect *Phanerogamous* or flowering plant.

Flower-buds are produced like leaf-buds, from which they differ chiefly in containing one or more incipient flowers within the leaves; the flowers being wrapped up in their own floral leaves, or bracts, within the ordinary leaves, which have their usual outer covering of scales. The growing point is generally developed when the leaves expand, but it is short and stunted, and unlike the branches produced from the leaf-buds. Every flower-bud, as soon as formed in the axil of the old leaf, contains within itself all the rudiments of the future flowers. If a bud be gathered from a lilac or a horse-chestnut very early in spring, all the rudiments of the future leaves and flowers will be found within it, though the bud itself may not be more than half an inch long, and the flowers not bigger than the points of the smallest pins.

Flowers.—A flower consists of several distinct parts—the calyx, corolla, stamens, disk, nectarium, pistillum, and receptacle. A flower is essentially constituted by the presence of sexual organs, either male or female. When there is only one of these present, the plant is termed unisexual; but more commonly these organs are both present in the same flower, which is in this case termed a hermaphrodite. In some instances, although the same plant bears both male and female organs, it is not hermaphrodite, as these organs occur in different flowers; in others, again, the male and female flowers exist only in different plants. Lastly, male, female, and hermaphrodite flowers are sometimes found mingled together, either on the same or on different foot-stalks. Sometimes the male or female organs alone, protected in a small scale, constitute the flower; but in general they are surrounded and protected by the corolla and calyx. All these are commonly borne on a stalk called the peduncle (from *pes, pedis*, a foot), which, expanding at its extremity, forms the receptacle or torus, as it has been called, upon which the whole



a a, stamens; *d*, filament; *b*, stigma, or summit of pistil; *e*, style; *c*, ovary, or seed-vessel; *f*, peduncle; *g*, calyx; *h*, corolla.

of the parts above-mentioned are supported. What is called the berry in strawberries, appears to be nothing more than the receptacle bearing the naked seeds on its surface. It is called common when a number of florets rest on one receptacle. The round button which is exposed when the downy seeds are blown from the head of the dandelion, is an instance of the common receptacle.

The *calyx* is the external leafy envelope surrounding the flower, and in which it rests as in a cup. Sometimes it is entire, but more frequently it is divided into segments (*sepals*), which are more or less separated from each other. It is most commonly green, but in some flowers it is highly coloured, and with difficulty to be distinguished from the corolla.

The *corolla* is the true flower or blossom, and consists of several divisions or leafy parts, called *petals*, which are almost all articulated at the base, and consequently fall off at the earliest manifestations of maturity or decay. The extensive variety of tints in the flowering part of plants, is a remarkable circumstance in vegetable economy; and what may be the precise use of such gaiety of colour, has formed the subject of philosophic inquiry. Independently of the exceeding beauty to the eye, which is certainly a matter for pleasing gratulation, it is believed that the lively colours are useful in attracting insects—these creatures incidentally performing an office in the reproductive economy, and in carrying off saccharine exudations.

The lower part of the single petal of a corolla is called the claw, corresponding to the stalk of the leaf; and the broad part is called the limb. The corolla is frequently furnished with certain appendages, attached either to the throat or to the base of the petals, called nectaries. These are placed in different parts of the corolla; in the common auricula they surround the edge of the throat; in the ranunculus or buttercup tribe, they appear like scales at the bottom of the claw; and in the monkshood, in the form of a spur behind the corolla. They receive the name of nectaries from the supposition that they secrete honey, and they are always found to contain a clear, sweet-tasted fluid.

Stamens, &c.—Within the beautiful corolla are observed several small filamentous objects, on some of which are particles of fine coloured matter like dust. These are parts of the reproductive organisation, and consist of stamens and pistils. In general, a stamen consists of two parts, in most cases of a filament (from *filum*, a thread), which is usually white, and always of an anther, which is generally yellow or purple. It has been shown that the stamens are always next to the petals—that is, between their base and the base of the seed-organ. It is upon the number and arrangement of the stamens that systematic botanical arrangements have principally been founded. The following are a few characteristics of the number, length, position, direction, &c. of the stamens. The number of stamens in each flower varies from one to twenty, or more. In length, they are equal or unequal, and this disproportion is sometimes symmetrical, sometimes not. In position, they may be opposed to the divisions of the petals, or they may alternate with them. Sometimes they protrude beyond the corolla, at other times they are wholly included within it. Their direction may be erect, pendant, or horizontal, and their summit is variously inclined to or reflected from the centre of the flower. The filament which supports the anther is most commonly straight and filiform; sometimes, however, it is otherwise. It varies from being as small as a hair to be large and flat like a petal, and its summit is either pointed or obtuse. On the summit is that essential part the *anther*, which is generally formed of two small membranous sacs, attached immediately to each other, or united by an intermediate connecting body. In form, anthers are subject to great variety, and, like the filaments, they sometimes cohere so as to form a sort of tube. Their colour is often yellow, orange, violet, white, &c. but never green or truly blue.

The pollen contained in the anthers consists of numerous regularly-figured small particles, which possess in different plants a very different figure, size, and colour. The number of particles in a cell, which is very small, sometimes amounts to many thousands. In some flowers the pollen consists of transparent grains; in others they are of a white, purple, blue, or brown, and more frequently of a yellow colour. When a grain of pollen is dropped into water, it swells and bursts, and a minute quantity of matter escapes, which is supposed to be the fecundating principle of the pollen. We may illustrate the action of the pollen from the anthers, by referring to the annexed engraving, in which *a* is the filament or stalk of the stamen, *b* the anther on its summit, and *c* the pollen or dust in the act of being shaken down upon the stigma or upper part of a pistil, of which we observe three in a group.

In this figure, it may be remarked that the anther is a roundish-shaped body, delicately poised on the filament, and ready to vibrate and impart its dust to objects beneath or near it.

The pistil is a kind of tube with a communication from the stigma, through its style or stalk, to the ovary or seed-bag beneath, and down this the pollen is permitted to exercise its influence. The seed-organ or ovary occupies almost always the inferior part of the pistil, and it is there that the process of fructification is fully effected. When cut open, it exhibits one or more cavities or cells, in which are contained the rudiments of the seeds or ovula; and it is in it that the change of the ovula into perfect seeds is effected. It is of various forms, but most commonly ovoidal. It is generally seated upon the receptacle together with the stamens, but frequently it is placed below the flower. Its cavity consists of one or more cells, in which the ovula or rudimentary seeds are found. It may be remarked, that the pistils spring from a nectary or disk in the centre of the flower, and are surrounded by the stamens.

The precise mode of fructification is by no means clearly ascertained. The stigmata are in all cases moistened with a clammy fluid, which causes the pollen-cells to swell, burst, and discharge their minute granules. Some suppose that these are taken up by spongelets in the summit similar to those of the root, while others allege that the fluid matter in which the granules float is sucked up. It has been discovered that the grains of pollen, when shed on the summit, in a few hours shoot out one or more delicate tubes, which by some physiologists are supposed to extend down as far as the seed-organs, and to expand around and between the nascent seeds. Some believe them to convey thither the granules, which at least enter into the tubes; others, however, deny that this is the case. The seed-organ lies at the base of the pistil, and contains the seeds, either nascent or advanced to maturity. It bears a very strong resemblance to the egg-organ of birds and insects, and its parts have accordingly received from naturalists the same scientific names. The seed-organ is usually of an egg-oblong form, and is always composed of an outer membrane, a middle membrane, and an inner membrane, all intimately united. As every seed derives its nourishment from the inner membrane, there must be a communicating point; and this point being always on the verge of the membrane, may be so termed; that on the seed being termed the seed-scar, but popularly, though improperly, named the eye. In some species the verge bears a number of smaller verges, to each of which a seed is attached, by means of the funicle or seed-stalk. All these parts are obvious in an unripe pea or bean.

Seed-vessels are various in form—as, for example, in the case of the pea (*a*), the vessel is a *legume* or pod; in the apple (*b*), it is the body of the fruit, or *pome;* and in the filbert, it is a nut.

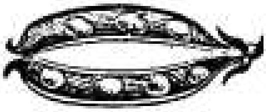


Fig. a.

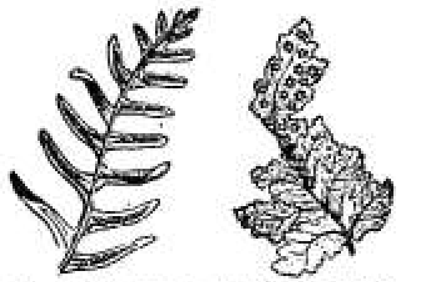
Fig. b.

All fruits, in reality, are but so many vessels, or receptacles for the seeds, and the various forms in which they appear are individually suitable to the purposes of their growth. The seed contains the *embryo* or germ of the future plant, which is generally surrounded by a nutritious substance termed the albumen, destined for the support of the young plant, before its organs are sufficiently matured to allow of its supporting itself. In most instances the albumen surrounds the embryo; but sometimes it forms part of the cotyledons or seed-lobes, and at others it is wanting altogether. Even where it exists, it varies very much in quantity, sometimes being much smaller than the embryo, while in other cases, as in the cocoa-nut, it weighs as many, or more ounces, than the embryo does grains. The albumen varies in quality as much as it does in quantity. It is generally fleshy, as in the pea and bean; but sometimes it is farinaceous or floury, as in the wheat, and in the marvel of Peru; at other times it is oily, as in linseed; horny, as in the coffee; or even stony, as in the kind of palm whose seed forms the substance called vegetable ivory. In the nutmeg and the custard apple tribes, it appears to be perforated in every direction by a mass of dry cellular tissue.

If the embryo consist of one seed-lobe or cotyledon, as the cocoa, it is said to be *monocotyledonous;* if of two, as in the beech and oak, *dicotyledonous*—and these terms are generally used indiscriminately for exogenous and endogenous; while cryptogamous or flowerless plants, from being propagated by sporules instead of seed, are said to be *acotyledonous*—that is, without any cotyledon whatever. (See SYSTEMATIC BOTANY.)

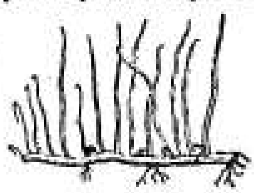
Fructification of flowerless plants.—As already stated, the lowest forms in which vegetables make their appearance are those of the *cryptogamous* or flowerless orders—such as the ferns, lichens, mosses, seaweeds, and fungi. In these the manner of fructification is very remarkable, and quite different from that of flowering plants. They have neither flowers nor seeds, but are propagated by little embryo plants, called *spores* or *sporules.*

In the ferns (*filices*), which are the largest and most highly organised of the flowerless orders, little brown spots, called *sori,* may be seen on the under-sides of the leaves or fronds (see fig.). Each of these is composed of a number of minute membranous capsules (*thecæ*), which contain the reproductive sporules, and which are often furnished with elastic apparatus for assisting in their dispersion. In some species the sori are situated merely under the epidermis of the leaf, forming little protuberances, which, on the slightest rupture, discharge their contents, to be scattered abroad by every breeze that blows. As an order, ferns are very widely distributed, generally consisting of a number of leaf-like



Ferns, showing the Sori on the back of the Fronds.

members, called *fronds,* attached by tough fibrous petioles to a subterranean stem—the fronds being the only visible portion of the plant. In some varieties, however, the stem rises above ground to the height of thirty or forty feet, forming the well-known *tree-ferns* of New Zealand and Van Diemen's Land. In the *equisetums,* or horsetails of our marshes and ditches, the capsules which contain the spores are placed on the points of bracteated spikes, arranged in rings round the stems. Each spore is furnished with an elastic filament, which is at first coiled around it, but which, in its endeavour to uncoil, makes the sporules jerk and leap as if they were alive. The horsetails are herbaceous perennial plants, having hollow striated stems, these being either simple or branched. In point of size they are now insignificant members of the vegetable kingdom; but geology has revealed the gigantic proportions they bore in ages long past, when, instead of slender stems of a foot or two high, they reared their gigantic pillar-like trunks to a height of twenty or thirty feet. The sporules of the pillworts (*marsileaceæ*) are enclosed in little ball-like receptacles at the bases of the leaves (see fig.); the club-mosses (*lycopodiaceæ*) have little cone-like spikes at the tips of their branches, under the scales of which lurk the reproductive embryos; and in the true mosses (*musci*), the spores are enclosed in urn-shaped capsules, which stand out from the leaves on slender hair-like stalks. In the liverworts and lichens there is a somewhat similar provision; and in the stoneworts and algæ (seaweeds), which are aquatic, the sporules are enclosed in the substance of the plants.



Pillwort.

The *fungi,* or mushroom tribe, which constitute the lowest forms of vegetable development, are extremely diversified in their size, shape, colour, and consistence. They are entirely composed of cellular tissue, and some are even apparently animated; so that they are regarded as connecting links between the vegetable and animal kingdoms. The common field-mushroom is one of the best known, and forms the type of the family; but the mould on cheese, stale bread, the mildew on trees, the rust on corn, and many other minute and yet unobserved appearances of a similar nature, are all fungi. They have no fronds or leaves, and are hence termed *aphyllous.* Their organs of reproduction consist of sporules, lying loose on the tissue of the plant, or collected in certain places, which are distended by their aggregation.

But though the botanist can thus detect, by the aid of the microscope, the embryos of flowerless plants, and can describe their situation and appearance, he understands as yet but little of the manner in which these reproductive organs perform their functions. "We are entirely ignorant," says Professor Lindley, "of the manner in which the stems of those that are arborescent are developed, and of the course taken by their ascending and descending sap—if, indeed, in them there really exist currents similar to those of flowering plants; which may be doubted. We know not in what way the fertilising principle is communicated to the sporules or reproductive grains; the use of the different kinds of reproductive matter found in most tribes is entirely concealed from us. It is even suspected that some of the simplest forms (of algæ and fungi, at least) are the creatures of spontaneous growth; and, in fine, we seem to have discovered little that is positive about the vital functions of those plants, except that they are reproduced by their sporules, which differ from seeds, in germinating from any part of their surface, instead of from two invariable points."

Functions of flowerless plants.—Insignificant and lowly as the cryptogamia may appear to the eye of the physiologist, they are nevertheless important auxiliaries in the operations of nature. It is true that man and his works may suffer from the ravages of fungus growth, that mildew, rust in corn, moulds, and other microscopic vegetation, by their rapid increase, and destructive effects on the substances from which they spring, may cause incalculable damage; but this very scourge provides an incentive to intelligent prevention and care, while in creation there are no more useful scavengers of decaying matter than the parasitic fungi. In a dry season, for example, and on a favourable soil, rust rarely makes its appearance: certain conditions are necessary for its development; and it is to obviating these that the farmer must look for exemption from this destructive malady in his crops. It is now placed beyond a doubt that it arises in many cases from the over-manuring of fields; the grain is overloaded with nourishment, and the dormant fungi, brought into a condition of development, speedily show their destructive properties. The tendency to rust may be neutralised by steeping the seeds before sowing in a corrosive solution, or strong brine; but the same end may be better secured by not over-manuring, or by a free use of saline manures. Again, most of the fungi existing only by the absorption of fetid exhalations, and rapidly depriving them of their insalubrious properties, execute duties analogous to those of certain tribes of insects (maggot-flies, for instance), and in this respect have been appropriately associated with these animals as the "scavengers of nature."

It will now be understood that mould is a fungous vegetation, produced by a previous deposit of germs in the tissue or on the surface of the object on which it grows. The proximate cause of its development is generally damp, and, without this condition, the embryo remains in a dormant state. Still, it may be asked, how cheese happens to have green mould at its very centre: the reply is, that the fungous germs floating in the atmosphere had various opportunities of finding admission into this article of diet. They may have been deposited on the grass of a field; the grass was eaten by the cow, and the germs were so lodged in the milk; or, what is more probable, the germs fell upon the curd, and there lay concealed till a certain dampness in the cheese brought their vegetative powers into operation. It is well known that the exposure of curd for a day to the atmosphere will have the effect of producing cheese liable to mould. A fully more surprising instance of fungous vegetation in a secluded situation, is that which occurs in the fermenting of yeast, and other substances. Fermentation is, in one respect, a chemical process, forming a first step towards dissolution; but the action is also vegetative. The whole mass of matter gradually assumes the condition of active vegetative growth. The fungous germs which had been incorporated in the material, begin to live and expand, each being a plant which grows and gives rise to new plants of the same species, until the entire fermenting principle is exhausted.

Another great object which nature has in view by the germination and dispersal of the algæ, mosses, and lichens, is clearly that of preparing the way for a higher order of vegetation. It cannot possibly escape our observation, that the tendency to vegetate is a power restless and perpetual. We hew a stone from the quarry and place it in a damp situation, on the ground or in a wall, it is all the same which, and shortly a green hue begins to creep over it. This is the commencement of a vegetable growth, produced by germs floated in the atmosphere; and being attached at random to the stone, have been brought to life through the agency of the moisture. Other stones equally exposed, but in dry situations, have also received a clothing of these germs, but circumstances not being suitable, they have not been developed: give the moisture, and they will immediately appear. We hew another stone from the quarry, and build it into the pier of a bridge, just within the surface of the water. Shortly, the same kind of green algæ will appear; but the wet being in greater abundance, and more continuous, the growth will become more luxuriant. Instead of the simple green ooze, we have the addition of long filaments resembling hairs (*confervæ*), which float and accommodate themselves to the water around.

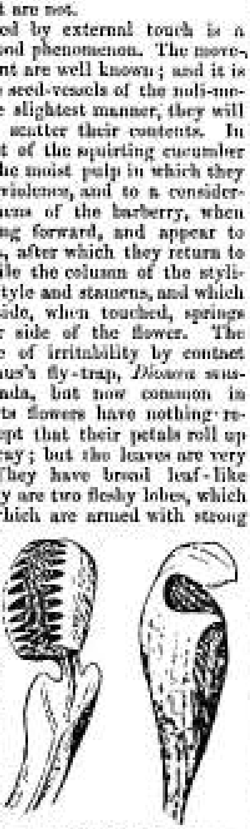
The inquiry may perhaps here be made—supposing that nature designs this species of growth to be a forerunner of a higher order of vegetation, how is that result to be brought about? To answer this we must take an expansive view of the subject, and not confine ourselves merely to one department of science. Nature is incessantly working out vast ends by humble and scarcely recognisable means. It seems to be a principle that nothing shall remain stationary or unchanged. The whole surface of our planet is every instant altering in its features. Mountains are being washed down into the plains, rocks are mouldering into soil, the sea is filling up at one place and encroaching on the land at another, and water-courses are constantly shifting their outlines. The duty of filling up seas, ponds, lakes, and rivers, is consigned to divers means within the animal and vegetable economy; and one of these is the growth of algæ and other aquatic plants. Take a pond of water, and shut off its means of supply from rivulets and springs, and then observe what an effort nature will make to fill it up. The sides and bottom become speedily covered with a luxuriant crop of confervæ; other plants, which grow only in water, begin to make their appearance, their seeds being wafted thither by winds; at length the superficial matting of herbage is able to support the weight of birds; grass grows; there is alternate vegetation and decay; finally, the pond is filled up, and a forest of the highest order of trees may in time cover the site of the original humble confervæ. What, indeed, are the extensive peat-mosses but lakes and pools choked with vegetable matter, which remains in a half-consumed condition. Thus we see that the green hair-like ooze which grows upon stones in the water, humble and apparently insignificant as it is, performs a distinct part in creation necessary to work out the important designs of Providence.

PHENOMENA OF VEGETATION.

In addition to the ordinary functions of the organs, which are the same in all plants of the same genus, there are certain anomalous functions which cannot be reduced to regular laws, and which differ in different species even of the same genus. The most remarkable of these are the occasional *irritability* of plants, their *colours*, *fragrance*, and *tastes*.

Irritability.—The irritability of animals depends entirely on their nervous system; but as plants have no nervous system, their irritability is more difficult to be accounted for. Dr Darwin, indeed, asserts that plants are only an inferior kind of animal, and that they, or at least some of them, have a brain and a stomach, and are endowed with the lower senses. According to this fanciful doctrine, the medulla or pith was made the seat of sensation, and was considered analogous to the spinal marrow of animals. The doctor, however, had no followers, as his hypothesis presented too many difficulties to be even partially believed. The principal phenomena of vegetable irritability may be divided into three kinds; namely, those caused by atmospheric influence, those depending upon the touch of other bodies, and those which appear to be perfectly spontaneous. Atmospheric influence occasions the closing of the leaves over the extreme point of the young shoot at night, as may be observed in the chickweed and several other common plants. The folding of some flowers in the absence of the sun, and the opening of others as soon as that luminary has withdrawn its beams, are ascribable to a similar cause. The white marigold closes its flowers on the approach of rain, and the dwarf calendrina folds up its bright crimson corolla about four o'clock every afternoon. The evening primrose, on the contrary, will not open its large yellow flowers till the sun has sunk below the horizon; and the night-blowing cereus only expands its magnificent blossoms about midnight. Some flowers are so regular in their hours of opening and shutting, that Linnæus formed what he called *Flora's Time-piece*, in which each hour was represented by the flower which opened or closed at that particular time. Solar light is the principal agent in producing these phenomena; but, in some cases, flowers have been known to open by artificial light. Decandolle found blossoms expand beneath a lamp nearly as well as beneath the sun itself; and the crocus-flower, which closes at night, has been known to expand as wide as possible when gently exposed to the light and heat of a fire. One of the most remarkable circumstances respecting the effect of atmospheric influences is, that the same causes do not affect all plants, and yet no peculiarity of construction has been discovered in those that are so affected to distinguish them from those that are not.

The irritability produced by external touch is a familiar but little understood phenomenon. The movements of the sensitive plant are well known; and it is also known that if the ripe seed-vessels of the noli-me-tangere be touched in the slightest manner, they will open with elasticity, and scatter their contents. In the same manner the fruit of the squirting cucumber throws out its seeds, and the moist pulp in which they are contained, with great violence, and to a considerable distance. The stamens of the barberry, when touched with a pin, spring forward, and appear to make a bow to the stigma, after which they return to their proper position; while the column of the stylidium, which includes the style and stamens, and which generally hangs on one side, when touched, springs with a jerk to the other side of the flower. The most remarkable instance of irritability by contact is that exhibited by Venus's fly-trap, *Dionæa muscipula*, a native of Canada, but now common in British conservatories. Its flowers have nothing remarkable about them, except that their petals roll up when they are about to decay; but the leaves are very curiously constructed. They have broad leaf-like petioles, at whose extremity are two fleshy lobes, which form the real leaf, and which are armed with strong sharp spines, three on the blade of each lobe, and a fringe of longer spines round the margin (*a*). When an insect touches the base of the central spines, the leaf collapses, and the poor insect is caught; being either impaled by the central spines, or entrapped by the others. The leaf then remains closed, the fringe of long spines being firmly interlaced and locked together, till the body of the insect has wasted away. This apparatus being the nearest approach to a stomach which has been yet observed in plants, an experiment was tried some years ago of feeding a dionæa with very small particles of raw meat, when it was found that the leaves closed in the same way as they would have done over an insect, and did not open again till the meat was consumed. Saracenia, or side-saddle flower, the leaves of which have a pitcher-shaped petiole (*b*), also decomposes flies and other insects caught in the pitcher—a peculiarity which seems to belong to all plants having pitcher-shaped leaves.



a, Leaf of Venus's Fly-trap; *b*, Leaf of Saracenia.

The spontaneous movements of plants are much more difficult to be accounted for than those occasioned by atmospheric phenomena, or by external touch. It is true that the leaves elongate, the flowers expand, the anthers burst, and the seed-vessels open spontaneously; but these are movements caused by the progressive development of the plant, and subjected to regular laws. The spontaneous movements which arise from irritability are quite different—as, for example, those of the leaves of *Hedysarum gyrans*. This plant has compound leaves, the terminal leaflet of which never moves except to fold itself close down to its own stalk; but the side leaflets have such eccentric movements, as to render it difficult, if not impossible, to explain them, and which might appear, indeed, to a fanciful mind as though the whole plant were actuated by a feeling of caprice. Generally, all the leaflets twist and whirl themselves about in an extraordinary manner, though the air of the house in which they grow is perfectly still; but frequently the leaflets on only one side will be affected, and sometimes only a single leaflet will move, or all will become motionless together; and when this is the case, it is quite in vain to attempt to set them again in motion by touching them; though sometimes in a moment, as if from the pure love of mischief, after the touching has ceased, the leaflets will begin to move again as rapidly as before. In the like manner, the side leaflets frequently continue their eccentric movements all night, while the terminal leaflet remains quietly folded up, and apparently fast asleep. Cold water poured upon this plant stops the motion of the leaves, but it is renewed as soon as the heat of the stove in which the plant grows has converted the water into vapour. Movements analogous to those of the hedysarum and other foreign plants have been detected by M. Dutrochet in several common vegetables, as the garden pea and cucumber; and he attributes them to an interior and vital excitation, and not at all to the action of light, which is opposed to, and, if vivid, arrests them.

Plants may be deprived of their irritability by keeping them without water, when they become flaccid; or by watering them with a poisonous liquid, in which case they lose not only their irritability, but their lives. Life, indeed, appears to be intimately connected with irritability, as the latter quality exists only in plants in a vigorous and healthy condition. The functions of vitality and irritability may be merely suspended without destroying life, by administering to them the same substances—opium, vapour of ether, &c.—which produce stupor in animals.

Colour.—The colour of plants generally depends on the presence of a substance called *chromule*, which is deposited in minute granules in the vesicles of the cellular tissue. This substance consists of pure carbon, which has been *fixed*, as physiologists term it, by the decomposition of the carbonic acid gas absorbed by the plant; the oxygen escaping again into the atmosphere, while the carbon is permanently assimilated. Both the absorption and decomposition of carbonic acid take place most effectively under the influence of solar light; hence plants grown in darkness become etiolated, or blanched. The chromule in all plants being the same, it is difficult to explain why leaves should be green, and flowers of so many varied hues; indeed, the cause is as yet but very imperfectly understood. It is found, however, that when the leaves first expand, and are of the brightest green, the grains of chromule are always surrounded by a thin film of gluten, the principal ingredient in which is nitrogen. In autumn, the gluten and carbon generally have both disappeared, particularly in plants which contain a notable amount of acid, the basis of which is oxygen. In proportion as the oxygen predominates, the leaves become red; hence the beautiful tints of red and crimson taken by some leaves in autumn. When the carbon disappears without the nitrogen, as is frequently the case, the leaves become yellow in autumn. It has been observed that the leaves of plants always turn yellow, red, crimson, or violet, and never blue; and this corresponds with the above theory, as the carbon, which is dark, is carried out of the leaves by the descending sap, and its place partially supplied by oxygen. Thus red, which is the colour produced by oxygen, predominates in decaying leaves; and violet, which implies a mixture of carbon, is only found in the dying leaves of the American white oak. The lime, and other trees which abound in mucilage, or gluten, further corroborate this theory, in having their decaying leaves yellow. In all cases, the colouring matter is not in the sap, which is either colourless, or tinged faintly with yellow, but in the cellular tissue; and thus, while the stem consists chiefly of cellular tissue, it is as green as the leaves.

The colours of flowers are more difficult to be accounted for than those of leaves, as they are evidently influenced by the soil in which the plants are grown more than by solar light. Mineral substances, particularly iron and manganese, are found abundantly in white flowers when burned; and it is known that many a common British weed, particularly the herb "Robert," varies from a dark rose colour to almost white, according to the soil in which it grows. Flowers grown in the shade are, however, seldom different in colour from those fully exposed to the air and light. The petals of the common buttercup, and the lesser celandrine, are of as brilliant a yellow in town gardens enveloped in the smoke of London, as on any country hill; and roses always maintain their brilliant tints, even when the bushes on which they are produced are evidently dying for want of a clear atmosphere. Flowers may be made to change their colours by the influence of the soil in a most remarkable manner. The petals of the common hydrangea, which are naturally pink, may be made blue by planting the shrub in soil impregnated with iron. The change produced in tulips, carnations, heart-eases, &c. is still more extraordinary. The flower of a seedling tulip is generally of a dull brownish crimson; and after remaining of this colour two or three seasons, it will suddenly *break*, as the florists term it, into the most brilliant and varied tints of rose, white, yellow, brown, or purple, without leaving any trace of the original colour. To produce this change, florists try a variety of means, all of which have relation to the soil; for example, they sometimes keep their tulips in poor soil, and then suddenly transplant them into one exceedingly rich; or they reverse the process: at other times they change them suddenly from a sandy to a clayey soil. As a further proof that light is not the sole cause of colour in plants, it is well known that ferns and mosses have been found green in mines where they have grown in total darkness; and green and red seaweeds of the most brilliant tints are frequently washed up from the bottom of the sea, where the light, being weakened by passing through such an immense body of water, can have but little effect in producing colour.

The colouring matter extracted from vegetables is of great economical value, being extensively used in the art of dyeing. Some of these dyes are the same with the natural colour of the parts from which they are derived; such as saffron, which is the yellow stigma of a species of crocus; but others are totally dissimilar, being blue or black, when the native vegetable texture is green!

Fragrance.—The cause of fragrance in flowers has never yet been fully explained. We know that all organised bodies consist partly of volatile matters, and thus we can readily account for the odours given out by decaying animal and vegetable substances, as they evidently proceed from the volatile parts being liberated by decomposition. The fragrance of flowers, however, escapes while the plants are in a living state, and that most abundantly when they are in vigorous and healthy condition. Besides the flowers, other parts of living plants frequently exhale fragrant odours—such as the leaves of the myrtle and geranium, and the wood and bark of pines. All these odours proceed from oily or resinous matters contained in the receptacles of secretion; but the laws which regulate their liberation, and define their physiological uses, are as yet imperfectly known. Some botanists consider them to be part of the excrementitious matter which is thrown off by plants, when it is no longer necessary to their growth; but if this were the case, the exhalation would continue the same during the whole period of growth, and not vary, as it does, at different seasons, and according to the state of the weather. It is well known that plants are most fragrant in damp weather; and some botanists have attempted to account for this by supposing, that the tissue being relaxed at such seasons, the stomata, or pores, open wider than at other times, and thus permit the escape of a greater quantity of the fluid. Trinchinetti thinks that the use of the odours of flowers is to ward off vapour, which might prevent the diffusion of the pollen; and it is thus that he accounts for the increase of the odour by damp. This explanation appears plausible; but neither it nor any of the others which have been suggested, will explain why the petals of roses, and other flowers, retain their fragrance when dried. The use of fragrance in leaves, bark, and wood, is apparently to preserve them from the attacks of insects; as we find that the smell of the red and Bermuda cedars, of which pencils are made, and of camphor (also a vegetable product), are sufficient to keep the moth from attacking substances with which these are in contact.

The odours of plants are of three kinds—permanent, fugitive, and intermittent. Permanent odours are those given out slowly by the plant, not only whilst it is living, but also after the fragrant part has been separated from the root, though it be not in a state of decay. Of this kind are the odours of fragrant wood, of the dried petals of roses, and some other flowers. In these cases the receptacles of secretion are generally buried so deeply in the tissue, that the essential oil with which they are filled can only escape slowly, and in very small quantities. In some cases, indeed, the receptacles of secretion are so deeply seated, that the wood to which they belong appears devoid of scent, till its essential oil is volatilised by exposure to heat. Fugitive odours arise from essential oils contained in receptacles just below the epidermis; and when there is only a minute quantity of oil in each cavity, the duration of the fragrance is correspondingly short. Intermittent odours are the most difficult to be accounted for by the vegetable physiologist. It is only known that the night-smelling stock, the Indian jasmine, and several other plants, which are entirely devoid of scent during the day, are delightfully fragrant during the night. One of the orchideous plants produces its powerful aromatic scent only when exposed to the direct rays of the sun; and the night-blowing cereus is fragrant only at intervals of about half an hour during the time of its expansion, preserving the same kind of intermittence even when separated from the stem.

Tastes.—The tastes produced by vegetable substances are generally recognised as sweet, acid, bitter, astringent, austere, or acrid. The juice of the sugar-cane, for example, is sweet, that of an unripe apple acid, the aloe bitter, the leaf of the bramble astringent, and the cranberry austere. It has been already stated that the ascending sap is at first insipid, and that it gradually acquires the peculiar taste of the plant; but it is only in the descending juice that the taste-yielding principle is fully developed. Why the taste of one vegetable should differ from that of another grown in the same soil, the physiologist is unable to determine;

he as yet only understands a few of the causes by which tastes may be modified or destroyed. The principal influences which modify the tastes of plants are atmospheric and solar; light, exposure, and warmth, being those under which taste, as well as all other qualities of vegetables, are most fully developed. Every one is acquainted with the blanching effects of *earthing*, as exhibited in celery, or in the shoots of the common rhubarb. The fruits grown in our own island during a wet and sunless season are insipid compared with what they are in a dry and bright summer; and the general vegetation of the arctic and temperate regions is less powerful in kind than that of the tropics. Even the successive periods of a day exercise an influence on the tastes of growing plants, according as they are stimulated by solar light to absorb or exhale oxygen—the principle on which the peculiarities of taste greatly depend. As a general law, it may be stated, that the drier and warmer the situation, the more exposed to light, and the slower the growth of any vegetable, the more intense is its peculiar flavour. The physiological uses of the different tastes are as imperfectly understood as the causes which produce them. Some of them may be given for the preservation of the vegetable against the attacks of animals at certain seasons of its growth, whilst others seem as directly bestowed to render plants agreeable to the animals destined to consume them.

Luminosity, heat, electricity.—The luminosity of plants—that is, the evolution of light either from living or dead vegetable structure—is a rare and curious phenomenon. Flowers of an orange colour, as the marigold and nasturtium, occasionally present a luminous appearance on still, warm evenings; this light being either in the form of slight electric-like sparks, or steadier, like the phosphorescence of the glow-worm. Certain fungi, which grow in warm and moist situations, produce a similar phosphorescence; and decaying vegetables, like dead animal matter, have been observed to emit the same kind of luminosity. This phenomenon seems connected with the absorption of oxygen; and the parts emitting it are most luminous when immersed in pure oxygen, and cease to emit it when excluded from that element. Luminosity is sometimes occasioned by actual combustion of the volatile oils, which are continually flying off from certain plants: those of the *Dictamnus albus* will inflame upon the application of fire.

The evolution of heat by living plants is a more common phenomenon. We are aware that warm-blooded animals have the power of keeping up a certain temperature within them, which varies at certain stages of their growth, and perhaps periodically. This result is obtained by respiration—the oxygen of the atmosphere uniting with the carbon of their blood, and producing a species of combustion. A similar, though less understood phenomenon, seems to take place in the respiration of plants. In germination, heat is sensibly evolved: a piece of ice placed on a growing leaf-bud will dissolve, when it would remain unchanged in the open air; and experiment has proved that the surface of plants is three or four degrees higher than the surrounding medium. Again, the internal temperature of a large trunk is always higher than the surrounding atmosphere, and though young shoots are sometimes frozen through, the general structure both of the wood and bark is such as to conduct heat so slowly, that the internal warmth is never reduced beyond what seems necessary to vitality. Generally speaking, it may be asserted that plants possess an internal vital temperature, and that, in the process of respiration (the giving off of carbonic acid or oxygen, as the case may be), a certain degree of heat is always evolved.

The connection of electricity with vegetable growth has recently excited the attention of physiologists; but little positive information has yet been ascertained. It has been long known that growth takes place with great rapidity during thundery weather; but this may result from the nitrogenised products of the showers which then fall, as well as from the effects of electricity. The progressive states of vegetable growth are the result of chemical changes; and as these changes are more or less accompanied by electricity, it is supposed that plants evolve electricity as well as heat. The conversion of water into steam is followed by a sensible evolution of electricity; and the evaporation which takes place from the surface of rapidly-growing leaves, produces the same phenomenon. The general electric state of plants is said to be *negative;* and some have attempted to connect the luxuriant vegetation of the tropics with the thunder-storms of these regions, on the supposition that when the atmosphere is *positively* electrified, the two opposite states will give rise to such commotions. Of late years attempts have been made to apply the principle to agriculture; conducting wires have been laid around experimental plots, but with such varied, and even contradictory results, as to preclude anything like a determinate conclusion.

SECRETIONS OF PLANTS.

Substances possessed of various properties are secreted by plants, according to their respective natures, and their healthy or diseased condition at the time of secretion. Some of these substances are produced by the ascending sap; but the greater number are deposited by the elaborated or proper juice, and consequently are never secreted during spring or early summer. The intensity of those derived from the latter source depends in a great measure upon the influence of solar light; hence they are much stronger, and more abundantly produced, in tropical than in temperate climates. Most of them being derived from the true or arterial sap, they would seem to serve some purpose in the reproduction or nourishment of the plant; but others, from the manner in which they are deposited or ejected, appear to be of no utility in the vegetable economy. Some of them are *excretions* as well as *secretions;* but whether they are to be considered as essential components of the sap, or evacuations necessary to the healthy condition of the secreting organs, has not yet been determined. Being exceedingly varied in their properties, they are of great utility to man, either as articles of food, clothing, medicine, ornament, or luxury.

The economical applications of vegetable secretions and excretions are so numerous, that it would be absurd, in our limited space, to enter upon anything like details. It is even difficult to attempt any classification of them; for, though differing in their properties and external appearance, many of them are identical in chemical composition, and, subjected to peculiar treatment, readily pass into new and similar combinations. Some, for instance, are farinaceous, as barley; while others are saccharine, as the juice of the sugar-cane; and yet both, when subjected to fermentation, produce similar liquors. Many are oleaginous, balsamic, or resinous; some are narcotic, aromatic, or mucilaginous; while others are astringent, purgative, or poisonous. For examples of these divisions, the reader has only to recall to mind such substances as palm and olive-oil, myrrh, resin, opium, camphor, gum-arabic, tannin, gamboge, prussic-acid, aloes, colocynth, and a thousand others of every-day familiarity.

Besides the proper excretions and secretions, there are several adventitious substances found in plants, which are not the products of vital organisation. Lime, for instance, is found in the ashes of many plants in union with acids, and sometimes it is excreted in the form of a thin crust on their leaves. Silica also occurs in considerable quantities, especially in the stems of reeds and grasses; it forms the glossy pellicle of the cane, and is sometimes found in the joints of the bamboo, where it is deposited in a soft pasty mass, called *tabasheer*, which ultimately hardens into pure semi-transparent silica. Besides these earths, there are various metallic oxides and salts, and the well-known alkalies—potash and soda. The physiological uses of such products are but imperfectly known to physiologists. Many of them—such as starch, gum, sugar, and the fixed oils—directly administer to the support of the young plant and to the formation of new tissues; while those which yield flavour and aroma seem to be connected with the preservation of plants, by protecting them from the depredations of insects and other animals. Others, again, such as silica and metallic oxides, give hardness and stability to the stems and branches; some give elasticity and pliancy to the young shoots, thereby preventing them from being broken by winds; and several seem to administer to the durability of the woody fibre, by their properties of resisting putrefaction.

METAMORPHOSES OF PLANTS.

The metamorphoses of plants forms one of the most interesting sections of vegetable physiology. Technically, it is termed *Morphology*—that is, a consideration of the changes and transformations which various parts of plants undergo, either from natural or artificial causes. We know, for instance, that many plants are made to change their appearance and qualities by cultivation; that by grafting, hybridising, and so on, the gardener can change the size, colour, and qualities of his fruits and flowers; and that analogous changes take place in a state of nature—such as the conversion of leaves into petals, and leaves and branches into thorns and spines. It is also well known that flowers become double by changing their stamens into petals; and it is from a knowledge of these facts, that botanists have asserted that all the appendages of the stem or ascending axis are modifications of a single organ, and may be considered *as leaves adapted to a special purpose.* This doctrine, at first broached by Linnæus, and subsequently expounded by the German poet Göthe, is now very generally adopted. It is usual to treat of this subject under two heads—namely, *regular* metamorphosis, or that connected with the structure of all vegetables; and *irregular* metamorphosis, or that which influences only a particular class of plants, or parts of these plants, and which occur under peculiar circumstances.

Regular metamorphosis seeks for facts to establish the doctrine, that all the appendages of a plant have a common origin with the leaf, and may therefore successively assume the form and appearance of that primary organ. The first protrusion of the plumule from the embryo is leaf-like, subsequently true leaves are developed, and from a succession of these are formed the stem. The branches of the stem take their origin from leaf-buds, and are again clothed with branches and leaves by the same process as in the main stem. As a branch proceeds towards the point of fructification, the leaves assume the form of bracts; these, again, are succeeded by the leaf-like sepals of the calyx; and next by the petals of the corolla. Within the petals are the stamens—which sometimes assume a leafy form—next the pistil, and ultimately the seed-vessels. Even the seeds are but leaves in another form, embalmed and preserved, as it were, for the reproduction of another plant; and in many, such as the beech-mast, the leaflets of the embryo may be distinctly seen, folded and imbedded in their future nutriment. Thus the growth and reproduction of plants may be regarded as a circle of leaf-like changes, the leaf, or some modification of it, being in all cases the organ which administers to the functions of vitality. We need not enumerate instances of these conversions, for every one who has intelligently observed the common garden-plants around him, must have sometimes felt the difficulty of distinguishing between calyx and corolla, must have seen stamens assume the aspect of petals, and not unfrequently the whole floral organ appear green and leafy. And just as there is an indubitable passage from leaves to every other organ, so may any one organ be found to revert to the primary form of the leaf.

Of irregular metamorphosis, or those changes which parts of plants, or classes of plants, may be made to assume, little is absolutely known. In a state of nature, certain tribes are limited to certain localities, these situations being characterised by some peculiarity of soil and atmospheric influence. If the conditions of soil and climate to which they are subjected remain the same, the character of plants is nearly uniform or stationary; and this may be always said of them in their natural state. But if they be removed from a poor to a rich soil, from a dry to a moist habitat, from a warm to a cold climate, or *vice versâ*, then their internal structure will undergo a change; and this change will manifest itself in one or other of their external characters. In some classes, this change is most evident in the roots and tubers; in others, in the stems and leaves; while in many the organs of fructification (the flowers and fruit) are the parts most affected. Sometimes this change of situation merely produces a more luxuriant development of all the parts of a plant, without causing any abnormal growth of a particular organ. Cultivation, and other artificial treatment, may be considered as the cause of these irregular metamorphoses, which assume in some plants a wonderful degree of permanency, and may be transmitted to successive races; though, generally speaking, if the artificial stimulus be not kept up, plants will return to their normal or natural condition. There are no such roots or tubers in nature as our cultivated beet, carrot, potato, and parsnip; no leaves like the thick succulent *hearting* of the cabbage; no flowers like our double roses, carnations, and ranunculuses; and no fruits or grains like our delicious pears, apples, and cereals.

The hybridism of plants is closely allied to the subject of morphology, and is, in fact, a transformation of character produced by artificial means. As among animals two distinct species of the same genus will produce an intermediate offspring—such as the *mule*, which is the offspring of the horse and ass—so among vegetables two species belonging to the same genus can be made to produce a *hybrid;* that is, a new plant possessed of characters intermediate between its parents. This power of hybridising is more prevalent among vegetables than animals; for the different species of almost every genus of plants are capable of producing this effect, if the pollen of one species be put upon the stigma of another. The union, however, can only take place between nearly allied species, occurs rarely among plants in a wild state, but is quite common among cultivated species. According to modern botanists, the character of the female parent predominates in the flowers and organs of fructification of the hybrid, while its foliage and general constitution are those of the male parent. Hybrids have not the power of perpetuating their kind like naturally-distinct species; for, though occasionally fertile in the second and third generations, they have never been known to continue so beyond the fourth. But though incapable of propagating themselves beyond a very limited period, the pollen of the parent species may be made to fertilise them, or their pollen to fertilise the parent; but in either case the new offspring gradually merges into the original species. Thus nature has wisely set a limit to the intermingling of species, by which they are preserved from ultimately running into confusion and disorder.

In an economical point of view, hybridism is of great value to man. By a knowledge of its principles he has been enabled to modify the characters of natural species, so as to adapt them to his special purposes; and thus have arisen most of those beautiful sorts and varieties of blossom which now adorn the flower-garden. So, also, by crossing varieties of the same species, our grains, fruits, and kitchen vegetables have been brought to a high state of perfection. The size of one species has been assiduously amalgamated with the durability of another; the beauty of a third with the flavour or odour of a fourth; and so on with other qualities. The principles of hybridism will yet be more extensively applied; and it is not too much to expect that the perfection of our field and forest produce will yet rival that of our orchards and gardens.

SYSTEMATIC BOTANY.

Botany—derived from the Greek word *Botané*, a plant—is that science which includes the study and investigation of the vegetable kingdom. *Vegetable Physiology*—treated in the preceding sheet—is that department of the subject which explains the organisation and vital functions of plants; *Systematic Botany* that which recognises their arrangement into orders, tribes, genera, and species, according to their respective forms and qualities. The former relates to functions which are common to all vegetables, the latter takes notice only of such peculiarities and attributes as serve to distinguish one individual from another, or one family from another family. The vegetable kingdom is supposed to contain upwards of 100,000 species; and therefore, without some system of arrangement into smaller groups and orders, it would be difficult to acquire a knowledge of the special characteristics of plants, or to convey that knowledge to others by any process of description. It is the aim of Systematic Botany to obviate this difficulty, by classifying plants according to certain types and resemblances which are common to a number of individuals; thus making one description equally applicable to a class as to an individual.

The advantages of classification, in lessening the labour of memory and description, become strikingly apparent when we reflect on the difficulty which would exist were each plant to be known by an entirely distinct name. For example, there are many species of roses, all of which are known by the generic term *Rosa*, each having a second or specific name to designate it separately, as *R. centifolia*, *R. damascena*, &c. Now, if a botanist hear of a plant called *Rosa*, though its specific name be quite new to him, he has instantly a general idea of what sort of plant it is, from his previous knowledge of the common characteristics which belong to the *genus Rosa*. The principle of classification is to assemble those plants which bear most resemblance to each other; and this has been done in different ways by different botanists; each method being called the *system* of the individual who devised it—as Tournefort's system, Linnæus's system, Jussieu's system. Of the several systems which have been suggested, only two are in use at the present time—namely, that of Linnæus, the great Swedish naturalist (1707-1778); and that of Jussieu—or rather a modification of that of Jussieu—an eminent French botanist, who, during the long period between 1770 and 1836, was closely engaged in improving the nomenclature and arrangement of the vegetable kingdom.

The system of Linnæus is founded solely on what are called the *sexes* in plants—that is, on the number, situation, proportion, and connection of stamens and pistils, which are regarded as respectively the male and female organs. This system appears at first sight extremely simple, as it depends entirely on counting so many visible parts; but it is very uncertain, as the number of stamens often differ, from accidental circumstances, in plants of the same genus; and it tells nothing of the plant but its class and order, which lead only to the discovery of its technical name, as plants of the most opposite qualities frequently agree in the number and disposal of their sexual organs. This mode of classification is known among botanists as the Sexual System, or the *Artificial System*, because it is founded on mere artificial enumeration, and not upon natural qualities or resemblances of the plants so arranged. That of Jussieu, on the contrary, is founded on the natural analogies of vegetables; and the botanist who is acquainted with its principles, can at first sight assign any plant to its proper class and order, as there is always a general resemblance among the plants belonging to the same natural order. Again, knowing the order, which is usually typified by some common plant, he can predict as to its qualities—a species of information which the artificial system does not attempt to convey. Jussieu's method has been greatly improved since the time it was suggested, particularly by the late Professor Decandolle of Geneva; and it is his modification of the original plan, with some further improvements, which constitutes the most generally adopted *Natural System* of the present day.

According to both systems, plants are divided into classes, orders, genera, species, and varieties. A *class* consists of plants resembling each other in some grand leading feature, and as strongly differing from another class as mammalia do from birds. Thus flowering plants with one cotyledon, whose trunks increase in thickness from within, as the palm, form a distinct class; while flowering plants with two cotyledons, and whose trunks increase by external layers, constitute another class. An *order* consists of plants still more closely allied, so that many orders may be found in the same class. Thus, as ruminant or cud-chewing animals form an order of mammalia, so do the leguminous or pod-bearing plants constitute an order of dicotyledonous vegetation. A *genus* consists of plants so very closely allied, that they may be compared to members of the same family. The pea, for example, constitutes a genus of leguminous plants, just as sheep form a family of the ruminants. A *species* may be compared to one of the members which compose the family; thus the garden-pea and sea-pea are different species of the same genus. A *variety* is merely a departure from the common appearance of the species, as regards colour of the flower, height of stem, or the like—differences which arise from climate, situation, greater or less humidity of soil, and other accidental causes. The boundaries between species and varieties are often very vague, some botanists regarding those plants as species which are mere varieties; but much doubt might be removed by attending to the fact, that a species reproduces itself from seed, and is always persistent under the same circumstances, whereas a variety has always a tendency to revert to its parent species, unless propagated by cuttings, and fostered by other artificial means. A *hybrid* is a plant raised by fecundating the stigma of one species with the pollen of another—a process which rarely occurs among plants in a wild state, though quite common in cultivation. In gardeners' catalogues, hybrids are generally ranked as species; but unless perpetuated by artificial processes, they all soon die out, or revert to their original stock. A *cross-breed* is a plant raised between two varieties of the same species, and generally ranks as a variety.

When there are two botanic names to a plant, the first is that of the genus, and the second that of the species—as, for example, *Quercus alba*, the white oak. When three names are given, the third signifies that the plant is a variety; and this is sometimes more strongly marked by using the contraction *var.* before the third name—as *Quercus ilex* var. *crispa*, the curled-leaved variety of that tree. Unless, however, the variety be of considerable importance, the third name is for the most part omitted in botanical catalogues, and the varieties indicated by figures, or by letters of the Greek alphabet—observing that the species is always reckoned as one, and that the varieties begin with the figure 2, or the letter β.

The primary arrangement of plants, according both to the artificial and natural system, is into those with flowers and those without flowers. The first division, or that which includes the flowering plants, is distinguished by the name Phanogamia, because in them the organs of reproduction are apparent. It comprehends all the trees and shrubs used in the economical arts, all the ornamental plants of our gardens, and, in short, all those that have distinct organs—as leaves, branches, flowers, and seeds. The second division, known by the term CRYPTOGAMIA, embraces, as the name implies, those plants in which the organs of reproduction are not apparent—as the lichens, mosses, and seaweeds. They have no leaves, flowers, or seeds, in the common acceptation of these words, their *fronds* or leaves being very different from those of flowering plants; and instead of flowers, fruit, and seed, they are furnished with little cases or *thecæ*, attached to their fronds, and in these are lodged the spores or embryo plants, minute as the particles of the finest dust. Here the resemblance between the two systems ceases—their classes and orders being arranged on totally different principles. We shall present, in the first place, an outline of the Linnæan system, both on account of its priority and simplicity, and as an initiatory step to gaining a knowledge of the different forms of flowers. It is true that it is now disused by most men of science; but for the reasons stated, as well as from the fact, that many excellent works have been arranged on its plan, it is necessary that the general reader should have some acquaintance with its leading features.

We must premonish, however, that Systematic Botany has no very alluring aspect to a beginner. The great number of titles of the classes and orders, to say nothing of the generic and specific names, is a bar to commencing the study; but when set about in earnest, first difficulties quickly vanish—the subject becomes every day more and more interesting; every new plant is sought and examined with avidity; research is no longer toil; and every accession to the previous stock of knowledge is attended by fresh gratification. 'The standing objection to botany has always been,' says White of Selborne, 'that it is a pursuit which amuses the fancy, and exercises the memory, without improving the mind or advancing any real knowledge; and where the science is carried no farther than a mere systematic classification, the charge is but too true. But the botanist who is desirous of wiping off this aspersion, should be by no means content with a list of names; he should study plants philosophically; should investigate the laws of vegetation; should examine the powers and virtues of efficacious herbs; should promote their cultivation; and graft the gardener, the planter, and the husbandman, on the phytologist: not that system is by any means to be thrown aside: without system, the field of nature would be a pathless wilderness; but system should be subservient to, not the main object of, our pursuit.'

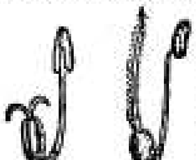
THE LINNÆAN SYSTEM.

The sexuality of plants had been discovered long before the time of Linnæus; but as far as is now known, he was the first who suggested the adoption of this characteristic as a basis of classification. According to his system, the vegetable kingdom is divided into twenty-four *Classes*, founded upon the number, the proportionate lengths, the connection, or the situation of the stamens. These classes are again subdivided each into one or more *Orders* depending upon the number of the pistils, the presence or absence of a seed-vessel, its shape, or the number and connection of the stamens, or on the arrangement of the florets. Terms compounded of the Greek numerals and the word *andria*, signifying man or male, are, for the most part, used to designate the classes; and similar compounds of these numerals, and the word *gynia*, which signifies woman or female, are employed to designate the orders. The following synopsis presents at one view an outline of the system:—

CLASSES.			ORDERS.
1. Monandria,	1 stamen,	has 2	— Monogynia and Digynia, or 1 and 2 pistils.
2. Diandria,	2 stamens,	... 3	— Monogynia, Digynia, and Trigynia.
3. Triandria,	3 ...	... 3	— Monogynia, Digynia, and Trigynia.
4. Tetrandria,	4 ...	... 3	— Monogynia, Digynia, and Tetragynia.
5. Pentandria,	5 ...	... 7	— Mono., Di., Tri., Tetra., Pentagynia, and Polygynia.
6. Hexandria,	6 ...	... 4	— Monogynia, Digynia, Trigynia, and Polygynia.
7. Heptandria,	7 ...	... 4	— Monogynia, Digynia, Tetragynia, and Heptagynia.
8. Octandria,	8 ...	... 4	— Monogynia, Digynia, Trigynia, and Tetragynia.
9. Enneandria,	9 ...	... 3	— Monogynia, Trigynia, and Hexagynia.
10. Decandria,	10 ...	... 5	— Monogynia, Digynia, Trigynia, Pentag., and Decagynia.
11. Dodecandria,	from 12 to 19 ...	... 7	— Mono., Di., Tri., Tetra., Penta., Hexa., and Dodecagynia.
12. Icosandria,	... 20 or more ... on the corolla or calyx,	... 3	— Monogynia, Digynia, Pentagynia, and Polygynia.
13. Polyandria,	... 20 or more ... on the receptacle,	... 6	— Mono., Di., Tri., Tetra., Pentagynia, and Polygynia.
14. Didynamia,	4 ... 2 long and 2 short,	... 2	— Gymnospermia and Angiospermia.
15. Tetradynamia,	6 ... 4 long and 2 short,	... 2	— Siliculosa and Siliquosa.
16. Monadelphia, all the filaments united,		... 8	— Tri., Pent., Hex., Hept., Oct., Dec., Dodec., and Polyand.
17. Diadelphia, filaments united into two sets,		... 4	— Pentandria, Hexandria, Octandria, and Decandria.
18. Polyadelphia, filaments in three or more sets,		... 2	— Decandria and Polyandria.
19. Syngenesia, five stamens united by their anthers,		... 5	— Polyg., Æqualis, Superfl., Necess., Frustan., Segregata.
20. Gynandria, the stamens growing on the pistil,		... 3	— Monandria, Diandria, and Hexandria.
21. Monœcia, flowers with stam., others with pist. on same plant...		10	— Mon., Tri., Tet., Pen., Hex., Oct., Icos., Polyan., Monad.
22. Diœcia, stamens on one plant, and pistils on another,		... 13	— Mo. Di. Tr. Tet. Pen. Hex. Oc. En. Dec. Do. Ic. Polyand., [and Monadelphia.
23. Polygamia, unisex. or bisex. flowers on same or diff. plants,...		2	— Monœcia, Diœcia.
24. Cryptogamia—inconspicuous flowers,		... 4	— Filices, Musci, Fungi., and Algæ (now extended).

I.—MONANDRIA.

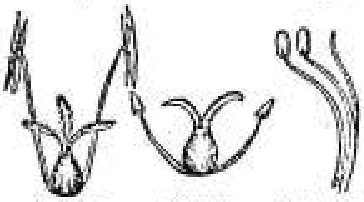
Flowers with one stamen, and with one or two pistils; thus constituting two orders, of which there are thirty-three genera, and above two hundred and fifty species. The first order, MONOGYNIA, contains many highly ornamental exotics, chiefly reed-looking herbaceous plants, with large leaves and showy flowers. The seeds and roots of many of these are used in medicine, as well as by the dyer—as galangale, tumeric, arrowroot, zedoary, and *Zingiber officinale*, the common ginger of commerce. Their predominating qualities are aromatic. Several of the genera are British—as hippuris, glass-wort, and wrack-grass. The second order, DIGYNIA, contains seven genera, one of which is *callitriche*, the water starwort, frequently met with in our ditches. There is another plant, sometimes sown in borders as an ornamental annual, which also belongs to it—namely, *Blitum capitatum*, the strawberry blite. Its chief ornament is its fruit, which is thickly set on its branches, resembling strawberries; hence its name.



Digynia. Monogynia.

II.—DIANDRIA.

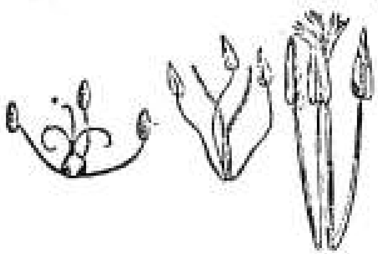
Flowers with two stamens, and with one, two, or three pistils; thus constituting three orders, of which there are upwards of sixty genera. The first order, MONOGYNIA, contains by far the greater number of the genera. Here we find the useful olive, the fragrant jasmine, the lilac, the fringe-tree, the catalpa, and many evergreen shrubs. Nor are the herbaceous members of the order less prized: the wild and cultivated speedwells, the delicate schizanthus, the showy justilias, and the elegant slipperwort, are some of the choicest gifts of Flora. The rosemary, and the numerous species of sage, are ranked in this order, though some botanists have suggested the removal of the latter plant to the class Didynamia, because, in addition to the two perfect stamens, there are the rudiments of two others in the flower. The second order, Digynia, which contains only three genera, are properly grasses—as the *Anthoxanthum odoratum*, which so greatly assists in giving hay its agreeable scent. In the third order, Trigynia, there are only two nearly allied genera—namely, *piper* and *peperomia*. The first is universally used as a spice, and is extensively cultivated in the East Indies as a most important article of commerce.



Trigynia. Digynia. Monogynia.

III.—TRIANDRIA.

Flowers with three stamens, and with one, two, or three pistils; thus constituting three orders, which embrace considerably more than two hundred genera. Almost all the grasses, as well as the grain-bearing *cereals*, are found in this class. Nor are the other genera less remarkable for the beauty of their flowers, than are the grasses and cereals for their usefulness. The well-known crocus, the corn-flag, and iris, and many allied foreign genera, are among the chief ornaments of our gardens, and which compensates in some measure for their want of usefulness when compared

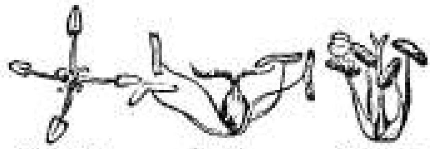


Trigynia. Digynia. Monogynia.

with their associates the cereals. No class shows more decidedly the artificial character of the Linnæan system than this; for assuredly the iris and wheat can claim no congeniality with each other, either in external structure or constitutional properties; but these having each three stamens, compelled the author to place them together. The second order, Digynia, contains most of our common grasses—as millet, panic grass, bent grass, fox and cat's-tail, oat and cock's-foot grasses, besides wheat, barley, &c. together with the far-famed sugar-cane, that source of wealth to the tropical planter, and indispensable condiment in the diet of all nations. The third order, Trigynia, contains only twelve genera, most of which are aquatic annual weeds; some are curious or pretty, but none are cultivated out of botanical collections.

IV.—TETRANDRIA.

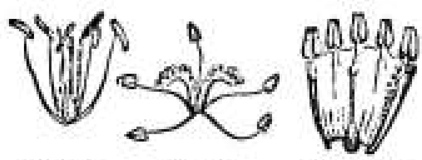
Flowers with four stamens *of equal length*, and with one, two, or three pistils, thus forming three orders, in which there are upwards of one hundred and thirty genera. The equal length of the stamens should be specially kept in mind, because the fourteenth class (*Didynamia*) has also four stamens, but of these two are longer than the others. Many of the genera in the order Monogynia are beautiful shrubs and trees, chiefly natives of the Cape of Good Hope and New Holland—as the *Proteas*, *Hakias*, *Banksias*, and the splendid waratah or *Telopia speciosissima*. Several fine ornamental Chinese shrubs—as the *Ixoras*, for instance—belong to this class, as well as many hardy plants, both shrubs and herbs, natives of Europe. The second, Digynia, contains only four genera, one of which is a British annual, *Buffonia tenuifolia*; named after the celebrated naturalist Count de Buffon. The witch-hazel, a hardy North American tree, is also placed in this order. The third order, Tetragynia, is also small, containing only eleven genera. Among these we find the well-known holly, which as a hedge plant and ornamental evergreen is unrivalled. Its timber, when it has attained full size, is solid, white, and of remarkably fine grain, and much used by musical instrument-makers and other artists. The common pond-weed, *Potamogeton natans*, so frequent in our slow-running rivers, also belongs to this order.



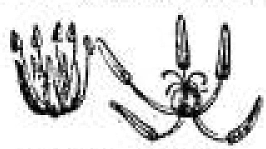
Tetragynia. Digynia. Monogynia.

V.—PENTANDRIA.

Flowers with five stamens, and with one, two, three, four, five, or many pistils; thus forming one of the most extensive of the Linnæan classes. The first order, Monogynia, is particularly abundant both in genera and species. Every description of flowering plant is found here—trees, shrubs, and herbs, terrestrial and aquatic; trailers, creepers, and climbers; annuals, biennials, and perennials; deciduous and evergreen. The second, Digynia, is also a large order, and comprises many beautiful and useful plants. Here we find the *Asclepias*, with its curiously constructed flowers, and the no less remarkable *Stapelia*, a family of leafless plants, but bearing flowers of uncommon character both in shape and colour, and, moreover, diffusing a scent so loathsome, that blowflies lay their eggs on the petals! Here also we find the remarkable English parasitical plant, the dodder, *Cuscuta Europæa*, and the stately elm-tree, so useful both for ornament and timber. The third order, Trigynia, embraces the ornamental laurustine, the elder, and other well-known plants. The sumach family, so variously useful in the arts, is also ranked here, with several other genera of inferior note. The fourth, Tetragynia, contains one genus only, and which happens to be a British plant, a beautiful inhabitant of our bogs and marshy ground, known by the name of Grass of Parnassus. There are four species of this plant already described; three of which are natives of North America. The fifth order, Pentagynia, contains nineteen genera, among which we find the highly ornamental family of *Crassula*, a tribe of succulents chiefly from the Cape of Good Hope. Here also we find the superlatively useful flax, the neat thrift, used for the edgings of walks in gardens, and the showy sea-lavender. The last, Polygynia, contains only three genera, two of which are exotics, and the other a native of Britain, common in corn-fields, called *Myosurus minimus*, or mouse-tail.



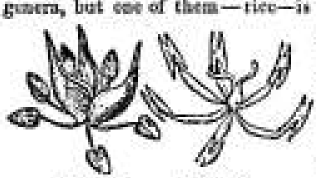
Trigynia. Digynia. Monogynia.



Pentagynia. Tetragynia.

VI.—HEXANDRIA.

Flowers with six stamens *of equal length*, and with one, two, three, or many pistils; thus constituting four orders, which embrace as many as two hundred genera. The fifteenth, *Tetradynamia*, has also six stamens; but four of them are longer than the other two. Besides this, the flowers of the two classes are obviously different. By far the greater number of our bulbous flowering and culinary plants—as the narcissus, the lilies, the long-lived American aloe, the magnificent crinums and pancratiums, the unequalled fruit of the pine-apple, and the equally useful onion, asparagus, &c.—belong to this class. The plants are chiefly herbaceous, and found in every clime from the torrid to the arctic zone, in the burning sands of Africa, and amid the snows of Siberia. The first is by far the largest order, containing nine-tenths of the whole class. The second order, DIGYNIA, contains only three genera, but one of them—rice—is most important to the inhabitants of tropical countries, and to those of the warmer parts of the temperate zones. It is the staff of life in India, and is cultivated on every spot of level ground where there is a command of water for irrigation. This plant is a true cereal, and has been properly placed by Jussieu among the grasses. The only British plant in this order is the *Oxalis reniformis*, or mountain sorrel. The third order, TRIGYNIA, comprehends a few bulbous and tuberous stemmed plants—as the bird's-tongue, the elegant trillium, and the meadow saffron, a common English plant, as also the well-known dock. The fourth order, POLYGYNIA, comprises only four genera, among which we find one of the most beautiful British genera—namely, the water plantain. It is only found in pools or turfy bogs; and if cultivated, it must have a place in the aquarium.



Trigynia. Digynia.

VII.—HEPTANDRIA.

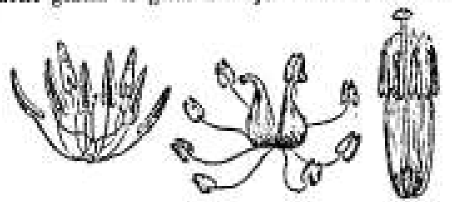
Flowers with seven stamens, and having one, two, four, or seven pistils; thus forming four orders, which comprise fifteen genera. The first order, MONOGYNIA, contains two nearly allied genera of trees—namely, the *Æsculus* and *Pavia*, better known by the name horse-chestnuts. They are among the most ornamental of our forest trees, though they are not natives. The flowers of the common sort are well known; one or two of the pavias have bright red flowers, and are most striking objects in ornamental scenery. The common horse-chestnut yields great crops of nuts; but except the deer, no other domestic animal will touch them. The second order, DIGYNIA, contains only one genus—namely, the *Limeum Africanum*, a perennial herb from the Cape of Good Hope. The third, TETRAGYNIA, comprises two genera—*Saururus*, lizard's-tail and *Astranthus*, a new genus lately introduced from China. The fourth order is HEPTAGYNIA. It is remarkable that among above three thousand genera, only one should occur with seven stamens and seven styles; indeed, as Rousseau remarks, nature has neglected the number seven in her arrangement of vegetable structure.

Digynia. Monogynia.

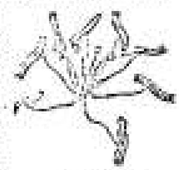
Heptagynia. Tetragynia.

VIII.—OCTANDRIA.

Flowers with eight stamens, and with one, two, three, or four pistils; thus constituting four orders, which include about eighty genera. The first order, MONOGYNIA, contains many genera, of which the heaths are the most conspicuous and numerous. Of this family alone there are five hundred and forty-three species already described, chiefly natives of the southern parts of Africa. A few are found in Britain, and several in other parts of Europe. The curious *rhexia*, the day and night-flowering *anothera*, and the elegant *fuchsia*, are found in this class; so also is the well-known mezereon, and many exotic genera of great beauty. The order DIGYNIA contains only five genera, all exotics, Weinmannia being the chief. The order TRIGYNIA comprises nine genera, among which the sea-side grape, and soapberry of the West Indies, are the most remarkable. The last order, TETRAGYNIA, contains six genera, having four pistils, among which is the curiously organised *Bryophyllum*, which bears viviparous progeny on the edges of its leaves. This is a remarkable departure from the usual way in which plants produce viviparous offspring. Bulbs send forth offsets from the radical plate or collet; some few from the axils of the leaves on the stem, as exemplified in the tiger lily; others, again, eject *living* seeds from their spathes, as some of the onion tribe; many trees and shrubs send up suckers from their roots, which become perfect plants; but in the case of the *bryophyllum*, young plants are produced from the vascular parts of the edges of the leaves, in addition to those which are yielded by the perfect seeds.



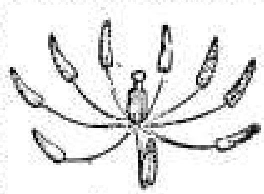
Trigynia. Digynia. Monogynia.



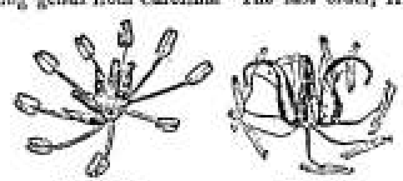
Tetragynia.

IX.—ENNEANDRIA.

Flowers with nine stamens, and with one, three, or six pistils; thus forming three orders, under which are ranked about a dozen genera. In the first, MONOGYNIA, we find the useful and fragrant cinnamon, and the famous laurel, whence so many medicinal oils and other useful substances are extracted. In the second, TRIGYNIA, there are the excellent medical and now culinary rhubarb, with only one other congener, the *Pleea*, a rush-looking genus from Carolina. The last order, HEXAGYNIA, contains but one genus, of which there are only two species—the flowering rush of Britain, and the broad-leaved rush from Nepaul. The flowering



Monogynia.

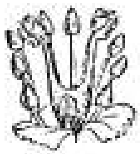


Hexagynia. Trigynia.

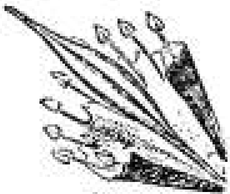
rush of Britain, *Butomus umbellatus*, is common in little ponds and ditches in many parts of this country, and is one of our most showy wild plants. The leaves are partly under and partly above water. The flower-stalk is elevated a foot or two in the air, and bears an umbel or tuft of very beautiful white flowers, often tinged with pink or blush-colour, and frequently entirely purple.

X.—DECANDRIA.

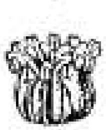
Flowers with ten stamens, and with one, two, three, five, or ten pistils; thus constituting five orders, and about ninety genera, many of the species of which are brilliantly flowering shrubs. In the first order, MONOGYNIA, we have the *Kalmias*, *Ledums*, *Rhododendrons*, *Andromedas*, &c. plants as generally admired as they are universally cultivated: we have also the arbutus, clethra, the fine aromatic scented storax tree, and many other exotics of the greatest beauty. In the order DIGYNIA we find the well-known *Hydrangea*, the extensive genus *Saxifrage*, and the equally extensive family of *Dianthus*, which include the carnation, pink, sweet-william, and other species and varieties of that favourite tribe. The order TRIGYNIA contains a great many plants which are allied to the *Dianthus* family. They are mostly slender annual weeds, though many are pretty, and a few ornamental. The catchflies, stitchworts, and sandworts, are all found here, and constitute the majority of the order. The fourth order, PENTAGYNIA, contains a good many plants, both native and foreign. The *Cotyledons* and *Oxalises* of the Cape of Good Hope, and the *Sedums* of Europe, are most numerous. The lychnis, mouse-ear, chickweed, and the common spurrey, are also placed here. The last order, DECAGYNIA, contains only one genus, and that a foreigner—namely, *Phytolacca*, of which there are nine or ten species.



Digynia.

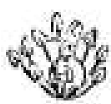


Monogynia.



Decagynia.

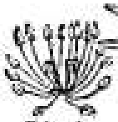
Pentagynia.



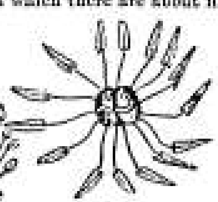
Trigynia.

XI.—DODECANDRIA.

There is no plant yet discovered with eleven stamens, and all those of this class have the number varying from twelve to nineteen. The pistils are either one, two, three, four, five, six, or twelve; thus constituting seven orders, in which there are about fifty genera.



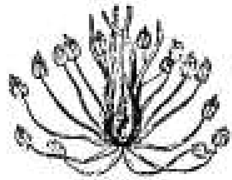
Trigynia.



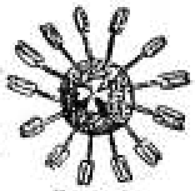
Digynia.

Monogynia.

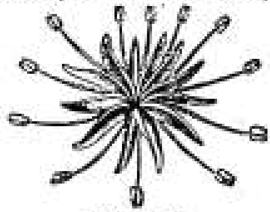
The first order, MONOGYNIA, among many fine tropical plants, includes the celebrated mangosteen, said to be the most delicious and wholesome fruit in the world. The garlic-pear, and the showy British plant which ornaments the banks of our rivers during summer, the *Lythrum salicaria*, also belong to this order. The second order, DIGYNIA, contains only two genera, of which the British plant agrimony, common on road-sides, is one. The third order, TRIGYNIA, contains the genus *Reseda*, some species of which (weld) are used by the dyer for producing a yellow colour; another species is the universal favourite, mignionette, *R. odorata*, cultivated entirely for its scent. The extensive *Euphorbia* or *Spurge* family also belongs to this order. The fourth, TETRAGYNIA, has only one genus—namely, the *Calligonum pallasia*, a native of the Caspian. The fifth order, PENTAGYNIA, contains three genera, of which the *Blackwellias* are the principal. They are all, except one, tropical shrubs. The order HEXAGYNIA contains a single genus—namely, *Cephalotus*—but that a very curious one; its leaves being formed into elegant pitchers, furnished with lids, like those of the *Nepenthes* or pitcher-plant. The last order, DODECAGYNIA, contains two nearly allied genera, one of which is the *Sempervivum* or house-leek, common on old walls and thatched cottages.



Pentagynia.



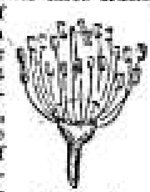
Tetragynia.



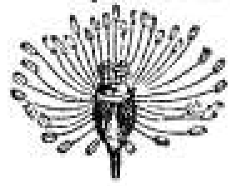
Dodecagynia.

XII.—ICOSANDRIA.

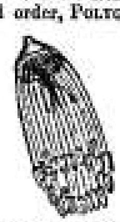
Flowers having twenty or more stamens seated upon the corolla or calyx. The situation, and not the number of the stamens, furnishes the characters of the class; they are also remarkable for rising directly from the calyx along with the corolla; the calyx is of one leaf, and hollow. The class is divided into three orders, comprising sixty genera, and is one of the most important of the Linnæan classes, as containing many of our most useful fruits, as well as most esteemed flowers. In the order MONOGYNIA we have the gorgeous *cacti*, *cereus*, *epiphyllum*, and *opuntias*; the myrtle, *eugenia*, and *eucalyptus*. Of fruits we have the guava, pomegranate, and several others. In the second order, DI-PENTAGYNIA—that is, plants having from two to five pistils—we have the pear, apple, quince, &c.; likewise the extensive genus *Mesembryanthemum*, of which there are three hundred and thirteen species. In the third order, POLYGYNIA, we have the rose, the strawberry, raspberry, and many others of great worth and beauty.



Monogynia.



Polygynia.

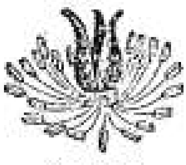


Di-Pentagynia.

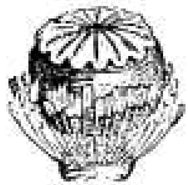
XIII.—POLYANDRIA.

Flowers having an unlimited number of stamens, distinct from each other, and seated on the receptacle.

There are six orders in the class, and one hundred and seven genera. The order MONOGYNIA comprises, among many others, the caper-tree, the well-known poppy, the curious sarracenia, and the magnificent water-lily. To this order also belongs the *Bixa orellana*, the red pulp of which is extensively used by dyers under the name

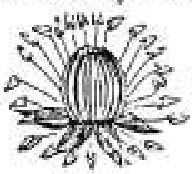


Di-Trigynia.

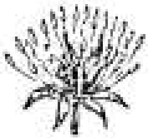


Monogynia.

of arnotta. The second order, DIGYNIA, is well typified in the splendid peony, a genus which has been lately much increased by new varieties, received from China and Siberia. The plants of this order have two pistils. The third order, TRIGYNIA, contains the beautiful larkspurs, the dangerous aconite, and the strong-scented *Hibbertia*. The fourth, TETRAGYNIA, contains only two genera—the butter-nut, a tropical fruit; and the *Drimys Winteri*, a tree allied to the magnolia. The fifth order, PENTAGYNIA, contains ten genera, of which the well-known columbine may be taken as a type. The last



Polygynia.

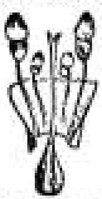


Pentagynia.

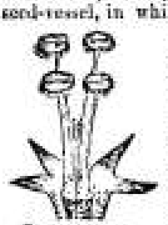
order, POLYGYNIA, includes a great many fine flowering plants, both shrubs and herbs; among the former, the magnolia is most conspicuous; among the latter, the anemone and ranunculus are confessedly beautiful. Of early or winter flowering plants, the aconite and hellebore are examples, and the globe-flower and marsh-marigold are showy plants.

XIV.—DIDYNAMIA.

The flowers of this class are generally ringent; they have four stamens, *two of which are superior;* and constitute two orders, under which are ranked one hundred and seventy genera. The flowers of the fourth class have also four stamens, but these are of equal lengths; while in this two are long and two short. The calyx also is of one leaf, and tubular, divided into five or two-lipped segments, which are unequal and persisting. The corolla is of one petal; the upper lip concave, and sometimes bifid, the lower lip trifid. In the first order, GYMNOSPERMA, the calyx is persisting, and becomes the seed-vessel, in which the seeds lie naked. In this order we find the germander, lavender, mint, and dead-nettle, and many others of similar character: several of them are useful in cookery. The order ANGIOSPERMA, so called because, though the stamens are the same in number and position, the seeds are differently disposed, being contained in a capsule. Many of the plants in this order are very beautiful; for instance, the bignonia, volkameria, antirrhinum, mimulus, &c. The common foxglove, *Digitalis purpurea*, so conspicuous in our hedge-banks, also belongs to this order, and is a good type of the whole. The seeds in the first order are four, situate at the bottom of the persisting calyx; in the second order they are numerous, and fastened to a filiform receptacle.



Angiosperma.



Gymnosperma.

XV.—TETRADYNAMIA.

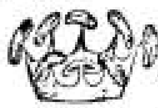
Flowers with six stamens, four of which are longer than the other two. Linnæus divided this class into two orders—SILICULOSA and SILIQUOSA; the former being a short roundish pod, and the latter a long one; but modern writers have discontinued this distinction, which is specific rather than generic. Many of the plants are dietetic—as the cabbage, turnip, radish, &c.; and some are finely scented and favourite flowers—as the wallflower, stock, arabis, rocket, &c. The seeds of several cruciferous plants yield oil of excellent quality. This is a truly natural class of plants, forming the *Cruciferæ* of Jussieu; great similarity of the flowers, seeds, &c. being observable throughout the whole of the

Stamens and Seed-vessels.

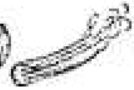
genera. The calyx is a four-leaved perianth, sepals concave, equal, and deciduous; corolla of four petals, claws inserted into the receptacle, limbs widening outwards, and assuming a cruciform direction; stamens six; filaments awl-shaped, the opposite ones shorter than the other four; anthers acuminate, often arrow-head shaped, diverging; pistillum germen superior, style short or wanting; stigma obtuse; seed vessel is a siliqua or silicula, of two valves opening at the base. The stigma is commonly persisting, and forms the apex of the dissepiment, which is prominent beyond the margins of the valves.

XVI.—MONADELPHIA.

The stamens are united into one set in this class, which is divided into eight orders, founded on the number of the stamens, not on that of the pistils, as in other classes; the whole containing one hundred and thirty-nine genera.



Octandria.



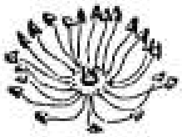
Heptandria.

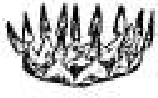
Pentandria.

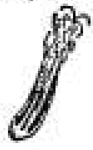
Triandria.

In the first order, TRIANDRIA, we find several beautiful Cape bulbs—as the *Ferraria*, *Tigridia*, *Herbertia*, &c. The flowers are not only of uncommon forms, but curiously spotted or streaked with dark colours. Of the second order, PENTANDRIA, the passion-flower is the most remarkable type. There is also the *Erodium* or heron's-bill, a section of plants formerly united with the geraniums. The third order, HEXANDRIA, contains but one genus, and is so distinct in itself, that it forms an order in the natural system. It is a bulbous-rooted plant, called *Gilliesia graminea*, having grass-like leaves and curious flowers. The fourth order, HEPTANDRIA, contains the pelargoniums, commonly called geraniums—a genus of plants unequalled for immense variety of forms and colours. Of pelargoniums there are above two hundred and thirty-eight species, and between three and four hundred varieties already enrolled in books. They are chiefly natives of the Cape of Good Hope, and have long held a distinguished place among our greenhouse plants. The fifth order, OCTANDRIA, contains only two genera, which have eight stamens, united in one set or brotherhood. The first genus is *Aitonia*, named by Linnæus in honour of the late William Aiton, Esq. royal gardener at Kew.

The second is *Conospermum*, hairy-seeded shrubs from New Holland. In the sixth order, DECANDRIA, we find


Polyandria.

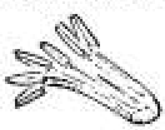

Dodecandria.

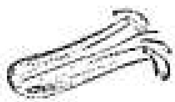

Decandria.

the true geraniums or crane's-bill. These are chiefly herbaceous plants, and found in many parts of the temperate latitudes. The herb-Robert is a common British plant, and is a good type of the genus. This order is, however, rich in showy plants of very differently-constructed flowers, called *papilionaceous*, or butterfly-shaped; their seed-vessels being pods. Hence we find here the crotalarias, the common furze, broom, genista, laburnum, rest-harrow, lupine, and many other beautiful plants, as well as trees, shrubs, and herbs. The seventh order, DODECANDRIA, comprises twelve genera, some of them highly ornamental, but they are all tropical plants. In the eighth order, POLYANDRIA, many of our gayest flowering plants are arranged—as the althea, lavatera, hibiscus, sida, silk-cotton-tree, the tea-tree, and its magnificent congener the camelia, now so common an ornamental favourite in British gardens. All the orders of this class are rich in fine flowering plants; and as a great majority of them were easily transported from the countries in which they were natives, a chief part of them has been long in cultivation in European collections.

XVII.—DIADELPHIA.

Flowers having two sets or brotherhoods of stamens. In general nine are united together, with a single one by itself, which is accounted the second brotherhood. The class contains one


Hexandria.


Pentandria.

hundred and twenty-nine genera, the flowers of which are chiefly butterfly-shaped. The first order, PENTANDRIA, contains only a single genus—namely, the *Monniera trifolia*, an African annual of no great beauty. The second, HEXANDRIA, contains six genera, of which the common weed fumitory is a good example. The third order, OCTANDRIA, comprises only four genera, of which the beautiful milkwort is the most numerous and conspicuous. The common one of this country is among the most interesting, and is found on chalk hills or other dry situations. The fourth

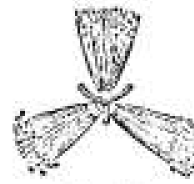

Decandria.

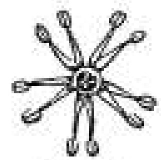

Octandria.

order, DECANDRIA, contains the greater number of the leguminous plants, or such as bear pods. They have all butterfly-shaped flowers, and comprise almost all our most useful kinds of pulse, forage plants, dyes, and many beautiful and valuable shrubs and trees. The pea, bean, tare, indigo, are examples of the order.

XVIII.—POLYADELPHIA.

This class contains all plants whose flowers have their stamens arranged in many brotherhoods. It is divided into two orders, embracing about twenty genera. The first order, DECANDRIA, has the flowers with ten stamens in several distinct bundles or sets. Here are only four genera, all tropical plants; among them we find the *theobroma*, which yields the useful chocolate nut. The second, POLYANDRIA, comprises plants whose flowers have many stamens in many distinct sets. This disposition of the parts on which


Polyandria.

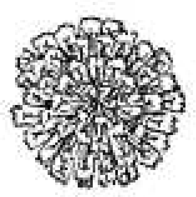

Decandria.

the order is founded, is exemplified in the St John's wort, a plant common in our fields as well as gardens; and in greenhouses the useful and beautiful fruit tree, the orange, affords a ready example.

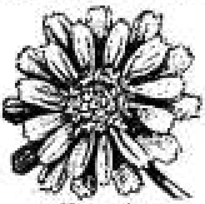
XIX.—SYNGENESIA.

This class contains all the compound or composite flowers which form the natural order *Compositæ*. The meaning of the term *Syngenesia* signifies to generate together, the seed-bearing florets being all crowded together on the same base or receptacle; or, more probably, from the circumstance of the stamens being united in a cylinder, and surrounding the style near its apex. The peculiar arrangement by which syngenesious flowers are distinguished from all others is this, that besides the union of the anthers, the flowers or florets, instead of standing singly, are here congregated; instead of each having a calyx and receptacle, one calyx and one receptacle is common to the whole, whatever that number may be. The whole together is called the *flower*, as that of a daisy: the separate parts composing the disk of it are called *florets*. The flower is supported on its exterior by a number of scale-like leaves, by some called *calyx*, but by others *anthodium*, and mostly attached to the outer rim of the receptacle, which bears the florets on its upper surface. The florets, however, are not always perfect in themselves; some of them are of two sexes, others male, or female, or neuter. On the difference of these in position and character, the orders of the class are founded. The florets have a calyx which is superior, and becomes the crown of the seed; a corolla which is of one petal and superior; the limb campanulate or ligulate; stamens five, filaments inserted into the tube of the floret; anthers united by their margins in all bisexual florets; germen inferior, being a naked seed crowned with the other parts; style erect; stigma in two parts, each revolute and divergent; seed single, either naked or crowned with the calyx, or with a pappus to assist the dispersion. The dandelion and thistle are familiar examples. This class contains two hundred and seventy-seven genera, and upwards of two thousand six hundred and fifty species.

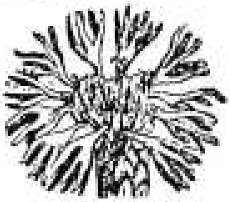

Superflua.


Æqualis.

The first order is ÆQUALIS, in which all the florets are of two sexes. It is very extensive, and contains many very common plants, as the sowthistle, lettuce, hawkweed, burdock, artichoke, &c. The majority of them are herbs, and many are annuals. The second order is SUPERFLUA; here we find plants, the flowers of which have the florets of the disk bisexual, and those forming the rays female, but which are impregnated by the anthers of the disk. This circumstance was considered by Linnæus as superfluous; hence the title. This is also a very large order, and contains many useful as well as beautiful plants. Of the first, tansy and chamomile are examples; of the second, the helichrisums, xeranthemums, and dahlias. The third order is FRUSTRANEA, so called because the florets of the disk are bisexual, and those in the ray or margin neuter. These last, having sometimes the rudiments of a pistil, but no other sexual organ, are said to be ineffectual or frustrated polygamy. The type of the order is the splendid sunflower, with which many of the same style of flowering plants are arranged, such as the rudbeckia, coreopsis, &c. The fourth

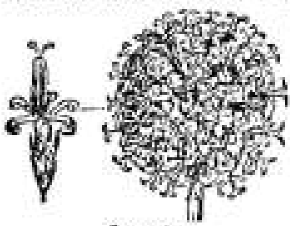


Necessaria.



Frustranea.

order is called NECESSARIA, because the florets of the disk, or centre of the flower, being all male, it is necessary that those of the ray or margin should be female, in order that there may be perfect seed. Calendula and arctotis, exotics chiefly from the Cape of Good Hope, are two of the most conspicuous genera. The fifth order is called SEGREGATA, because the florets have each its proper calyx (different from the perianthe of the floret), besides the common anthodium or exterior calyx; or there are several florets contained in each calyculus. All the plants in this order are exotic herbs and under shrubs, the globe-thistle being the most common in British gardens.



Segregata.

To the above five orders Linnæus added a sixth, called MONOGAMIA, in contradistinction to the others, which are polygamous. The plants which stood in this were such as had their stamens united, as in the other orders of the class, but had simple flowers, not aggregated florets. The genus *Lobelia* was one, but which is, as well as all the others (except one), now placed in the class *Pentandria Monogynia*.

XX.—GYNANDRIA.

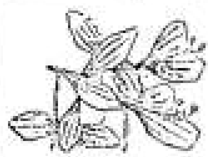
This class contains plants which have their stamens seated upon the pistillum, and comprises one hundred and ten genera. The species are generally herbaceous, with tuberous roots, curious gouty or climbing stems; many are epiphytes growing on trees, or flourishing in rotten vegetable matter in moist places. Some of their flowers are splendid, many highly fragrant, and all of remarkable conformation. The class is divided into

Hexandria. Diandria. Monandria.

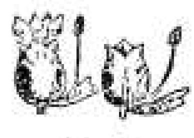
three orders. The first, MONANDRIA, contains plants having one anther seated on the pistillum, and comprises some of the most attractive wild British plants—as the orchis, ophrys, epipactis, &c. These, however beautiful, are excelled by those of the same tribe from America and other parts of the world. In the second order, DIANDRIA, which has flowers having two anthers seated on the pistillum, we find one of the greatest British beauties—namely, the ladies'-slipper, found in damp woods, particularly in the north of England. The third order, HEXANDRIA, containing plants which have six stamens seated in the pistil, has only one genus—namely, the *Aristolochia*, or birthwort, a very curious family of climbing exotics; one only being found in Britain—namely, the *A. clematis*.

XXI.—MONŒCIA.

This class consists of plants which have male and female flowers separate but on the same root, and contains ten orders, and one hundred and forty-seven genera. It may here be observed, that in syngenesious flowers the unisexual florets stand separately, but are included in the same cover; here they also are separate, but in distinct covers. The first order, MONANDRIA—that is, separate male flowers bearing one stamen—comprises five genera, one of which is the celebrated bread-fruit, tree, a native of the South Sea Islands. The only British genus arranged here is the *Zannichellia palustris*, the common pond-weed. The second order, DIANDRIA, having distinct male flowers bearing two stamens, contains only four genera, three of them exotic, and one British—namely, the common

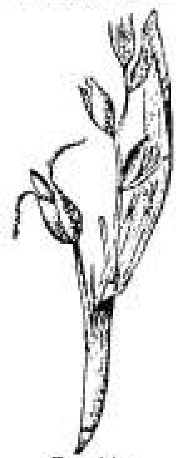


Diandria.

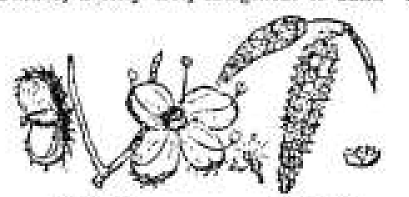


Monandria.

duckweed. The third, TRIANDRIA, consisting of plants having separate male flowers bearing three stamens, embraces a few tropical trees, and a great many coarse European grass-like plants. The cat's-tail and bur-reed are common aquatics, found in many parts of Britain. The maize, or Indian corn (*Zea*), also ranks in this order. The fourth, TETRANDRIA, includes all plants whose separate male flowers have four stamens—as the alder and birch; the box and mulberry; the common nettle; and the well-known foreigner *Aucuba japonica*. The fifth, PENTANDRIA, contains all monœcious plants whose male flowers bear five stamens. The amaranthus is most conspicuous here. The sixth, HEXANDRIA, has separate male flowers, furnished with six stamens. Its members are chiefly palms, or allied to that tribe—as the cocoa-nut, sago palm, and acrocomia. The seventh order, OCTANDRIA, has separate male flowers, bearing eight stamens, and contains only one genus, the *Dacrium*, a lofty tree, indigenous to Chili. The



Triandria.

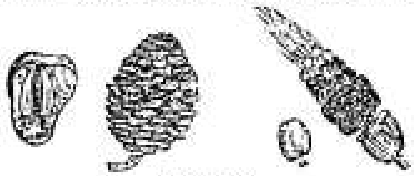


Pentandria. Tetrandria.

eighth order is ICOSANDRIA, containing plants which have male flowers separate, and bearing many stamens inserted into the calyx. Botanists have as yet discovered only one genus which can with propriety be placed here, and this is a tree from New Holland,


Polyandria. Hexandria.

called *Atherosperma moschata*. The ninth order, Polyandria, contains plants whose male flowers are separate, and which bear many stamens seated on the receptacle. It is a large order, and comprises the beautiful *Begonia*, the chestnut, beech, hazel, walnut, and, above all, the

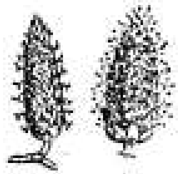


Monadelphia.

oak. The tenth, Monadelphia—plants having male flowers distinct, and whose stamens are united at the base into one brotherhood—is the most extensive, and contains some of the most magnificent forest trees—as the pines and firs, larch, cedar, cypress, &c. Here are also the gourd, melon, and cucumber, the poisonous janipha manihot, and the medicinal palma Christi.

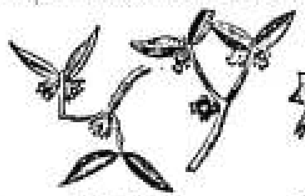
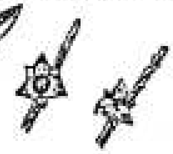
XXII.—DIŒCIA.

This class is composed of plants which have unisexual flowers, not on the same but on different roots. It is divided into as many as thirteen orders, and embraces upwards of one hundred genera. The first order, Monandria, consists of plants bearing unisexual flowers on different roots, those of the male plant having but one stamen. It contains only two genera, one being the remarkable screw-pine: so called because the leaves resemble those of the pine-apple, only much larger, and they issue from the stem in a very different manner; that is, neither opposite nor alternately, but the last always a little to the left of the former, so that they are expanded spirally like the worm of a screw.



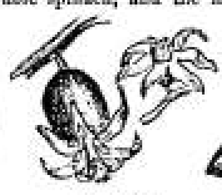

Diandria. Monandria.

The second order, Diandria, contains plants having unisexual flowers on different roots, the males bearing two stamens, and comprises four genera, of which the common willow is the principal; there being of this genus no less than 167 species already described. The third, Triandria—having male flowers on one plant, and females on another, the former being furnished with three stamens in each—contains twelve genera, among which one is a common trailing plant, found on our moist moors—namely, the crow-berry. The date-palm, so useful to the people in Persia, and other countries where it grows naturally, belongs to this order. The fourth, Tetrandria, consists of plants having flowers of one sex, but on distinct roots. The male plants have four stamens in each flower. This order contains fifteen genera, among which we find the candle-berry myrtle, one species of which is found wild in Britain—namely, the sweet-gale. It includes the mistletoe, common in England on oak-trees, white-thorn, and particularly in apple orchards. The fifth

Tetrandria. Triandria.

order is Pentandria, the male plants of which bear flowers having five stamens. It contains thirteen genera, among which are the well-known culinary vegetable spinach, and the no less valuable hop. The

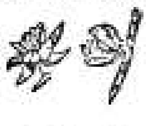



Hexandria. Pentandria.

sixth order, Hexandria, bearing male flowers, having six stamens, comprises seventeen genera, among which are six palms, some of them of stately growth, and highly ornamental in their native countries. The genus *Smilax* is also here, some of the species of which yield medical drugs. The only British genus is the


Enneandria. Octandria.

black bryony. Order seven is Octandria, the males of which have flowers furnished with eight stamens. The only genus is the poplar, four species of which are natives of Britain. The eighth, Enneandria, the male plants of which bear flowers having nine stamens, contains only three genera, two of which, the mercury and frog-bit, are British. The third, triplaris, is an American tree, useful for its timber. The ninth order,




Dodecandria. Decandria.

Decandria, the male plants of which have ten stamens, contains five genera, all of which are exotics. One of the principal is the papaw, a large tree-like herb, bearing bunches of fruit resembling melons, much used in India. The tenth order, Dodecandria, the male plants of which are furnished with twelve stamens, contains six genera; among them we find only one British, an aquatic, called the water-soldier (*Stratiotes*). Another is the menispermum, or moon-seed, which, with all the others, is exotic. The eleventh order is Icosandria, the male plants of which bear flowers having above twelve stamens inserted in the calyx. There are only three genera, none of which are British. Order twelve is Polyandria, the male plants of which are furnished with many stamens, fixed on the receptacle. It contains seven genera, all of which are exotics. Here we find *Cliffortia*, a genus common in our green-houses. Also *Cycas* and *Zamia*, plants of a singular character, to be met with in most

Polyandria. Icosandria.

collections. The last order of the class is MONADELPHIA, the male plants of which bear flowers, in which the stamens are united in one brotherhood. It comprises fifteen genera, of very various bulk and manner of growth. Here are the magnificent Bourbon palm, the lofty and symmetrical araucaria, the humble butcher's-broom, the juniper, the yew, the nutmeg, and the curious pitcher-plant.

Monadelphia.

XXIII.—POLYGAMIA.

The class POLYGAMIA (a word signifying many marriages) is composed of plants having both unisexual and bisexual flowers on the same or on different roots. There is considerable uncertainty about the arrangement of this division, because some of the genera are not always constant in their modes of flowering; and even single plants will occasionally exhibit all the characters by which the different orders are distinguished. The class is now divided into two orders, and contains about seventy genera.

The first order, MONŒCIA, comprises plants in which the polygamy is complete on one root—that is, where there are male flowers having stamens only, female flowers having pistils only, and flowers in which the stamens and pistils are united. This is a very extensive order, and contains many highly beautiful as well as useful plants. Here are the mimosas, the acacias, the maples, the beautiful ailantus, and the mango. There are also a good many of the grasses in this order.

Diœcia.

The second order, DIŒCIA, contains plants which have the polygamy complete on two different roots. There are eighteen genera, among which are the ash, so useful for its timber, the bread nut, the anacardium, and the numerous family of the fig.

XXIV.—CRYPTOGAMIA.

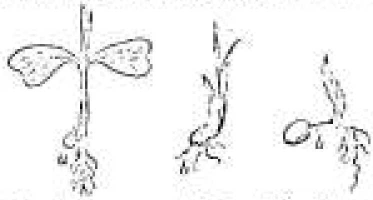
The class *Cryptogamia* (a term signifying hidden marriages) is divided into nine orders, and contains nearly four hundred genera. It is sometimes called *Agamia*, a term implying the absence of the usual organs of fructification which distinguish the flowering or Phænogamous classes. The orders are—FILICES, ferns; EQUISETACEÆ, horse-tails; LYCOPODIACEÆ, club-mosses; MUSCI, the true mosses; MARSILIACEÆ, pillworts; HEPATICÆ, liverworts; LICHENES, lichens; FUNGI, mushrooms; ALGÆ, sea-weeds—all of which form very natural and well-defined families under the Jussieuan arrangement, and whose structural peculiarities have already been adverted to under the head of VEGETABLE PHYSIOLOGY.

THE NATURAL SYSTEM.

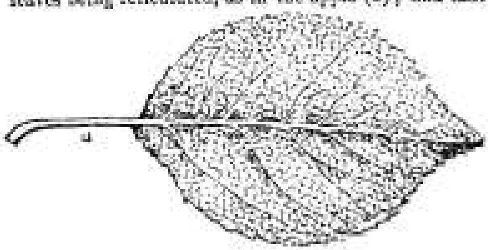
"The Natural System of Botany," says Dr Lindley, "being founded on these principles—that all points of resemblance between the various parts, properties, and qualities of plants shall be taken into consideration; that thence an arrangement shall be deduced in which plants must be placed next each other which have the greatest degree of similarity in these respects; and that, consequently, the quality of an imperfectly-known plant may be judged of by that of another which is well known—it must be obvious that such a method possesses great superiority over artificial systems, like that of Linnæus, in which there is no combination of ideas, but which are mere collections of isolated facts, having no distinct relation to each other. The advantages of the Natural System, in applying botany to useful purposes, are immense, especially to medical men, who depend so much upon the vegetable kingdom for their remedial agents. A knowledge of the properties of one plant enables the practitioner to judge scientifically of the qualities of other plants naturally allied to it; and therefore the physician acquainted with the natural system of botany, may direct his inquiries, when on foreign stations, not empirically, but upon fixed principles, into the qualities of the medicinal plants which have been provided in every region for the alleviation of the maladies peculiar to it. He is thus enabled to read the hidden characters with which Nature has labelled all the hosts of species which spring from her teeming bosom. Every one of these bears inscribed upon it the uses to which it may be applied, the dangers to be apprehended from it, or the virtues with which it has been endowed. The language in which they are written is not indeed human: it is in the living hieroglyphics of the Almighty, which the skill of man is permitted to interpret. The key to their meaning lies enveloped in the folds of the natural system, and is to be found in no other place." Such a system as is here eloquently delineated, we aim at rather than possess. All the modifications—and they are neither few nor unimportant—of Jussieu's original plan which have been promulgated, are merely contributions to one great end; and years of patient research, crowned by the most extensive powers of generalisation, must elapse before botany can boast of a perfect system. Passing, then, numerous recent suggestions, British and continental, we shall adhere in our brief exposition to that modification of the natural system which seems most applicable to botanical works now in current circulation; and which perhaps is better adapted than any unestablished innovations to convey to the reader a general idea of its principles of classification.

According to the original system of Jussieu, all the known plants were arranged into a hundred Orders, beginning with the *Fungi*, and mounting upwards to the *Coniferæ*; and these Orders were divided into three great Classes—namely, the ACOTYLEDONS, or plants without any cotyledon in the seed; the MONOCOTYLEDONS, plants with one cotyledon; and the DICOTYLEDONS, those with two or more cotyledons. The Acotyledonous plants were not subdivided; but the Monocotyledons were arranged into sub-classes, according as the stamens were *hypogynous*, or growing from under the pistil; *perigynous*, or growing away from the pistil; and *epigynous*, or growing on the pistil. The Dicotyledons were divided into the *apetalous*, or those without petals; the *monopetalous*, those with one petal; and the *polypetalous*, those with several petals: and these again were subdivided, according to the position of the stamens with regard to the pistil, in the same manner as the Monocotyledonous plants. To these were added what Jussieu called *Diclines*, or separated unisexual flowers, which included plants some of the flowers of which had only pistils, and others only stamens. The fault of this system, like that of Linnæus, was that it associated individuals dissimilar in their nature; the classification depending on one peculiar feature more than on the general appearance, qualities, and habits of the plant.

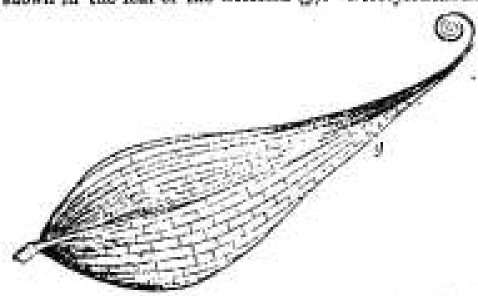
The system of Jussieu, as improved by Decandolle, cannot strictly lay claim to the term natural, as it depends principally on the number of cotyledons in the seed, and on the position of the stamens with regard to the pistil. Decandolle at first made 161 Orders; but these were afterwards greatly increased, and now some botanists enumerate as many as between 270 and 280. The first grand division of Decandolle, like that of Linnæus, is into the Flowering and Flowerless plants, which he designates respectively the *Vasculares* and the *Cellulares*. This division, however, is not absolutely correct; for although all the flowering plants contain vascular tissue, and the flowerless consist principally of cellular tissue, yet spiral vessels and ducts have been found in the ferns and club-mosses, and may possibly exist in others. The *vasculares* and *cellulares* of Decandolle may be considered as equivalent to the *Phænogamia* and *Cryptogamia* of the older botanists. His second division depends upon the cotyledons in the embryo; and, like Jussieu, he divides the flowering plants into DICOTYLEDONS, or those with two or more cotyledons or seed leaves, as *a*; MONOCOTYLEDONS, those which have only one seed leaf (*b b*); and ACOTYLE-



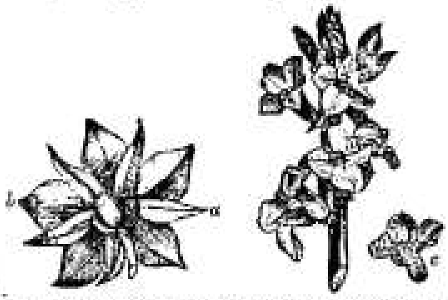
DONS, those having no seed leaf, and, in fact, no seeds—such as the Cryptogamia. The differences between these three divisions are very great, and spread through every part of the plant; but they are particularly conspicuous in the leaves—the venation of Dicotyledonous leaves being reticulated, as in the apple (*a*); and that



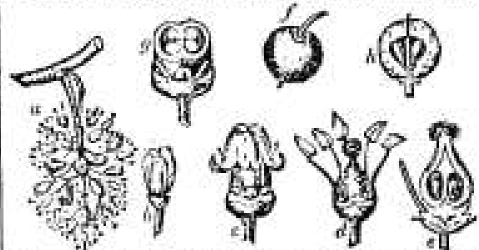
of Monocotyledonous being chiefly in parallel lines, as shown in the leaf of the Gloriosa (*g*). Dicotyledonous



trees are said to be *Exogenous*, from the fact of their trunks increasing by external layers; Monocotyledonous ones, *Endogenous*, on account of the enlargement taking place from within; and Acotyledonous trees, *Acrogenous*, because the increase takes place only at the top or growing-point. Dicotyledonous plants are again divided into the *Dichlamydeæ*, or those with two floral envelopes—that is, having a separate calyx (*a*) and corolla (*b*); and the *Monochlamydeæ*, or those having only one floral envelope, which is always called the calyx, as in the detached floret of the evergreen (*c*). These distinctions, however, are of comparatively little value, as many plants in the first division have no corolla, but simply a coloured calyx.

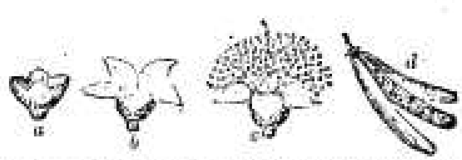


The *Dichlamydeæ* are farther divided into three subclasses:—I. *Thalamifloræ*, in which the stamens and petals are all inserted in the receptacle, as represented in the accompanying dissection of the common vine.



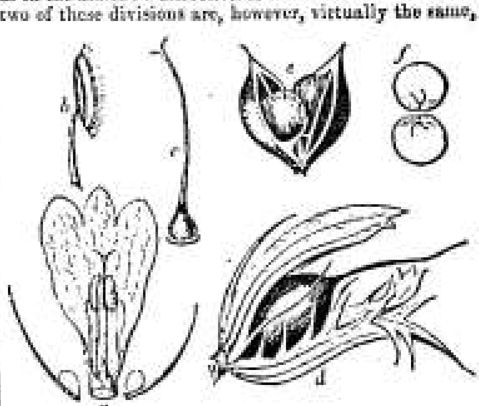
Vine.—*a*, bunch of flowers; *b*, flower before expansion; *c*, flower expanding; *d*, stamens, pistil, and germ; *e*, vertical section of the pistil and germ; *f*, fruit; *g*, horizontal section of the ovary; *h*, vertical section of the fruit, showing the position of the seed.

II. *Calycifloræ*, in which the stamens and petals are said to be inserted in the calyx, as shown in the subjoined dissection of one of the acacias. III. *Corolli-*



Acacia.—*a*, calyx; *b*, corolla; *c*, full flower; *d*, seed-pod open.

floræ, in which the stamens are inserted in the petals, as in the annexed dissection of the acanthus. The first two of these divisions are, however, virtually the same,

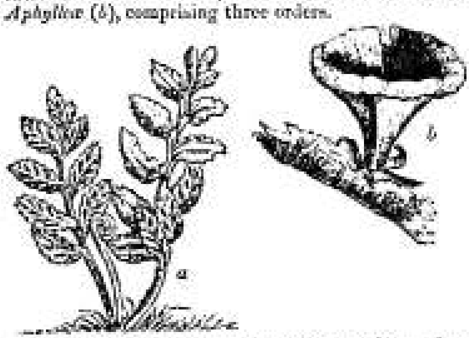


Acanthus.—*a*, corolla opened, showing the stamens and pistil; *b*, one stamen; *c*, pistil; *d*, ripe seed-vessel, covered with its calyx and bracts; *e*, seed-vessel burst previously to shedding its seeds; *f*, seed opened, showing the radicle and plume.

as in the second the stamens are inserted not in the calyx itself, but in the dilated receptacle which lines the calyx. The third division is, on the other hand, quite distinct, as the plants belonging to it have their petals united at the base, below the ovary, and the stamens are really inserted in the fleshy part of the petals. The first two of these sub-classes contain about sixty orders each, while in the third there are only about thirty orders. The *Monochlamydeæ* are those having only one floral envelope; they consist of about thirty orders, and are not subdivided.

Monocotyledonous plants are divided into those with petals, called *Petaloideæ*, which consist of about thirty orders; and those with glumes like the oat, *Glumaceæ*, which contain only two orders. The *Flowering*, or *Phanerogamous* orders, now generally admitted, amount therefore to about two hundred and twelve.

Flowerless, or *Cryptogamous* plants, are divided into two classes—those with leaves, *Foliaceæ* (*a*), of which there are seven orders; and those without leaves, *Aphyllæ* (*b*), comprising three orders.



The distinctions between the orders are drawn from the number of petals, sepals, and stamens, whether the stamens are hypogynous, epigynous or perigynous; the construction of the anthers, and the manner in which they burst; the construction of the seed-vessel and of the seeds with the position of the embryo; the position of the leaves, whether alternate or opposite, or with or without stipules; and the general habits and properties of the plants.

Having thus explained the basis of arrangement, we shall now proceed to consider the orders—premising that while the whole are tabulated, our space will only permit us to detail a few of the more interesting and important. This, however, we shall endeavour to do in such a manner as may at once present an outline of the System, and render the reader familiar with the phraseology and plan of procedure.

§ THALAMIFLORÆ.

Ranunculaceæ—Crowfoots
Dilleniaceæ—Dilleniads
Magnoliaceæ—Magnoliads
Anonaceæ—Anonads
Menispermaceæ—Menispermads
Berberidaceæ—Berberids
Cabombaceæ—Water-shields
Nymphæaceæ—Water-lilies
Sarraceniaceæ—Sarraceniads
Papaveraceæ—Poppyworts
Fumariaceæ—Fumeworts
Cruciferæ—Crucifers
Resedaceæ—Weldworts
Datiscaceæ—Datiscads
Capparidaceæ—Capparids
Flacourtiaceæ—Bixads
Cistaceæ—Rock-roses
Violaceæ—Violetworts
Droseraceæ—Sun-dews
Polygalaceæ—Milkworts
Tremandraceæ—Poreworts
Pittosporaceæ—Pittosporads
Frankeniaceæ—Frankeniads
Caryophyllaceæ—Cloveworts
Linaceæ—Flaxworts
Malvaceæ—Mallowworts
Bombaceæ—Silk-cottons
Byttneriaceæ—Byttneriads
Tiliaceæ—Lindenblooms
Elæocarpeæ—Elæocarps
Dipteraceæ—Dipterads
Chlænaceæ—Chlænads
Ternstrœmiaceæ—Theads
Olacaceæ—Olacads
Aurantiaceæ—Citronworts
Hypericaceæ—Tutsans
Guttiferæ—Guttifers
Hippocrateaceæ—Hippocrateads
Marcgraviaceæ—Marcgraviads
Erythroxyleæ—Redwoods
Malpighiaceæ—Malpighiads
Aceraceæ—Maples
Hippocastanaceæ—Horse-chestnuts
Rhizobolaceæ—Rhizobols
Sapindaceæ—Soapworts
Meliaceæ—Meliads
Cedrelaceæ—Cedrelads
Vitaceæ—Vineworts
Geraniaceæ—Cranesbills
Tropæolaceæ—Indian Cresses
Limnantheæ—Limnanths
Balsaminaceæ—Balsams
Oxalidaceæ—Oxalids
Zygophyllaceæ—Bean-capers
Rutaceæ—Rueworts
Simarubaceæ—Quassiads
Ochnaceæ—Ochnads
Coriariaceæ—Coriariads

RANUNCULACEÆ—CROWFOOTS.

The plants constituting this order are herbs, or rarely shrubs, with deeply-cut leaves and stem-clasping petioles. The majority of the species are hardy, and all abound in an acrid poisonous juice, as is well exemplified in the common buttercup of the meadows—*Ranunculus acris*—from which the order takes its name. They are very irregular in their flowers; many of them having merely one floral envelope, and others having a coloured calyx, with only very small and inconspicuous petals. When the flowers are regular—that is, when they have both a calyx and a corolla—the latter has generally five petals, and the calyx five sepals, though the number of the petals sometimes varies from three to fifteen. There are numerous stamens which grow from beneath the pistil, and are always separate, having their anthers bursting outwardly. The seeds are for the most part contained in several carpels which grow close together, but are either quite distinct or so slightly united as to be easily separated with a pin. The embryo is very small, and placed at the base of the albumen, which is either fleshy or bony. In consequence of the irregularity of their flowers, the Ranunculaceæ are somewhat perplexing to the learner, though they may be generally known by their numerous distinct stamens springing from below the pistil, and by their distinct carpels, which frequently grow in several whorls round an elevated receptacle, as in the crowfoot and *Flos Adonis*. The calyx generally falls off with the petals, but in the peony it remains till the seed is ripe. The carpels are in many cases only one-seeded, and are sometimes winged, as in the anemone and clematis, in order to scatter the seeds, as the carpels in this case do not open naturally, but fall with the seed. It is owing to this circumstance that the seeds of many of the members are so retentive of their vitality, and lie so long in the ground before germinating, as may be remarked of the *Flos Adonis*. Sometimes, however, the carpels are many-seeded, and open naturally when ripe, as in the peony, the larkspur, the columbine, &c.

The principal genera—and which lie within the examination of every one—are the Ranunculus and Peony, having regular flowers and two floral envelopes; the Anemone, the Hepatica, the Christmas Rose, and the winter Aconite, which have regular flowers, but generally only one floral envelope; and the Larkspur, Monkshood, and Columbine, which have irregular flowers. The Clematis is one of the few shrubby plants belonging to the order; it has regular flowers, and generally only one floral envelope.

The Ranunculaceæ are of little economical importance, in consequence of their usually poisonous qualities, as evinced by the aconite and hellebore in particular; though a few are simply astringent, as the Coptis trifolia, or gold-thread, of North America. The juice of the whole order is acrid, the roots of many intensely bitter, and the bark of a few tonic and bitter. The seeds of the Nigella are aromatic, and were formerly used as pepper; but those of all the other genera are poisonous, unless husked. The flowers of some are objects of great beauty—as the larkspurs, ranunculuses, anemones, peony, and columbine.

PAPAVERACEÆ—POPPYWORTS.

This order consists of very handsome herbaceous plants, annual and perennial, and a few under shrubs, most of which are natives of the temperate parts of Europe and Asia. The leaves are alternate, sometimes deeply cut, and without stipules. The flowers are solitary, elevated on long peduncles, showy, and usually white, yellow, or red; and the bud in all, except the large scarlet Eastern poppies, is shrouded in only two sepals, which fall off as soon as the flower expands. The Oriental species have three sepals, and one of them (*Papaver bracteatum*) has two large bracts which remain after the flower has expanded, and form a kind of calyx, though the real calyx has dropped off. There are generally four petals, or a multiple of four, which are crumpled in the bud, and soon fall off. The stamens are very numerous, inserted in four or more parcels beneath the pistil (*a*). The ovary is solitary, forming, when green, a capsule which consists of several carpels grown together and enclosed in the dilated fleshy receptacle which rises round them; stigmas generally stellate on the flat apex of the ovary. Notwithstanding the fleshy ovary, the fruit is a dry capsule, with only one cell, the divisions between the carpels having disappeared. The seeds are numerous, have a minute straight embryo, imbedded in albumen between fleshy and oily, and become loose in the capsule when they are ripe. Before the seeds are ripe, the walls of the capsules become as hard as a shell; and the stigmas, which have grown together, and become equally hard, form a star-shaped lid for the capsule (*b*). Under this there are a set of valves that open for the discharge of the seed.

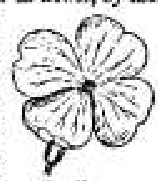
P. somniferum.

The genera most common in Britain are—*Papaver*, the poppy, of which there are twenty-five species; *Argemone*, the prickly poppy; *Meconopsis*, the Welsh poppy; *Sanguinaria*, blood-root; *Glaucium*, horned poppy; *Chelidonium*, greater celandine or swallow wort; *Eschscholtzia*; *Hunnemania*; *Romeria*; *Hypecoum*; *Platystemon*; and *Platystigma*. In the horned poppy, which is common on the south-east coast of England, the seed-vessel is formed of only two carpels grown together, which look like a pod; and when ripe, from their length and stiffness, bear a considerable resemblance to horns; hence the name. The botanical term *glaucium* alludes to the extreme glaucous hue of the plant. The greater celandine has a seed-vessel like a pod; and its juice, as well as that of the prickly poppy, is yellow—the juice of the others being white. In the Eschscholtzias the sepals do not separate; but becoming detached at the base, they retain the shape of a hood or extinguisher, till pushed off by the expansion of the corolla. The capsules of the Eschscholtzias are elongated, and are easily known by the large fleshy projection at their base. Though treated as annuals, they have large flesh roots, which render them difficult to be removed unless when quite young. The plants of the order are easily detected by their general resemblance to each other, especially in their flowers, with the exception perhaps of the celandine, the flowers of which are small.

All the Poppyworts abound in a thick glutinous juice, which poisons by stupifying. All parts of the plant furnish more or less this milky sap, but the main supply is derived from the unripe seed-vessels. When in a green state, those of the large white poppy (*P. somniferum*) are slightly wounded with a knife, which causes the juice to exude freely; and on exposure to the air, it concretes or becomes inspissated. In this state it forms crude or lump opium, which, dissolved in spirit of wine and filtered, produces the laudanum of the shops. Chemically, opium consists of an insoluble gum, a small quantity of resin, and caoutchouc. Its effects on the animal system depend upon two alkaline principles which it contains—namely, morphia and narcotine; the former producing a sedative, and the latter a stimulating effect. It is curious that the seeds possess none of the stupifying properties of the plant, but is mucilaginous and oily, and may be eaten with impunity. The seeds of one species, however (*Argemone Mexicana*), are said to be narcotic, especially when smoked; but it is probable that in this case the opiate resides in the coating of the seed rather than in the albumen.

CRUCIFERÆ—CRUCIFERS.

This is one of the most extensive and important of the natural orders. Most of the genera are herbaceous annuals and perennials, only a few are shrubby. The leaves are alternate, and the flowers are produced in corymbs or racemes. The flowers are regular, with a calyx of four sepals, and a corolla of four petals, disposed in the form of a Maltese cross: hence the name *Cruciferæ*, or cross-bearing. There are six stamens, two much shorter than the others, as shown under the Linnæan class, *Tetradynamia*. The pods open naturally when ripe, the valves curling outwards. The seeds have no albumen, and the cotyledons are curiously folded down on the radicle. There can be no difficulty in recognising a cruciferous plant when it is in flower, by the cross-form of its corolla, as in the adjoining figure, and its six stamens, two of which are shorter than the others; besides, it has a permanent distinction, in having the pods equally divided. Even when it has neither flowers nor seeds, a plant of this order may be known by its straggling habit of growth and its pungent taste.


Crucifer.

Among the more common genera may be mentioned *Brassica*, including all the cabbages; *Cheiranthus*, the wall-flower; *Mathiola*, the stocks; *Iberis*, the candytuft; *Isatis*, the woad; *Cochlearia*, the horse-radish; *Sinapis*, the mustard; and many other well-known plants. Most of them are natives of Europe; but plants of the order, which contains about 170 genera, are found in every part of the world.

The properties of the Crucifers are antiscorbutic and stimulant, combined with an acrid flavour, and the seeds of many abound in a fixed oil: properties of which the common cress, mustard, and rape may be taken as examples. Most of them form articles of human food, and are valuable not only for their antiscorbutic properties, but from the fact that they contain a large amount of nitrogen, and therefore supply the place of butcher-meat better than any other vegetable. It is this gas that occasions them to have so unpleasant a smell when decaying, as may be experienced in the case of the common cabbage. The flowers of the order are most commonly yellow or white, though some, as the Virginian stock (*Malcomia maritima*), have pink and reddish colours.

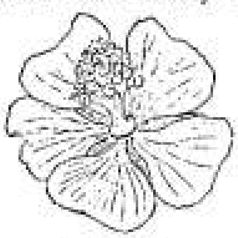
LINACEÆ—FLAXWORTS.

A very small order, formerly included in *Caryophyllaceæ*, but differing in the stems not being swollen at the joints, in the leaves being not usually opposite, in their being void of stipules, and in their presenting no traces of volatile secretion. The flowers are in five parts, like those of the cloveworts; but the sepals of the calyx are always distinct, and instead of being arranged in a regular whorl, two are placed a little lower than the others, as in the *Cistaceæ*. The stamens are united at the base into a cup, which has five little teeth peeping up between the stamens. The ovary has five styles and stigmas; but the seed-vessel splits into ten valves, each carpel containing two seeds, separated by an obscure partition, which gives the carpels the appearance of being only one-seeded. The seeds are flat and shining, with a large embryo.

The only genera are Linum and Radiola; the former comprehending many species, of which the common flax (*L. usitatissimum*) is the most important and best known. Flax will grow in almost any part of the world; and though but an annual, its stem contains so much woody fibre that it is exceedingly tough and durable. This external coating of tough fibre, and the peculiar construction of the flower, are amongst the most obvious distinctions of the tribe, though only one or two of the members yield fibre sufficiently strong for economical purposes. This fibre, separated from the stem by maceration and bleaching, produces the flax of commerce, so extensively used in the manufacture of linen, thread, and cordage. The seeds contain a great quantity of oil—*linseed oil*—which is obtained from them by pressure, and the refuse forms *oil-cake*, employed by farmers in feeding cattle. The seeds also abound in mucilaginous matter, and are thus made use of medicinally, for coughs, &c.; or, when ground into meal, for poultices. Though at one time pretty extensively grown in Britain, our manufacturers now derive the greater part of their supplies from the countries adjoining the Baltic, from which, in one year, not less than 70,000 tons of flax, and about 2,000,000 bushels of linseed, have been imported. The valley of the Nile, anciently celebrated for its fine linen, now yields but an inconsiderable quantity, in consequence of the present barbarous condition of the inhabitants.

MALVACEÆ—MALLOWWORTS.

This is a very marked and natural order, all the plants belonging to it bearing a striking resemblance to each other, and remarkable for their large showy flowers. The petals and sepals are both five in number, but the calyx has three bracts on the outside, which are frequently so near to it as to have the appearance of a second calyx below the true one. Estivation twisted. The most remarkable part of the flower is the central column, and this is so decided, that a botanist is always able to recognise one of the Malvaceæ at first sight. This column is formed by the filaments of the stamens growing together, so as to leave only a small portion just below the anthers free, as is seen in the flower of the marsh-mallow—the lower portion forming a tube round the pistil. The anthers themselves are also peculiar: they are one-celled, kidney-shaped, and burst transversely. This peculiar construction of the stamens may be observed distinctly in the common mallows, the Lavateras, the hollyhocks, and, in short, in all the genera belonging to the order; and thus no malvaceous plant can ever be mistaken by any one in the least acquainted with botany. The styles also grow together, as may be seen when the stamens are removed; and the carpels, which are of the same number with the styles, form what children call "mallow cheeses." The carpels are one or many seeded, sometimes closely united, sometimes separated or separable; fruit capsular or baccate. Most of the species are herbaceous plants; several, trees or shrubs. Leaves alternate, more or less divided, and stipulate.



Marsh-mallow.

This order consists of twenty-two genera, which are sometimes subdivided into those having the calyx double—as *Malva*, *Althæa*, *Lavatera*, *Hibiscus*, *Gossypium*, &c.; and those having it single—as *Palavia*, *Cristaria*, *Sida*, &c. All of them possess showy flowers, abound in mucilage, and are destitute of unwholesome qualities. It will be seen that there is a considerable resemblance between the flax and the mallow tribes. Both possess mucilaginous qualities; in both the parts of the flower are in fives; and in both the filaments of the stamens are partially united; though in the flax the union is only at the base, whereas in the mallows it is carried up so as to form the central column, which is so marked a feature of the order. The herbaceous species of the Malvaceæ have woody fibre in their stems, but not in such abundance as in the common flax. The one-celled anther of the mallows, and the central column, are, however, the striking marks of distinction. Plants belonging to the order are found in almost every part of the world, but the cotton plants (*Gossypium*) will only thrive in hot climates.

The economical uses of the order are highly important. Cotton, on which so much of British commerce depends, is obtained from several species of gossypium, and is the downy covering which envelopes the seeds. The quantity of cotton imported into Great Britain is enormous—being in some years upwards of five hundred millions of pounds. There is only one species of cotton-tree in the West Indies from whence we obtain our principal supply of the raw material; several in the East Indies, and another in China, which has its cotton naturally of a buff colour. It is from the latter that the Chinese manufacture the stuff called *nankeen*, which is cotton cloth in its natural dye. Many of the Malvaceæ are also medicinal and dietetic. The *pâté de Guimauve*, which is made from a species of marsh-mallow, is much used on the continent in all disorders of the lungs; from the *Althæa officinalis* is prepared, in France, the vegetable tracing paper known by the name of *papier végétal*; and a blue matter, not inferior to indigo, is said to be obtained from the leaves of the hollyhock, *A. rosea*.

TERNSTRŒMIACEÆ—THEADS.

This is one of the most interesting natural orders, as, besides other fine plants, it contains the camelias and tea-trees. All the members are trees or shrubs, with very handsome flowers. The leaves are alternate, and without stipules; they are frequently leathery, and are sometimes marked with pellucid dots. The flowers have generally five sepals and five petals; sometimes there are two additional sepals a little below the others. The stamens are numerous, and either grow together into a central column, or are in five distinct bundles. The seeds are contained either in five distinct carpels, or in a capsule with five cells. There are but few seeds, which are large, and entirely filled with an embryo having thick cotyledons like the bean, and no albumen.

Only a very few genera belonging to this order have been introduced into this country; but there are a number of equally beautiful species said to be found in the East Indies and South America. Those best known in Britain are the genera *Gordonia*, *Stuartia*, *Malachodendron*, *Camelia*, and the *Tea-tree*. The camelia—for example, *C. Japonica*—is too well known to need any description, and its beautiful flowers and thick leathery leaves must be familiar to every one who takes any interest in plants. The tea-tree (*Thea viridis*) is very nearly allied to the camelia, but its flowers are smaller, and its leaves of a thinner texture. The outside of the capsule, which is furrowed in the camelia, is smooth in the tea-tree. Two kinds of tea-tree have been introduced into this country, the green and the black (*Thea Bohea*); but it is frequently asserted that the greater part of the dried leaves sent to this country is gathered from the green tea-tree, and that the difference in colour depends solely on the manner of drying the leaves, and on the time of gathering them. Be this as it may, *T. Bohea* has smaller leaves, and is a more tender and less vigorous-growing plant than *T. viridis*. The young leaves of *Camelia Sasanqua*, and some of the other camelias, are also dried and mixed with the tea. All these plants are natives of China and Japan; seem to thrive well in northern India; and require a slight protection in England during winter.

The properties of most of the species are as yet but little understood. An excellent table oil is obtained from the seeds of *Camelia oleifera*. The tea of commerce is produced by several species of Thea and Camelia; and this is well known for its astringent and stimulating qualities. About fifty millions of pounds is said to be annually exported from China, which furnishes almost the sole supply of the world. The tea plant is cultivated by the Chinese as the coffee-tree is in the West Indies, and as vines are in France; that is, it is planted in rows at regular intervals, and the leaves are gathered regularly at particular seasons. It is stated by those who are best informed on the subject, that no leaves are gathered till the trees are three years old, or after they are seven, and that a young plantation is formed every year, in order to have a constant supply at the proper age. Three several gatherings take place during the year—the leaves of the earliest being esteemed the strongest and best.

AURANTIACEÆ—CITRONWORTS.

The golden fruit of the orange and lemon, so characteristic of this order (*Aurum*, gold), is so beautiful, that it is supposed to have been typified by the celebrated apples of the Hesperides. The order comprises fourteen genera, generally elegant and fragrant trees. The leaves, though apparently entire, are called compound by some botanists, because they are articulated with the petiole, which in the orange, and some other species, is winged. The calyx is tubular, with five short teeth, and this small calyx remains on the front till it is ripe. The petals of the corolla are five in number, thick and fleshy, and when held up to the light, they appear full of pellucid dots, which are receptacles of secretion filled with fragrant oil. There are generally twenty stamens, which are divided into five bundles, the filaments in each bundle adhering together. The fruit is a kind of berry, divided into numerous cells by dissepiments, and having a central placenta of pith, to which the ovules are attached in the ovary; but as the fruit swells, the seeds become detached, and the cells fill gradually with cellular tissue, till at last they become replete with an acid and bitter pulp, in which the seeds are immersed. The seeds are marked conspicuously with a chalaza and raphe, the vessels of which are spread beautifully over the testa.


Lemon.

The most familiar genus is Citrus, the species of which are trees or shrubs, chiefly natives of the tropics—most of them being found in a wild state exclusively in the East Indies. The orange, however, appears to have an extraordinary facility of adapting itself to any country the climate of which is dry and sunny; and thus have arisen the orange groves of St Michael's and of Florida, besides those of Malta, and various parts of Europe and North Africa. All the kinds of orange, lemon, shaddock, citron, &c. belong to the genus *Citrus*—as *C. aurantium*, the sweet orange; *C. vulgaris*, the bitter or Seville orange; *C. nobilis*, the Mandarin orange; *C. medica*, the citron; *C. limonium*, the lemon; *C. limetta*, the sweet lime; *C. Paradisii*, the forbidden fruit; and *C. Decumana*, the shaddock. The Wampee, the fruit of *Cookia punctata*, is much admired in India, but does not appear to have been introduced into Europe.

All the Aurantiaceæ abound in a fragrant oily matter, which is contained in the receptacles of secretion, in the rind of the fruit, and in the leaves of the tree. This oil is volatile, fragrant, bitter, and exciting. The pulp of the fruit is more or less acid, and is used either in its natural state, or medicinally in the form of salts, essence, or other extract. About 272,000,000 of oranges are said to be annually imported into Great Britain. The productiveness of the common orange is enormous: a single tree at St Michael's has been known to produce 20,000 oranges fit for packing, exclusively of the damaged fruit and the waste, which may be calculated at one-third more.

ACERACEÆ—MAPLES.

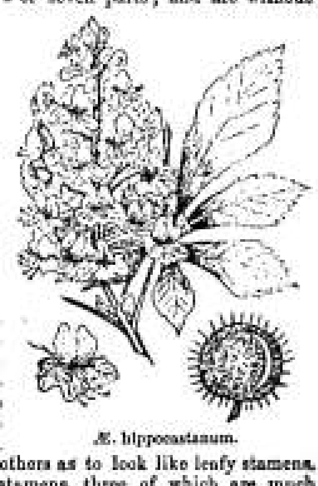
This order consists of three genera, and of fourteen or sixteen species, all of which are trees natives of temperate climates. The leaves are opposite, and without stipules; they are generally large and handsome, with five or seven lobes, though the *Negundo*, or box-elder, has the leaves pinnate. The flowers are small, but pretty, being in long drooping racemes or corymbs. The male and female flowers are distinct. The stamens, which are eight in number, are the only conspicuous part of the flower, as the petals are frequently wanting. The bracts are large and leathery, and generally roll back when the flowers expand. Most people have seen the fruit, or *keys*, as they are called, of the sycamore and maples, the botanical term for which is *samara*. This kind of fruit consists of two cells joined together on one side, each having a long membrane-like wing. There is usually only one seed in each cell; the embryo has two, and sometimes three, large thin cotyledons, which are curiously folded up, and fill the whole seed. This is rather a remarkable construction, as where there is no albumen, the cotyledons are for the most part fleshy.

The genera are *Acer*, *Negundo*, and *Dobinea*; of which only the two former are common in Britain. The genus *Acer* comprehends all the maples, and the sycamore. *Negundo* is easily distinguished from the maples by its compound leaves, which resemble those of the ash, and by its long pea-green shoots, which have very few buds. The male and female flowers of this genus are on different trees, and very inconspicuous. The common maple, *A. campestre*, and the sycamore, *A. pseudo-platanus*, are the only members of the order natives of Britain, though a number of other species have been introduced by culture. The Negundo belongs to America, and the other genus to Nepaul.

The ascending sap of all the maples is remarkably sweet, and sugar is frequently made in America from that of *A. saccharinum*. Indeed the sugar-maple may be said to be a rival of the sugar-cane, the United States alone producing not less than 10,000,000 pounds per annum. The timber of the maples and sycamore is remarkably light and close-grained, and therefore much used in veneering and inlaying. The beautiful veneers called *bird's-eye maple* are obtained from the cuts of *A. saccharinum*. The bark is astringent, and yields the dyer reddish-brown and yellow colours.

HIPPOCASTANACEÆ.—HORSE-CHESTNUTS.

This order contains only two genera—namely, *Æsculus*, the horse-chestnut; and *Pavia*, the scarlet-flowering chestnut. The species are all trees and shrubs, natives of temperate climates. The leaves are palmate—that is, divided into five or seven parts; and are without stipules. The flowers are produced in large panicles or racemes; and though they are very handsome, they are extremely irregular in their construction. There are five petals, two of which are smaller than the others, and all of which have very small claws. In the scarlet horse-chestnut, and some other kinds, there are only four petals; and in the *Pavia*, two of the petals are so much smaller than the others as to look like leafy stamens. There are seven stamens, three of which are much


Æ. hippocastanum.

shorter than the others. The fruit of the horse-chestnut consists of a leathery husk, which opens when it is ripe into three valves. The ovary is usually only one-celled, with two ovules, of which seldom more than one ripens. The husk of the pavia is smooth. The scar of the hilum is very strongly marked on the testa of the nuts of both genera; and in the pavia it is so conspicuous, as to give rise to the American name of the genus, which is called *Buck's-eye*, from the resemblance of the hilum to the pupil of an eye. When the seed is put into the ground, the cotyledons only open sufficiently to allow the escape of the plumule and the radicle. The plumule is very large, and has two leaves in the seed; and the radicle is close to the hilum, where of course is also the foramen. There is no albumen, the nourishment for the young plant being laid up in the thick fleshy cotyledons.

The horse-chestnuts are supposed to belong originally to the north of India; but they have been so long cultivated in Europe, as now to spring up like natives of the soil. The pavias are all natives of North America. Both of the genera are amongst the finest of our flowering trees, and on this account are common in park scenery. The seeds of the order abound in starchy matter, which renders them nutritious; they also contain much potash, and are bitter. The bark of the common *Æsculus hippocastanum* is bitter, astringent, and has been recommended as a valuable febrifuge in intermittent and other fevers.

VITACEÆ—VINES.

This order comprises four genera, and fifty-three species, natives of temperate climates. Their prevailing habit is a long dangling growth of stem, thyrsus of simple colourless flowers, or tendrils opposite the leaves, and yielding bunches of berried fruit. The stem and branches are furnished with tumid articulated nodes; the leaves are lobed or compound, generally alternate with stipules. The flowers are small, often with the male and female distinct; calyx very small; sepals and petals four or five, the latter sometimes cohering and falling off before the bursting of the anthers; stamens equal in number to the petals, and opposite to them; ovary two-celled; fruit, a berry, with the seeds immersed in pulp; seeds with a bony testa; albumen hard; embryo small. The curious formation of the flower and berry is well illustrated by the dissection of the common vine, as shown in page 91.

The genera are—*Ampelopsis*, the vine-leafed ivy; *Vitis*, the grape vine; *Leea*, and *Cissus*. With the exception of the vine, the other genera are of little interest, being employed only as ornamental creepers; as *A. hederacea*, which grows with amazing rapidity, and soon covers any straggling fence or unsightly wall. *Leea* is nearly allied to the Meliaceæ, and forms, as it were, a connecting link between the two orders.

The properties of the grape, either in its fresh state, or dried to form raisins and currants (Corinths), or expressed and fermented to form wine, &c. are too well known to require description. The berries of the Virginian creeper (*A. hederacea*) are small and unpalatable, but might be eaten with perfect safety. According to Von Martius, the leaves and fruit of *C. tinctoria* abound in green colouring matter, which soon becomes blue, and is highly esteemed by the natives of Brazil as a dye for cotton fabrics. Acid leaves, and a fruit like that of the common grape, are the usual characters of the order.

GERANIACEÆ—GERANIUMS.

This *Geraniaceæ* comprise only five genera, but above four hundred species. They are herbs or shrubs, with stems which are tumid and articulated at the joints. The leaves are generally lobed, and furnished with small stipules. Calyx persistent in five-ribbed sepals. Corolla generally five-petalled, with strongly-marked veins. Stamens twice as many as the petals, usually half of them abortive; filaments united at the base. Fruit consists of five elastic one-seeded carpels, called *cocci*, adhering to a central axis, or gyno-base, from which they part with an elastic jerk when ripe. Seeds without albumen; cotyledons rolled up or folded.

The chief genera are *Geranium*, *Pelargonium*, and *Erodium*, respectively crane's-bill, stork's-bill, and heron's-bill, from the fancied resemblance of the ripe seed-vessel to these objects. Many of the species, which are very widely distributed, are natives of Europe; but the majority of our greenhouse favourites are from the Cape of Good Hope. The herb Robert (*G. Robertianum*), and the meadow crane's-bill (*G. pratense*), are common British weeds, as are also *E. cicutarium* and *moschatum*. All the pelargoniums have their flowers in heads, or umbels, and the calyx remains till the seeds are ripe. Their leaves vary very much, some being round—as the horse-shoe geranium—and marked with a dark stripe; and others are deeply lobed, as the rose-scented varieties. Many are shrubby; some are herbaceous; the stems of some are warty, and the roots of others are tuberous. In the Erodiums, the filaments are less united at the base, and five of the stamens are always sterile. The Geraniums have all the stamens perfect, but are alternately long and short, and have a gland at the base of each.

The Geraniaceæ are all innocuous plants, being generally slightly acid, and sometimes astringent. They are all more or less fragrant, secreting oils and resins; and in some, these secretions are so abundant—*Sarcocaulon L'Heritieri*—that the stems burn like torches, and emit an agreeable odour during combustion. In America, the roots of *G. maculatum* are used as a remedy for diarrhœa; the British Erodiums are sometimes employed as aromatic bitters; from *P. odoratissimum* a fragrant oil has been distilled, resembling the attar of roses; the underground tubercles of *P. hirsutum* are esculent, and prized by the Arabs as food; and Mr Backhouse, in his recent travels, mentions that the tubers of *G. parviflorum* are eaten by the natives of Van Diemen's Land, where it is called the Native Carrot. Notwithstanding these uses, the members of the order are chiefly esteemed for the beauty of their flowers, and have long continued among the most admired favourites of the conservatory.

These and the other orders tabulated in page 92 comprise all the plants belonging to the sub-class Thalamifloræ. They include several interesting members, some of which are of the greatest importance to man. By far the greater part of the genera contain only herbaceous plants; and the few timber trees that are among them have all very light wood, though it is generally fine-grained, and in some—as the mahogany, satin, maple, and partridge woods—extremely beautiful. Flax and cotton, both belonging to this division, are also of the greatest economical importance. The contrast between the durability of these two kinds of thread is very striking, and of peculiar interest to the student of vegetable physiology. Linen thread, being the *woody fibre* of the flax plant, is much stronger than cotton thread, which is composed entirely of *cellular tissue*. The particles of cotton, however, adhere together more firmly than any other kind of cellular tissue; and though several seeds are also abundantly enveloped in down, that of the cotton is the only one capable of being spun into thread. The bombax, or silk-cotton-tree, forms no exception to this statement, because though the silky hairs that surround the seeds are used to stuff cushions and beds, and though a sort of felt has been made of them, yet they cannot be spun into threads of sufficient tenacity to endure weaving. Ropes and other fabrics are manufactured from the barks of many of the trees included in this division, but none of these is in very general use except the bast mats, made from the macerated bark of the lime-tree. Cocoa and chocolate, tea, wine, oranges, lemons, maple-sugar, opium, several fruits, drugs, dyes, and oils, are the produce of plants belonging to this division; and to these may be added cabbages, mustard, horse-radish, turnip, and other esculents.

§ CALYCIFLORÆ.

Of the plants comprised in this sub-class, the greater number have their petals and stamens inserted in the calyx, or rather in the mouth of the dilated disk which lines the tube of the calyx and surrounds the ovary. The sepals of the calyx are always united, so as to form a tube in the lower part, with the upper part divided into a lobed limb; and this, in fact, constitutes the principal difference between the plants of this and the previous section. Another distinction consists in the stamens of the Thalamifloræ being *hypogynous*—that is, inserted in the disk at the base of the ovary; whereas in the Calycifloræ they are generally inserted in an elevated part of the disk, so as to appear placed upon the ovary, *epigynous*; or they grow out of the calyx at a distance from the ovary, when they are termed *perigynous*. Of the orders comprised in this section, about forty have their stamens attached to the disk which lines the tube of the calyx, and seventeen have their stamens attached to the corolla: the latter being sometimes arranged under the sub-class Corollifloræ. The reason why Decandolle placed these doubtful members in the present section, appears to be that the petals do not unite beneath the ovary, as they do in the other genera of Corollifloræ. Subjoined are the usually admitted Orders:—

Celastraceæ—Spindle-trees	Turneraceæ—Turnerads
Rhamnaceæ—Rhamnads	Portulaceæ—Purslanes
Bruniaceæ—Bruniads	Illecebraceæ—Knotworts
Samydaceæ—Samyds	Crassulaceæ—House-leeks
Homaliaceæ—Homaliads	Cactaceæ—Indian figs
Chailletiaceæ—Chailletiads	Grossulariaceæ—Currantworts
Aquilariaceæ—Aquilariads	Escalloniaceæ—Escalloniads
Terebintaceæ—Terebinths	Saxifragaceæ—Saxifrages
Leguminosæ—Leguminous [plants]	Cunoniaceæ—Cunoniads
Rosaceæ—Roseworts	Umbelliferæ—Umbellifers
Calycanthaceæ—Calycanths	Araliaceæ—Ivyworts
Memecylaceæ—Memecyls	Hamamelidaceæ—Witch-hazels
Combretaceæ—Myrobalans	Caprifoliaceæ—Caprifoils
Vochysiaceæ—Vochyads	Loranthaceæ—Loranths
Rhizophoraceæ—Mangroves	Chloranthaceæ—Chloranths
Onagraceæ—Onagrads	Rubiaceæ—Madderworts
Haloragaceæ—Hippurids	Valerianaceæ—Valerianworts
Ceratophyllaceæ—Hornworts	Dipsaceæ—Teaselworts
Lythraceæ—Loosestrifes	Calyceraceæ—Calyceres
Tamaricaceæ—Tamarisks	Compositæ—Composites
Melastomaceæ—Melastomads	Lobeliaceæ—Lobeliads
Alangiaceæ—Alangiads	Stylidiaceæ—Styleworts
Philadelphaceæ—Syringas	Goodeniaceæ—Goodeniads
Myrtaceæ—Myrtle-blooms	Campanulaceæ—Bellworts
Cucurbitaceæ—Gourds	Gesneraceæ—Gesnerworts
Passifloraceæ—Passionworts	Vacciniaceæ—Cranberries
Malesherbiaceæ—Crownworts	Ericaceæ—Heathworts
Loasaceæ—Loasads	Penæaceæ—Penæads

TEREBINTACEÆ—TEREBINTHS.

An extensive order, containing sixty-seven genera and about one hundred and eighty species of trees and shrubs, which vary much in their character and qualities. The order was originally constituted by Jussieu, but modern botanists have found it necessary to subdivide it into seven tribes, and even with respect to these they are far from being agreed. It is more than likely, therefore, that as the species become better known, these tribes will be recognised as independent orders. The general characters of the order, as it now stands, may be described as follows:—Trees or shrubs abounding in a resinous, gummy, caustic, poisonous, and sometimes milky juice; leaves alternate and simple, ternate or pinnate, for the most part without stipules, and dotted. Flowers terminal or axillary, mostly unisexual; calyx two, four, or five cleft, usually the latter number; petals equal in number to the segments of the calyx; stamens as many as the petals, sometimes twice the number; disk fleshy; ovary simple; fruit indehiscent, with a solitary ex-albuminous seed.

The following are the seven sections or tribes into which Brown and others have divided the order:—1. ANACARDIACEÆ, including the cashew-nut (*Anacardium occidentale*), the mango (*Mangifera indica*), and the turpentine-trees (*Pistacia*). In these the leaves are alternate, and not dotted; the parts of the flower in fives; the fruit drupaceous; and the species trees or shrubs with resinous, gummy, caustic, or milky juice. 2. SUMACHINEÆ, which contains the genera *Rhus*, *Schinus*, and *Duvaua*, all nearly allied to the preceding tribe. The species are trees with unequally pinnate leaves, but otherwise agree with the general character of the order. In the Venetian sumach (*R. cotinus*), the flower-stalks which do not bear fruit dilate after the fall of the flower, and become covered with white cottony hair; hence the French name of the tree—*Arbre à perruque*. 3. SPONDIACEÆ, containing the hog-plum of the West Indies (*Spondias mombin*). The leaves are without dots, unequally pinnate, and the juice is non-resinous. 4. BURSERIDEÆ, including the Jamaica birch (*Bursera*), and the balm-of-Gilead-tree (*Balsamodendron*). Trees or shrubs abounding in balsam, gum, or resin; leaves alternate, usually without dots; fruit compound, in which respect it differs from the first and fifth tribe. 5. AMYRIDEÆ, represented by the West Indian *Amyris*. In this tribe the species are resinous trees and shrubs, with opposite, compound, and dotted leaves; the parts of the flower are in fours; fruit somewhat drupaceous. 6. SPATHELIACEÆ, the West Indian sumach (*Spathelia*). 7. CONNARACEÆ, including *Connarus*, *Omphalobium* and *Cnestis*, which are trees and shrubs with compound alternate leaves, without dots or stipules, without resinous juices, and with capsular fruit. The Connards are now generally treated as an independent order.

It will be seen, from what has been stated, that this order contains many plants of considerable economical importance. Among the edible fruits may be mentioned the cashew and pistacia nuts, the spondias, and the esteemed mangoes of India. Many of them also are plants yielding gums, resins, &c. useful in the arts, besides spices and balsams—as frankincense, myrrh, obilanum, balsam of Mecca, mastich, and the like. The bark of most of the genera is aromatic, bitter, and astringent, employed medicinally against diarrhœa, and in some instances (*Rhus coriaria*) used by tanners. The beautiful zebra-wood of the cabinetmakers, according to Sir Robert Schomburgk, is produced by *Omphalobium Lamberti*, a large tree common in the forests of Guiana; where also abounds the *Icica altissima*, whose gigantic trunk furnishes the light, easily-worked, and highly-aromatic cedar-wood of Guiana.

LEGUMINOSÆ—LEGUMINOUS PLANTS.

This is one of the most extensive and best defined orders in the vegetable kingdom, containing upwards of four hundred and forty genera, and nearly six thousand species. It embraces all the plants bearing butterfly-shaped (papilionaceous) flowers, and podlike seed-vessels, among which may be mentioned, as familiar examples, the pea, vetch, bean, lupine, restharrow, broom, furze, and laburnum. In an order so extensive, it may be expected that there will be many minor differences requiring subdivision into tribes; but without adverting to these in the meantime, the following may be stated as the general characteristics of the *Leguminosæ*:—Herbs, shrubs, or trees; leaves alternate, generally compound, and frequently have the common petiole tumid; usually two stipules at the base of the petiole, and also two to each leaflet in the pinnate leaves; the pedicles are generally articulated, and the flowers are furnished with small bracts; calyx five-parted, the segments being sometimes unequal and variously combined; petals never more than five, but often less, and sometimes wanting, inserted into the base of the calyx, and variously arranged, being usually papilionaceous, and sometimes spreading, the odd petal being always superior; stamens definite or indefinite, inserted with the petals, or sometimes hypogynous, dis-

Papilionaceous.

tinct, or in one, two, or three bundles; ovary superior, for the most part one-celled; ovules one or many; style and stigma simple; fruit a true legume, a modified form of legume or loment, or when containing only one seed, drupelike; seeds one or several, sometimes furnished with an arillus; albumen none; embryo straight, with the radicle in some instances bent along the edge of the cotyledons.

This order has sometimes been divided into two sub-orders—namely, *Papilionaceæ*, or those genera which have butterfly-shaped flowers and true legumes; and *Lomentaceæ*, those in which the corolla is regular and somewhat rosaceous, and the fruit a loment or modified form of legume. This division, though sufficiently distinct, serves little purpose in detail; and therefore that of Decandolle, which arranges the order into the following tribes or sections, is now generally received:—1. *Sophoreæ*, the sophora tribe, handsome flowering plants; 2. *Loteæ*, the lotus tribe, several species of which are found in Britain, and known as the bird's-foot trefoil; 3. *Hedysareæ*, the sainfoin tribe; 4. *Vicieæ*, the vetch tribe, including the pea and bean; 5. *Phaseoleæ*, the kidney-bean tribe; 6. *Dalbergieæ*, the gum-dragon, a group of stately trees and twining shrubs; 7. *Swartzieæ*, a tribe of evergreen shrubs; 8. *Mimoseæ*, including the well-known mimosas of our conservatories; 9. *Geoffrieæ*, the earthnut tribe, including the earthnut (*Arachis*), and the tonquin bean (*Dipteris*); 10. *Cassieæ*, the cassia tribe; and 11. *Detarieæ*. Some botanists exclude *Moringa*, the horse-radish tree, in the Leguminosæ, while others make it a separate order, under the name of *Moringaceæ*. The main point of distinction consists in the fruit, which is a three-valved podlike capsule; but as others of the Leguminosæ have their carpels similarly united, the Moringas may be regarded as the twelfth tribe of the Leguminous order.

This family, says a recent writer, is amongst the most important to man, whether as affording objects of beauty, of utility, or of nutriment. The bean, the pea, the vetch, and the clover tribe belong to it; as do the logwood, the laburnum, indigo, the tamarind, liquorice, senna, and the acacias. Its general property is to be wholesome, but there are several exceptions. Thus the seeds of laburnum, and the juice of *Coronilla varia*, are poisonous. Senna obtained from various species of cassia is purgative, and several others of the order possess a similar property. The pericarp of some contains much tannin; dyes are obtained from others; and many yield gums and balsams. But it would consume pages to enumerate all the uses to which this, one of the most extensive orders in the vegetable kingdom, has been applied.

ROSACEÆ—ROSEWORTS.

Like the preceding, this is one of the most extensive natural orders, comprehending upwards of seventy genera, and about nine hundred described species. The genera are herbs, shrubs, and trees, often of very dissimilar habits and appearance, but all bearing a striking resemblance in their inflorescence to the single or wild rose of our woods and hedges, which has been taken as the type of the order. Among the trees may be mentioned, as familiar examples, the almond (*Amygdalus*), the pear and apple (*Pyrus*), the sloe and plum (*Prunus*), the peach and nectarine (*Persica*), the cherries and laurels (*Cerasus*), and the japonicas (*Eriobotrya*); among the shrubs, the rose (*Rosa*), the hawthorn (*Cratægus*), the bramble and raspberry (*Rubus*), and the quince (*Cydonia*); among the herbs, the common yellow *Potentilla* of the roadsides, the *Geum*, the *Tormentilla* of our woods and commons, and the delicious strawberry (*Fragraria*). From the mention of these plants, the reader will be enabled to form some

Rosaceous.

idea of the order, and to perceive that the varied nature of its genera requires a subdivision into several tribes for the purposes of detailed description. Before mentioning the different sections into which the *Rosaceæ* have been arranged, the following may be taken as their general characteristics:—Herbs, shrubs, and trees; leaves alternate, generally compound, and always furnished with stipules; calyx five-lobed, united below, but separate and expanding above; corolla four or five petals, for the most part five. The ovary is one-celled, and there is seldom more than one seed, scarcely ever more than two in each cell. Carpels numerous, and generally enclosed in the fleshy tube of the calyx.

The order is usually divided into the following tribes:—1. CHRYSOBALANEÆ, or cocoa-plum family, represented by *C. icaco*, an irregular shrub, eight or ten feet high, found in South America and the West Indies, where its fruit, which is about the size of a plum, of a whitish-yellow, and possessing a sweetish taste, is brought to the markets. There are nine genera belonging to this tribe, all of which are trees or shrubs, with simple alternate stipulate leaves, and flowers in racemes or panicles. They are natives of the warmer parts of Africa and America, and differ from the almond tribe in having irregular petals and stamens, and in the style arising from the base of the ovary. 2. AMYGDALEÆ or almond family, represented by the common almond (*A. communis*), and embracing the peach, apricot, nectarine, plum, cherry, &c. well known for their delicious fruits, and a few bushes remarkable for their gay appearance during the flowering season. The fruits of this tribe are for the most part edible; and though the leaves and bark possess medicinal properties, yet one of the most subtile poisons—prussic acid—can be extracted both from the fruit and leaves of the almond. 3. SPIRÆEÆ, deciduous shrubs and perennial herbs, represented by *Spiræa salicifolia*, or bride's-wort. In this section the five-cleft calyx is lined with the dilated receptacle, which forms a sort of cup for the carpels; the petals are small and round, overset by from twenty to fifty stamens, which project far beyond them. The carpels are follicles, and from two to five in number, opening at the tops to discharge the seeds when ripe. 4. DRYADEÆ, embracing all those plants which agree with the common *Potentilla* in the construction of their flowers—that is, in having a calyx of ten sepals, a cup-shaped corolla of five petals, and the stamens, which are numerous, forming a ring round an elevated receptacle, on which are placed numerous carpels. By this test the student will find that the section comprises not only herbs, such as the potentilla, geum, tormentilla, and strawberry, &c. but also erect and trailing shrubs, as the raspberry and bramble. These genera, though alike in their flowers and in many of their habits, are otherwise very dissimilar. In the potentilla, for example, the carpels form the prominent part of the so-called fruit, while in the strawberry it is the receptacle which dilates and becomes edible. Again, in the raspberry the receptacle is a torus surrounded by the carpels, which swell out and soften, forming the edible portion, while the receptacle constitutes the core or torus. The leaves and stems of these genera are also very dissimilar, but the habit of increasing by suckers or runners is very prevalent in all. 5. SANGUISORBEÆ, a section of herbaceous perennials, illustrated by *S. officinalis*, or the weed burnet of our pastures. The flowers have no petals, but the clefts of the calyx are coloured instead, besides being generally furnished with glossy coloured bracts. 6. ROSEÆ, or roses proper, the type of which is the single wild-rose, or dog-rose of the hedges. The characters of this section are too well known to require much description. They have all a cup-shaped corolla of five equal slightly indented petals, capable of being increased indefinitely by cultivation; numerous yellow stamens; a five-cleft calyx, the throat of which is filled with the receptacle. The pitcher-shaped portion of the calyx becomes the hip as the seeds ripen, and forms a false pericarp, enclosing the numerous bony carpels. They are all shrubs, with pinnate leaves and prickly stems—the prickles differing from thorns in being articulated to the stem—that is, of being separated without tearing the bark. Most of them are fragrant, and the leaves of some, as the sweetbrier, are replete with a fragrant volatile oil. 7. POMEÆ, an extensive and varied section, the type of which is the common apple (*Pyrus malus*). It comprehends the apple, pear (*Pyrus communis*), the mountain-ash (*P. aucuparia*), the wild service (*P. torminalis*), the quince (*Cydonia*), and the hawthorn (*Cratægus*). In all of these genera, which are trees and shrubs, the flowers are remarkably similar; but the habits of the plants, the leaves, and the fruit, present numerous differences. These, however, are too well known, or at least can be so easily ascertained, that it is needless to describe them.

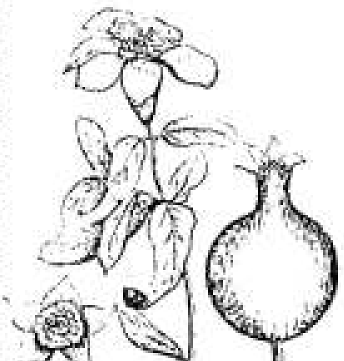
The properties of the order have already been so far noticed in the preceding detail, that it may be stated of them generally as follows:—The fruit of some of the *Chrysobalaneæ* are eaten under the name of the cocoa-plum. The *Amygdaleæ*, including the almond, plum, cherry, sloe, &c. are well known; the leaves and kernels contain prussic acid, which, in a concentrated form, is one of the subtlest poisons; but being generally diluted in a natural state with gum, sugar, &c. it is harmless, and serves to give an agreeable flavour to the fruits containing it. Of the *Potentilleæ*, the roots of several are astringent and febrifugal, and the fruits of such as the raspberry and strawberry are delicious and wholesome. The *Roseæ* are chiefly valued for their ornamental flowers, but they also yield valuable extracts—as attar of roses, rose-water, conserve of roses, &c. The *Pomeæ*, under cultivation, supply wholesome and delicious fruits, of which the apple, pear, quince, and serviceberry, are familiar examples.

MYRTACEÆ—MYRTLE-BLOOMS.

This important order consists of upwards of sixty genera, and about thirteen hundred species. They are all trees or shrubs, often with angled branches, with simple exstipulate leaves, which are for the most part opposite, full of transparent dots, and with a transparent line round the edge—rarely alternate or without dots. The substance of the leaf is coriaceous, and the dots are glands, or cysts, full of a fragrant volatile oil. The inflorescence is both terminal and axillary, variable in its form, but generally aggregate—the flowers being regular and united, of a white, red, or sometimes yellow colour, but never blue. The tube of the calyx adheres to the germen; the limb from four to eight cleft, persistent and deciduous. The petals, which are rarely wanting, are equal in number to, and alternate with, the segments of the calyx; the stamens are inserted with the petals, and are twice as many, or (usually) indefinite, and then arranged in several series; the anthers are oval, two-celled, and burst longitudinally. Ovary cohering with the tube of the calyx, and from one to six celled; style and stigma simple. The fruit is various, being either dry or fleshy, capsular, baccate, or drupaceous; many-celled, or one-celled by the obliteration of the dissepiments of the carpels. Seeds generally indefinite, seldom few, and without albumen.

In an order so extensive, strict uniformity of character is scarcely to be expected; hence the variations which occur in the fruit, manner of flowering, and arrangement of the leaves, have induced botanists to suggest various subdivisions. For example, a twofold division has been proposed; namely, those genera which have a dry capsule for the fruit—as *Melaleuca*, *Eucalyptus*, &c.; and those with berry-like fruit, like the myrtle (*Myrtus*), the guava (*Psidium*). This division, however, gives little aid to discrimination: and perhaps the best arrangement is that given by Decandolle; 1. CHAMÆLAUCIEÆ, having a one-celled ovary and capsule, with leaves opposite and dotted; 2. LEPTOSPERMEÆ, having a many-celled capsule, with opposite or alternate leaves, which are usually dotted; 3. MYRTEÆ, having a berry, distinct stamens, opposite leaves, which are always dotted; 4. BARRINGTONIEÆ, having a fleshy, one-celled fruit, monadelphous stamens, and opposite or whorled leaves without dots; 5. LECYTHIDEÆ, having a many-celled woody capsule, that opens with a lid or remains closed, monadelphous stamens, leaves alternate and without dots. All the species are natives of mild and warm climates; the most northerly situation in which they are known to grow to perfection being the southern latitudes of Europe.

The myrtle-blooms are possessed of many useful as well as ornamental properties. Among the edible fruits may be mentioned the guava, yielded by several species of *Psidium*; the rose-apple and jamrosade, produced by *Eugenia* and *Jambosa*; the Brazil nut, which is the seed of the *Bertholletia excelsa*, there being from sixteen to twenty of these seeds in the larger woody capsule. Of spices yielded by the order, which are all more or less aromatic, we have the clove, being the unexpanded flower-bud of the *Caryophyllus aromaticus*; all-spice, the dried berries of *Eugenia pimento*; and also the dried berries of the common myrtle. It is the volatile oil which is found in the dots of the leaves, the unexpanded petals, and in almost all the parts of the plant, that gives to them their fine aromatic fragrance. The pomegranate, *Punica granatum*—now ranked under this order—forms a delicious fruit in warm countries; the pericarp or rind is used in the East as an astringent; and the bark of the root is esteemed an efficient anthelminthic. The name pomegranate—*pomum - granatum*—is derived from the resemblance of the fruit to an apple filled with grains or seeds; and the term *punica*, either from its being obtained from the Punic or Carthage shores of the Mediterranean, or from its bright scarlet colour (*punicus*).



Pomegranate.

CUCURBITACEÆ—GOURDS.

This is a large and interesting family of herbaceous plants, containing fifty-six known genera, and about three hundred species. The roots are annual or perennial, fibrous or tuberous; the stems succulent, climbing by means of lateral tendrils formed of the abortive stipules, and furnished with alternate, palmated, rough leaves. The flowers are usually unisexual, solitary, or panicled; and of a white, red, or yellow colour. The calyx is five-toothed, sometimes obsolete; petals five, more or less united, sometimes scarcely distinguishable from the calyx, strongly marked with reticulated veins, sometimes fringed; stamens five, distinct, or in three bundles; anthers two-celled, long, and sinuous; ovary inferior, one-celled, and adhering to the calyx; style short; stigmas five, two-celled, velvety or fringed. Fruit a peponida (as illustrated by the cucumber and melon); seed usually ovate and flat, enveloped in a juicy or dry and membranous arillus; testa leathery, often thick at the margin; embryo without albumen; cotyledons leafy.

The Cucurbits are natives of all hot climates, but are most abundant in India; a few exist in the northern parts of Europe and America, and some are found at the Cape of Good Hope. Decandolle divided the order into two sections—NHANDIROBEÆ and the true CUCURBITACEÆ: the former including the genera *Nhandiroba* and *Zanonia*, &c.; and the latter the well-known gourds and pumpkins (*Cucurbita*), the cucumbers and melons (*Cucumis*), the white bryony (*Bryonia*), the spirting cucumber (*Momordica*), the bottle gourd (*Lagenaria*), and the snake gourd (*Trichosanthes*). Some botanists include the papaw-tree (*Carica papaya*) under this family; but it is better to consider it as a separate order.

In an economical point of view, the order is of considerable importance, furnishing the well-known esculents—the cucumber, melon, gourd, pumpkin, and calabash; and the purgatives colocynth and elaterium. The general properties of the gourd family may be regarded as bitter and purgative—these qualities pervading more or less all the species, and rendering their fruit either esculent or purgative. The seeds of all are sweet and oily, and from some a considerable quantity of fine-flavoured oil may be expressed. The roots and leaves are sometimes replete with a bitter drastic juice. The fruit of many of the members grow to an enormous size; the calabash, for example, being sometimes found six feet long and eighteen inches in circumference. *Gerkins* are the fruit of the common cucumber pickled when in a young state.

CACTACEÆ—INDIAN FIGS.

The Indian Figs or Cactuses constitute one of the most singular and interesting orders in the vegetable kingdom. They are unique in their forms and habits, and meet with but very distant allies in the other fleshy-leafed orders. They are perennial succulent shrubs, some having tall angular stems, and others rounded spiny ones, not above a few inches in height. In general, the stems and branches are jointed; the leaves are either very minute, or altogether wanting, their place being supplied by spines, either solitary, or growing in bunches. The flowers are sessile, usually white, scarlet, or purple, in many cases showy and attractive, and frequently ephemeral; the sepals are numerous, either crowning the ovary, or covering its surface; petals numerous, arising from the mouth of the calyx, and more or less combined; stamens also numerous, in many rows, and more or less cohering with the petals and sepals; filaments long and slender; anthers ovate; ovary one-celled; style filiform; stigmas many and clustered; fruit a fleshy berry, smooth, scaly, or tuberculated; seeds enveloped in pulp.

The order is usually divided into the OPUNTIACEÆ and RHIPSALIDEÆ; the former including the genera *Cactus*, *Melocactus*, *Opuntia*, *Cereus*, *Mamillaria*, *Echinocactus*, *Epiphyllum*, and *Pereskia*—in which the ovules and seeds are fixed to the parietes of the fruit—the latter the solitary genus *Rhipsalis*, in which they are attached to a central axis. All the genera have leaves only when very young; and as soon as the plant begins to grow, the leaves either fall off, or their place is taken by prickles. They are all natives of tropical America, but thrive well in all hot, dry, and exposed places. Of the more common genera we may mention the following:—*Mamillaria*, so called from the pap-like tubercles which cover its sub-cylindrical stem. Each tubercle is crowned with a little tuft of radiating spines; and the flowers, which are sessile, are ranged in a kind of zone round the plant. The melon cactus (*Melocactus communis*), which has a globose stem, with alternate furrows and ridges, the latter being armed with tufts of spines. The stem is crowned by a woolly tuft, from which spring the flowers. The hedgehog thistle (*Echinocactus*) has also a globose stem, but wants the woolly head, and has its flowers springing from the tufts of spines which arm the ridges. The torch thistle (*Cereus*) has the stem angular, the projecting angles being armed with spiny tufts, from which the flowers generally spring. The old man cactus (*Pilocereus*) is so called from its resemblance, when of small size, to an old man's head, being covered with long white hairs. In our hothouses it is generally of small size; but in its native country it is said to attain the height of twelve or fifteen feet. The Peruvian torch thistles (*C. peruvianus* and *hexagonus*) are still more gigantic plants, often attaining a height of forty feet, though their stems be not thicker than a man's arm. The creeping cereus (*C. flagelliformis*) is well known from its long whip-like stems, which hang down from the sides of the suspended pots in which it is usually grown. The night-flowering cereus (*C. grandiflorus*), so called from its blossoms opening during night, and fading before morning, has an angular, branched, and climbing stem, throwing out roots at every point. The rays of the calyx are of a bright yellow when open, and the petals are of the most delicate white. The genus *Rhipsalis* has slender jointed stems, which look like samphire; and the opuntias, which are numerous and useful, are distinguished by their round, flat, leaf-like bodies, united together by joints, and for the most part covered with spines.

The fruit of many of the cactaceæ are esculent, but are rather insipid, having little of that acidulous flavour which characterises the Currantworts, to which they are allied. It is upon the cactus and opuntias that the cochineal insect, so valuable in the arts, chiefly feeds. It is stated that not less than 300,000 lbs. of cochineal is annually brought to Europe, one-fourth of which is consumed in Britain alone, at the cost of £300,000 sterling: so valuable to man is an insect which ignorance would be apt to regard as mean and insignificant. In the south of Europe, the prickly pear (*O. communis*) is reared as a hedge, and also for its fruit, which is edible, and yields a rich carmine pigment; and the Indian fig (*O. tuna*) is grown for similar purposes in Brazil. In our conservatories, the cactuses are cultivated as ornamental plants alone, either for the beauty of their flowers or the singularity of their structure.

GROSSULARIACEÆ—CURRANTWORTS.

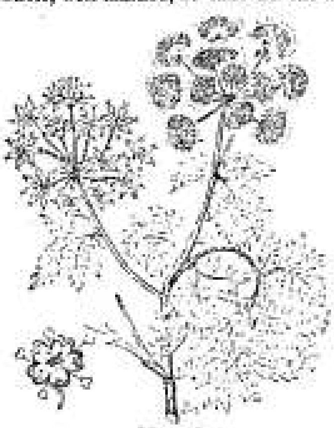
This is a well-known order, consisting of two genera, one of which, *Ribes*, includes all the gooseberries and currants of our gardens. The species, of which there are upwards of eighty, are unarmed or thorny shrubs, with round or irregularly-angled stems and branches; simple, lobed, alternate leaves, destitute of stipules and tendrils. The inflorescence is axillary and in racemes; the pedicle is furnished with two bracteoles, and a large deeply-cut bract at its base. The calyx, which is coloured, is four or five cleft; petals perigynous, equal in number to, and alternate with, the segments of the calyx; stamens of the same number, alternate, and inserted with the petals; filaments distinct; anthers two-celled, bursting longitudinally; ovary one-celled, cohering with the tube of the calyx; ovules indefinite; style several cleft; placentas two, parietal and opposite; fruit a berry, crowned with the remains of the flower, one-celled, filled with pulp; seeds numerous, suspended among the pulp by filiform funicles; testa externally gelatinous; albumen horny.

By Jussieu and other French botanists, this order, on account of its perigynous stamens, is considered as allied to the cactuses and saxifrages; but Dr Lindley considers it as allied to the vine in its succulent fruit-lobed leaves and racemose inflorescence. It, however, differs very essentially in having a superior calyx—into the sides of which the stamens are inserted—and in its fruit containing but one cell with parietal placentation. The order is very conveniently grouped into two sections—namely, the gooseberries, which have prickly stems, and the flowers either singly, or in clusters of not more than two or three; and the currants, which are entirely without spines, and the flowers in racemes. There are a few species, such as *R. diacantha* and *saxatile*, which may be considered as intermediate, these having the spines and habit of growth of the one and the racemose inflorescence of the other. The common gooseberry (*R. grossularia*), the red currant (*R. rubrum*), the black currant (*R. nigrum*), and the flowering currant (*R. sanguineum*), are familiar examples of the order, and all too well known to require any detailed description. The gooseberry is found wild in many parts of Britain; and is reared in England to greater perfection than in any other country, Lancashire prize specimens having been known to weigh an ounce and a half.

Gooseberries and currants are well known as agreeable acid fruits, their acidity or sweetness depending upon the relative quantities of malic acid and sugar which they contain. They are used both as dessert and kitchen fruits; preserved with sugar, they make the best jams and jellies; and when fermented, produce wines little inferior to that of the grape. The blackberry has tonic and astringent properties, infusions of the leaves being used for this purpose.

UMBELLIFERÆ—UMBELLIFEROUS PLANTS.

This is one of the most extensive and important of the natural orders, comprising nearly three hundred genera, and above fifteen hundred species. The genera, though presenting many minor differences, are, on the whole, well-marked, so that no one who has seen the flower of the parsley and common hemlock, can have any difficulty in detecting an umbelliferous plant. The species are for the most part herbs, seldom shrubs, with fistular, furrowed stems, loving damp waste places, and varying much in their properties, according to the climate under which they are grown. The leaves are generally divided, sometimes simple; are alternate, and clasp the stem by a sheathing petiole. The flowers are white, pink, yellow, or blue, and in umbels, which are simple or compound, and these are with or without bracts at their base; when seated at the base of the umbel, the bract is called an involucre, when at the base of the umbellules in the compound head, an involucellum. The calyx is superior and five-toothed; petals five, and inserted on the outside of a fleshy disk, which is placed on the top of the ovary; stamens five, and inserted alternately with the petals; ovary inferior, and two-celled, with pendulous ovules; styles two, distinct; stigmas simple. The fruit consists of two carpels, united by a common axis, from which they separate when ripe; the external part of the carpels is traversed by linear ridges, which are divided into primary and secondary, there being five of the latter, and four of the former, between them. The ridges are separated by channels, below which are often placed, in the covering of the seed, receptacles or vittæ of an oily matter. The seed is pendulous, usually cohering with the carpel, rarely loose. The fruit and seed are often confounded in common language, but this arises from their peculiar position, as a little inspection will show.



Hemlock.

Among the more familiar genera may be mentioned the parsnip (*Pastinaca*), the cow parsnip (*Heracleum*), the celery (*Apium*), the carrot (*Daucus*), the hemlock (*Conium*), the cow-bane (*Cicuta*), and the coriander (*Coriandrum*). Several relations have been pointed out between the Umbelliferæ and other orders; such as their agreement with the Crowfoots in the sheathing leaves, the acrid juice, and large albumen; with some of the Geraniums in their habit, form of leaves, and poisonous properties; and with Ivyworts, from which they differ little, except in the parts of the flower. Decandolle has arranged the genera into three sub-orders—namely, 1. ORTHOSPERMÆ, having the albumen of the seed flat on the inner surface, neither involute nor convolute; 2. CAMPYLOSPERMÆ, having the albumen rolled inward at the edge; and 3. CŒLOSPERMÆ, having the albumen curved inwards from the base to the apex. The first of these sub-orders comprises eleven tribes—as Hydrocotylidæ, Mulinidæ, &c.; the second four tribes, as Elæoselinidæ, &c.; and the third only one tribe—namely, the Coriandridæ.

The properties of this order are very variable and important. Generally speaking, all the genera are characterised by an acrid principle, which finds its full development in the hemlock, rendering the roots of that plant virulently poisonous. This principle is more or less diffused through the whole order, but is often enfeebled by change of situation, or altogether destroyed by cultivation. It is this principle which gives the peculiar flavour to celery, parsley, and samphire. Another important secretion is the aromatic oil contained in the vittæ of the pericarps, which is used in diet as a condiment, and in medicine as an aromatic and carminative. It is found abundantly in the anise, caraway, dill, cumin, and coriander. A gum-resinous exudation characterises others of the genera, which yield the valuable medicines assafœtida, galbanum, opopanax, sagapenum, &c. The roots of many of the Umbelliferæ, when cultivated and properly treated, are replete with starch and sugar—as the common carrot, the parsnip, the skirret, and the arracacha of the South Americans.

CAPRIFOLIACEÆ—CAPRIFOILS.

A well-known order, consisting of twelve or fourteen genera, and upwards of two hundred and ten species. They are shrubs, rarely trees, having opposite, simple, or pinnated leaves, without stipules; and flowers terminal, in corymbs, or axillary. The flowers are white, scarlet, or yellow, and often sweet-scented, as in the common honeysuckle. The essential characters of the reproductive organs are—calyx superior, with its limb five-lobed; corolla inserted on the calyx in one piece, with its margin lobed, sometimes irregular, the divisions alternate with those of the calyx; stamens equal in number to the segments of the corolla, alternate with them, and inserted on the calyx; filaments awl-shaped; anthers ovate, two-celled; ovary cohering with the calyx, from one to five-celled, with a few pendulous ovules in each cell; style exserted; stigmas as many as the cells, either distinct, or combining into one capitate stigma; fruit one or more celled, either dry, fleshy, or succulent, and crowned by the persistent limb of the calyx; seeds generally solitary, pendulous; embryo straight; albumen fleshy.

The order has been divided into two sections—namely, the SAMBUCEÆ or elder tribe, and the LONICEREÆ or true honeysuckle tribe. In the former, the corolla is regular and rotate, seldom tubular; ovary three or four-celled; style none; stigmas three, sessile; raphe on the inner side of the ovule. It includes the genera *Sambucus* and *Viburnum*. In the latter, the corolla is tubular, often irregular; style one; berry from two to four-celled, each cell containing one or many seeds; raphe on the outer side of the ovule. It embraces the genera *Caprifolium*, *Lonicera*, *Triosteum*, *Diervilla*, *Abelia*, *Symphoricarpus*, *Linnæa*, &c. As examples of the first tribe, may be mentioned the common elder (*Sambucus nigra*)—well known by its pinnate leaves and terminal cymes of white flowers, which blow in June; by its dark purple pulpy berries, which ripen in September; and by its yellow wood, which is full of a light white pith—also the dwarf elder or Danewort (*S. ebulus*), the red-berried elder (*S. racemosa*), and the white-berried, which is only a variety of the common kind. The Laurestinus (*Viburnum tinus*) is a well-known evergreen, whose showy white flowers appear during winter; and the Gueldres rose (*V. opulus*) is common in gardens under the name of the 'snowball-tree.' In the Viburnums the leaves are not pinnate, and the wood is hard, and without the spongy pith of the elders. As examples of the second, may be mentioned the climbing honeysuckles (*Caprifolium*); the upright species or fly honeysuckles (*Lonicera*); the snow berry (*Symphoria*); and the little graceful *Linnæa borealis*, called in honour of the immortal botanist. The Caprifoils grow chiefly in the temperate regions of the northern hemisphere, and delight in cool shady places.

The properties of the order are varied, and of considerable utility. The berries of the elder are fragrant and sudorific; they contain malic acid, and a wine is often made from them, which is drunk warm with spices and sugar. The leaves are emetic and purgative; and the berries, in a green state, are poisonous to some animals. The wood, which is hard and yellow, is used by turners, and the pith is often employed in electrical experiments. The fruit of Viburnum has an austere astringent pulp, but becomes eatable after fermentation. The wood of the wayfaring tree is in great repute for the tubes of tobacco-pipes in some parts of Turkey; and the bark yields a viscous substance, used as birdlime. The roots of *Triosteum* and *Diervilla* are used in America instead of ipecacuanha; and the berries of *T. perfoliatum* are said to form no bad substitute for coffee. The honeysuckle is a purgative, but is employed principally as a handsome and fragrant climber. Indeed the whole genera are grown more for their beauty than economical uses—the climbing species for adorning old walls and trunks of trees, and the upright sorts for their shelter and covert; the elder, for example, growing in exposed places by the seaside, where any other plant would perish.

RUBIACEÆ—MADDERWORTS.

This is a large, and in many respects not a well-defined order, composed of small trees, shrubs, and herbs. It has been proposed to separate it into two orders—CINCHONACEÆ, containing those plants most resembling cinchona; and GALIACEÆ, those most resembling the galiums or bedstraws. Decandolle has proposed a further subdivision into thirteen sub-tribes, taking the genera *Cinchona*, *Gardenia*, *Hedyotis*, *Isertia*, *Hamelia*, *Cordiera*, *Guettarda*, *Pæderia*, *Coffea*, *Spermacoce*, *Anthospermum*, *Rubia*, and *Operculuria*, as the types. Without following these details, it may be stated that, collectively, the Rubiaceæ are described as herbaceous plants, with square or angular stems, and whorled and exstipulate leaves; the verticilli being formed of two opposite gemmiferous leaflets, with a variable number of intermediate ones, not differing in appearance from the general foliage, but destitute of buds. The inflorescence is in panicles; the florets small, and in general united; the calyx is superior, the tube joined to the germen, and the limb from four to six cleft; the corolla is synpetalous, rotate, or funnel-shaped, regular, with its petals equal to the sepals, and exserted from the calyx; the stamens are as many as the lobes of the corolla, and exserted alternately with them; the filaments are free, the anthers incumbent, two-celled, and open longitudinally. The germen consists of two connected carpels, invested by the adherent tube of the calyx; the styles two, and the stigma headed.

By far the greater number of the species are tropical plants, though many are amongst the most common and neglected British weeds. Madder (*Rubia tinctorum*) is common in gardens, and is much cultivated in Belgium and Holland for its roots, which yield a rich brownish-red dye. The *Galiums* or bedstraws are familiar plants, growing on hedges, on dry banks, or sides of old ditches, and known by the common names of cleavers, ladies' bedstraw, crosswort, and the like. *Asperula odorata*, another of the order, is the well-known woodruff, which acquires, when dried, a most delicate fragrance. The coffee-tree (*Coffea*), Jesuit's bark (*Cinchona*), the Cape jasmine (*Gardenia*), and ipecacuanha (*Cephäelis*), are also well-known members.

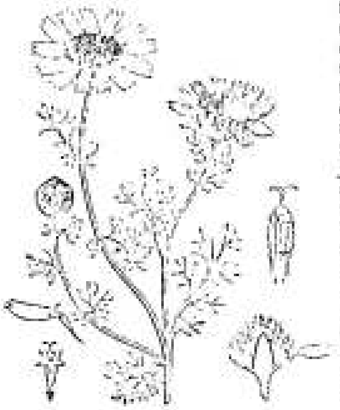
As might be expected, the properties of such an indefinite order are very varied. The roots of many, as the madders and bedstraws, contain a large quantity of colouring matter; in others they are acrid, emetic, purgative, or diuretic. The bark (as that of the Cinchonia or Peruvian bark) is sometimes bitter, tonic, and astringent, and highly prized in intermittent fevers. The value of the roasted albumen of the coffee-berry is too well known to require allusion; and perhaps, if trial were made, the fruit of others of the order might answer the same purpose. The fruit of the genipa and sarcocephalus are eaten in their native countries; and the fragrance and beauty of some, as the Gardenias, Hindsias, and Ixoras, are unsurpassed in the vegetable kingdom. Among our ancestors, the dried soft haulm of the galliums was much used for beds; hence the term 'bedstraws' for the plants of this sub-tribe.

COMPOSITÆ—COMPOSITES.

This is one of the most extensive of the natural orders, containing not fewer than nine hundred genera, and upwards of eight thousand species. The members are herbaceous plants or shrubs, with leaves alternate or opposite, without stipules, and usually simple. What is called the flower is an aggregation of unisexual or hermaphrodite *florets*, collected in dense heads upon a common receptacle, surrounded by an involucre, as exemplified in the common daisy, marigold, and dandelion. As the compound leaf is composed of a number of leaflets, so is the composite flower made up of a number of florets arranged on one receptacle, which is furnished with a calyx-like involucre. Each floret is complete in itself, having all the appendages of bracts, calyx, corolla, stamens, and pistil. The bracts may be either present or absent; when present, they are stationed at the base of the florets, and designated the *paleæ* of the receptacle. The calyx is superior, and united with the ovary, so that the tube is rarely sufficiently distinct to be perceptible; the limb is either wanting, or membranous, and cut into long feathery segments called pappus. The corolla is monopetalous, and either ligulate, tubular, or bilabiate—that is, has two equal lips cut into several lobes. The stamens are equal in number to the teeth of the corolla, and alternate with them; the anthers grow together, so as to form a kind of cylinder, through which passes the style, ending in a two-lobed stigma. The ovary is inferior, one-celled, with a single erect ovule. The fruit is an achenium, which retains the pappus when ripe, and falls without opening; the adherence of this pappus or down is familiarly illustrated in the head of the ripe dandelion.

The term COMPOSITÆ is employed in consequence of the crowding together of the florets into *heads*. The term SYNANTHEREÆ has been also proposed, on account of the cohesion of the anthers; and from the star-like arrangement of the florets, some have applied the word ASTERACEÆ. Retaining, however, the original Jussieuan term, the Composite order has been divided into three sections:—1. *Cichoraceæ*, in which all the florets are ligulate; 2. *Corymbiferæ*, most of the florets tubular, involucre soft and unarmed, style not jointed; 3. *Cynarocæ*, most of the florets tubular, involucre hard or spiny, style jointed at the end. To these Decandolle has added a fourth section—*Labiatifloræ*—in which the florets are bilabiate; a distinction either overlooked or unknown to the founder of the Natural System. The Composite plants are widely scattered over the globe, forming, according to some authorities, one-twelfth of its vegetable productions. Humboldt states that they constitute one-seventh of the flowering plants of France, one-eighth of those of Germany, one-fifteenth of those of Lapland, a sixteenth of those of New Holland, a sixth of the North American Flora, and one-half of that of America within the tropics. Though their increase and decrease do not follow any law of climate, it may be stated generally that the Chicoraceæ are chiefly found in cold, and the Corymbiferæ in warm regions. The Composites are herbaceous in the colder quarters of the globe, and become shrubby as we approach the equator.

The Chichoraceæ are well illustrated by the common lettuce (*Lactuca*), the dandelion (*Taraxacum*), the succory (*Chicorium*), and the sow thistle (*Sonchus*), which are common and familiar British plants. All the members of this section yield a milky juice, which is bitter, astringent, and slightly narcotic. Many of them are used in medicine—as the lettuce, from which the narcotic and diuretic *Lactucarium* is obtained. Many are also used as articles of food; thus endive (*C. endivia*) is employed as a salad, so is the garden lettuce when young, the root of the sonchus, and perhaps more than all, the root of (*C. intybus*) or wild succory, which is roasted and largely mingled with coffee under the name of chicory. The Corumbiferæ, which have the central florets tubular, and the outer ones generally ligulate, are illustrated by the tussilago or colt-foot (*T. farfara*), by the daisy (*Bellis perennis*), the chamomile (*Anthemis nobilis*), the groundsel (*Senecio*), the tansy (*Tanacetum vulgare*), the dahlia, marigold, &c. The juice of this section is watery; sometimes bitter and tonic, and sometimes acrid. Many of them, either in their seeds, or in the whole substance, contain volatile oils, which are used for various purposes; and some yield yellow and other dyes. Among the most useful of the section may be mentioned the Jerusalem artichoke, wormwood, chamomile, tansy, arnica, and ragwort; indeed most of the corymbifers are of medicinal value. The Cynaraceæ embrace all those which bear an affinity to the common cardoon (*Cynara cardunculus*). Their juice is watery, bitter, and tonic. By cultivation this bitterness is lessened, and the plants, or portions of them, become edible. The section may be illustrated by the cardoon and common artichoke, all the thistles (*Carduus*), the burdock (*Arctium*), the corn blue-bottles (*Centaurea*), the safflower (*Carthamus*). The properties of the artichoke are well known, as are also those of the carthamus, which is used in dyeing as well as in medicine. The Labiatifloræ are less known, being rarely seen in British gardens. *Mutisia* and *Triptilion* are examples of this section, which possess to a certain extent the bitter and tonic properties of the order.



Chamomile.

ERICACEÆ—HEATHWORTS.

This is an extensive order of shrubs or undershrubs, with leaves evergreen, rigid, entire, whorled, or opposite, and without stipules. 'The name of the heath family,' as it has been very appropriately remarked, 'conjures up immediately the image of a number of narrow-leaved plants, with globular, ventricose, or bell-shaped flowers; and we are apt at first to think that the family is so natural a one, as to require very little explanation.' Did the order include only the heaths, this would be the case, for all the heaths, differing as they do in some particulars, may be recognised at a glance; but as the order includes the Rhododendra, the Azaleas, and Kalmias, besides several other plants which have not so strong a family likeness to each other as the heaths, it becomes necessary to say a few words on the botanical resemblances which connect them together. The first and most striking of these is the shape of the anthers, each of which appears like two anthers stuck together; and the manner of their opening, which is always by a pore or round hole in the upper extremity of each cell. The filaments also in all the genera, except Vaccinium and Oxycoccus, grow from beneath the seed-vessel, being generally slightly attached to the base of the corolla. There is always a single style with an undivided stigma, though the capsule has generally four cells, each containing several of the seeds, which are small and numerous. The calyx is four or five cleft, and the corolla is tubular, with a larger or smaller limb, which is also four or five cleft. The above are the connecting points between the various genera which compose the family; but the differences are such as, according to most botanists, to require a subdivision of the Ericaceæ into four sub-orders, or even into four distinct and independent orders. Adopting the former idea, we shall consider the heath family under the following subdivisions:—1. *Ericeæ*, or those most closely resembling the true heaths; 2. *Rhodoreæ*, those allied to the Rhododendra; 3. *Vaccinieæ*, those associated with the common bilberry; and 4. *Pyroleæ*, those allied to the winter-green and fir-rape of our woods and commons.

1. *Ericeæ.*—This sub-order may be arranged into two sections—namely, the true heaths (*Ericidæ*), having bracteal pedicles of flowers, the corolla of each flower being more or less bell-shaped or globose, with a four-cleft limb, a four-lobed calyx, and eight stamens; and the *Andromedidæ*, which have the corolla more globose, the limb five-cleft, the calyx five-lobed, and ten stamens. In other respects, both sections are nearly alike: both have a honey-bearing disk under the ovary; and both have the leaves, which are narrow and leathery, slightly rolled in at the margin. The stamens appear differently in the several genera, some being capitate, others ending in awn-shaped horns; in some they are concealed by the corolla, in others they are exposed. The style, in some of the genera, projects considerably beyond the corolla, in others it is rather contracted. The more familiar genera are the besom-heath of our moors (*E. tetralix*), the Cape heath (*E. hispida*), common ling or heather (*Calluna vulgaris*), the moor heaths (*Gypsocallis*), and those Cape heaths with shiny, glutinous, cylindrical corollas (*Callista*). All of these are true heaths, and bear so striking a resemblance to the common ling of our moors, as to be at once recognised. The genera *Andromeda*, *Zenobia*, the strawberry-tree (*Arbutus*), the bearberry of our Highlands (*Arctostaphylos uva-ursi*), and *Gaultheria*, frequent in gardens, are illustrations of the second section. The heaths cover large tracts of our own country, are common in North and South America, and abound at the Cape of Good Hope, which has supplied our gardens with hundreds of the most beautiful species. All of them possess bitter, astringent, and diuretic properties; and the berries of some, as well as the flowers, have been used in dyeing. The Arbutus is a very ornamental shrub, the berries of which are edible, and may be used in the preparation of a wine. The Picts are said to have derived a wholesome beverage from the heath; and the bearberry plant is used in some parts of Russia for tanning. The Highland heaths furnish excellent pasture for bees, and its seeds furnish the principal food of the grouse.

2. *Rhodoreæ.*—The plants in this sub-order have all less or more a resemblance to the well-known genus *Rhododendron*—the species of which have generally evergreen leaves, and large showy flowers produced in terminal corymbs. The calyx is small; the corolla large in proportion, bell-shaped, and deeply five-cleft; the stamens five or ten; the capsule five-celled, and five-valved. The flowers are generally purple or whitish, though in some they are yellow, pink, or bright-scarlet, as in the Nepaul tree-rhododendron. The genus *Azalea* is very nearly allied to the Rhododendra; but its species—the Indian and American—differ considerably in their inflorescence and leaves; the latter in some species being deciduous. *Kalmia* and *Menziesia* are familiar garden genera: *Ledum palustre*, or wild rosemary, and the Labrador tea-plant (*L. latifolium*), also rank

under this section. The members of this sub-order have an extensive range, being found abundantly in Europe, Asia, and North America. They are chiefly inhabitants of high cold regions, and in this particular agree with the general habit of the order. The Rhododendra possess soporific properties—*R. crysanthum* being used in gout and acute rheumatism. The Azaleas are astringent, and some, as *A. pontica*, is said to be poisonous. The same may be said of the Kalmias; and indeed the whole of this section require to be used with caution. The intoxicating effect of liquors is increased by an infusion of any of the species.

3. *Vaccinieæ.* — This section, which we have tabulated as a separate order, contains two well-known genera—*Vaccinium*, the bilberries and whortle-berries; and *Oxycoccus*, the cranberries. They are shrubs with alternate, leathery leaves, and of a close-growing bushy habit, with round or angled stems. The flowers are solitary, or in racemes, and in their general structure differ little from the heaths, except in the ovary being inferior. In Vaccinium, the stamens are eight or ten, and the anthers horned or spurred; in Oxycoccus, the stamens are eight, and the anthers without spurs. The members are natives of Europe and America; the former genus delighting in high dry situations, and the latter in marshes and swamps. Both yield edible berries, which have austere antiscorbutic properties. The bilberry or blaeberry (*V. myrtillus*) of our woods and hills is familiar to every one, as also the whortleberry (*V. vitis-idæa*). In North America there are many species—as *V. angustifolium* (bluets); *V. stamineum* (deerberries); and *V. frondosum* (blue tangles). Of the cranberry there are generally reckoned two species—*O. palustris*, the common cranberry of European morasses; and *O. macrocarpa*, the American cranberry, which has a larger and more oblong fruit. The berry of both is extensively collected, and used for tarts and other conserves.

4. *Pyroleæ.*—The main distinction of this sub-order is the long arillus or skin which encloses the seeds, and gives them the appearance of being winged. It is well illustrated by the winter-green (*Pyrola*), which is common in British woods; and by the fir-rape (*Monotropa*), a rather rare parasite, which attacks roots of the beech and pine. The species of Pyrola are described as 'pretty little evergreen plants, with white flowers, the corollas consisting of five distinct petals, and which have ten stamens, the anthers of which are two-celled, each cell opening by a pore: the style is single, ending in a capitate stigma cut in five lobes; the fruit a five-celled capsule.' The yellow fir-rape has a coloured stem, furnished with scales instead of leaves. The flowers, which are drooping, have a four or five parted calyx, and a four or five petalled corolla.

§ COROLLIFLORÆ.

The plants belonging to this subdivision have the stamens inserted in the fleshy part of the petals, which are joined together so as to form a monopetalous corolla. This corolla furnishes, as it were, a cup for the stamens and pistil, quite distinct from the calyx. The Orders exhibiting these distinctive characteristics are as follow:—

Epacridaceæ—Epacrids	Convolvulaceæ—Bindweeds
Styracaceæ—Storaxworts	Boraginaceæ—Borageworts
Myrsinaceæ—Ardisiads	Cordiaceæ—Sebestens
Sapotaceæ—Sapotads	Solanaceæ—Nightshades
Ebenaceæ—Ebenads	Scrophulariaceæ—Figworts
Brexiaceæ—Brexiads	Lamiaceæ } —Labiates
Oleaceæ—Oliveworts	Labiatæ }
Jasminaceæ—Jasminworts	Verbenaceæ—Verbenes
Strychnaceæ—Strychnads	Myoporaceæ—Myoporads
Apocynaceæ—Dogbanes	Acanthaceæ—Acanthads
Asclepiadaceæ—Asclepiads	Orobanchaceæ—Broomrapes
Gentianaceæ—Gentianworts	Lentibulariaceæ—Butterworts
Bignoniaceæ—Bignoniads	Primulaceæ—Primworts
Pedaliaceæ—Pedaliads	Globulariaceæ—Globulariads
Polemoniaceæ—Phloxworts	Plumbaginaceæ—Leadworts
Hydrophyllaceæ—Hydrophyls	Plantaginaceæ—Ribworts

OLEACEÆ—OLIVEWORTS.

Under this order is reckoned upwards of twenty genera, and about one hundred and thirty species. They are trees and shrubs with erect or climbing stems, and with leaves opposite, petiolate, simple, seldom ternate or pinnate, and destitute of stipules. The inflorescence is in panicles; the flowers regular and united, or sometimes, by abortion, polygamous; calyx free, divided, and persistent; corolla hypogynous, four-cleft, and rarely wanting; stamens two, hypogynous when the corolla is absent, alternating with its lateral lobes when present, or when there are four petals connecting the lateral petals in pairs; filaments free; anthers two-celled, bursting longitudinally; ovary free, two-celled; ovules pendulous and in pairs; style sometimes wanting; stigma entire or bifid; fruit drupaceous, baccate, or samaroid. According to the character of the fruit, the order is sometimes subdivided into the OLEÆ, having it a drupe or berry, and the FRAXINEÆ, having it samaroid.

The principal genera are *Olea*, the olive; *Fraxinus*, the ash; *Ornus*, the manna-ash; *Ligustrum*, the privet; *Syringa*, the lilac; *Chionanthus*, the fringe-tree; *Phillyrea*, *Millingtonia*, *Linociera*, *Fontanesia*, and *Notelæa*. The olive (*O. sativa*) is a well-known tree, with small white flowers, and a fleshy drupe like a sloe, from which is expressed the oil of commerce. The ash (*F. excelsior*) is a common British tree, with pinnate leaves, the flowers without a corolla, and the fruit a winged samara or key, resembling a dry leaf, with one or two seeds. The manna-ash (*O. Europæus*), though closely resembling the common ash in its leaves and samara, has loose panicles of white flowers, the corollas of which are divided into four long narrow segments. The privet (*L. vulgare*), the lilac (*S. vulgaris*), and Phillyrea, are too common ornamental shrubs to require particular notice.

Economically, the oliveworts are of great importance. Besides the oil of the olive, so universally used in Europe, the unripe berries are pickled and eaten on the continent to provoke an appetite; and the bark, which is bitter and astringent, is used as a substitute for cinchona. The bark of the common ash, as well as that of several members, is astringent and febrifugal, while the wood of the former is easily worked, and exceedingly tough and durable. Manna, which is a saccharine cathartic, is procured by wounding the bark of the Ornus, &c. The sweetness of this substance is not due to the presence of sugar, but to a distinct principle called Mannite, which differs from cane-sugar in not fermenting with water and yeast. The lilac, like the ash and others, is held in great repute, in some of the marshy districts of France, as a febrifuge; being indeed the only remedy ever employed for the marsh or intermittent fever which prevails there. The flowers of *O. fragrans* are said to be employed by the Chinese to impart a delicate flavour to some of their teas.

CONVOLVULACEÆ—BINDWEEDS.

A well-defined order, containing above forty genera, and between six and seven hundred species. The members are herbaceous plants or shrubs, with stems usually twining, smooth, or pubescent, and with leaves alternate, undivided or lobed, and exstipulate. The inflorescence is axillary or terminal; peduncles one or many flowered, the partial ones generally with two bracts. The essential characters are—calyx persistent in five divisions, and imbricated as if in more whorls than one—often very unequal; corolla monopetalous, hypogynous, regular, deciduous; the limb five-lobed, and plaited; stamens five, inserted into the base of the corolla, and alternate with its segments; ovary simple, with two or four cells, few-seeded, the ovules definite and erect; style one, usually divided at the top; stigmas obtuse or acute; capsule with the valves fitting at their edges to the angles of a loose dissepiment, bearing the seeds at its base.

The more familiar genera are—*Convolvulus*, *Caly-*

stegia, *Ipomæa*, *Falkia*, *Cuscuta*, and *Batatas*. All these genera have the corollas marked with a decided fold or plait, have the peculiarly imbricated calyx, are climbing plants, and not to be easily confounded with any other family. The *Convolvulus arvensis* is the wild climber of our hedges; and *C. tricolor*, so common in gardens, is a native of Sicily. The bindweed, *Calystegia sepum*, is another of our hedge natives, and is the well-known pest of the farmer. The *Cuscutas*, or dodders, often arranged into an independent order, are extremely destructive parasites, originally springing from the ground, but decaying at the root as soon as they are established on the plants they attack. The other genera are chiefly natives of warmer regions; none have yet been discovered in the coldest climates.

The roots of the order abound in an acrid, purgative, milky juice, exemplified in *jalap*, which is obtained from *Ipomæa Xalapa* (from Xalapa in Mexico); and in *scammony*, the concrete juice of the root of *Convol. scammonia*, found principally in Asiatic Turkey. Excellent jalap is also obtained from *Exogonum purga*, a beautiful climber with crimson flowers; and indeed more or less from almost the whole of the order. Notwithstanding, the roots or tubers of *Batatas edulis*, the common sweet potato, is edible, as is also that of *Ip. macrorhiza*, whose insipid farinaceous tubers are found in the sandy soil of Georgia and Carolina, weighing as much as forty or fifty pounds. The majority of the members have fine showy flowers, which add greatly to their importance.

SOLANACEÆ—NIGHTSHADES.

An extensive and somewhat varied order, of between fifty and sixty genera, and nearly nine hundred species. They are herbaceous plants or shrubs, with alternate leaves, and with angular or rounded stems. The essential characters are—calyx five (rarely four), plaited and persistent; corolla with the limb having the same number of lobes as the calyx, somewhat unequal, and deciduous; æstivation folded or imbricate; stamens alternating with the segments of the corolla, sometimes one abortive; anthers bursting longitudinally, or by terminal pores; ovary two or more celled, rarely one-celled; ovules usually indefinite; style continuous; stigma obtuse, very rarely lobed; fruit either a capsule opening variously, a berry with the placenta adhering to the dissepiment, or a nuculanium, with five spurious-celled nucules, which have one seed in each; seeds sessile. Though agreeing in most of the above characteristics, the various members have differences sufficient to require a division into four sub-orders—namely, *Soleneæ*, *Nicotianeæ*, *Verbasceæ*, and *Nolaneæ*.

1. The *Solaneæ* closely resemble each other in their flowers, of which those of the garden night-shade and potato may be taken as examples; and also in their berry-like fruit, which is always crowned by the persistent calyx. The genus *Solanum*, to which belongs the bitter-sweet (*S. dulcamara*), the garden nightshade (*S. nigrum*), and the potato (*S. tuberosum*), has the anthers opening by two pores like the heaths, whereas all the other members of the order have a slit down each cell. The tomato, or love-apple (*Lycopersicum esculentum*), with its edible fruit; the capsicum (*C. frutescens*), whose dry inflated berry yields the cayenne pepper of commerce; the winter cherry (*Physalis Alkekengi*), also with edible berry-like fruit; the deadly nightshade (*Atropa belladona*), which furnishes the deadly poison of that name; and the Barbary or box-thorn (*Lycium barbarum*), all belong to this sub-tribe. The Solaneæ are rather dangerous in their qualities, the leaves and flowers being an acrid or narcotic poison, and the fruit and tubers only becoming wholesome and nutritious when cooked. 2. The *Nicotianeæ* closely resemble the preceding sub-tribe in their folded-like corolla, but differ in having capsular fruit; that is, in having the seed-vessel dry and hard when ripe, and not soft and pulpy like a berry. The flowers are also more funnel shaped, with a longish tube and spreading limb. The principal genera are *Nicotiana* (*N. tabacum*), being the Virginian tobacco of commerce; *Petunia*, which furnishes some of our best-known garden favourites; *Nierembergia*, a genera of ornamental green-house plants; *Hyoscyamus*, the poisonous henbane; *Datura*, *D. stramonium*, being the common thorn-apple; and *Brugmansia*, *Salpiglossis*, and *Schizanthus*, all more or less prized for their showy funnel-shaped flowers, some of which are highly fragrant. The members of this sub-order also require to be used with caution, on account of their acrid and narcotic properties, which are well illustrated by the henbane and tobacco. 3. The *Verbasceæ* have not the corolla plaited in the bud, and possess only one-celled anthers. The genera *Verbascum*, *Celsia*, and *Anamonda*, illustrate this sub-tribe. *V. thapsus* is the common weed shepherd's club, so called from the club-like raceme of its flowers; it has mucilaginous and emulcent properties. 4. *Nolaneæ*. 'This tribe,' says Mrs Loudon, 'is principally known by the genus *Nolana*, the species of which are annual plants, natives of Chili and Peru, which have of late been much cultivated in British gardens. The flowers of *N. atriplicifolia*, one of the commonest kind, very much resemble those of the convolvulus tricolor, and the leaves are large and juicy like those of the spinach. On opening the corolla there will be found five stamens, surrounding four or five ovaries, which are crowded together on a fleshy ring-like disk. These ovaries, when ripe, become as many drupes, enclosing each a three or four celled nut or bony putamen, which is marked with three or more grooves on the outside, and has three or more little holes beneath. All the species of Nolana have the same peculiarities in their seed-vessels, though they differ in many other respects.' In this sub-tribe there is also the genus *Grabowskya*, the nuts of which resemble those of the coffee.

Besides the genera contained in the preceding sub-tribes, there are others, placed by some botanists under the nightshades, and by others under the figworts—such as *Anthocercis*, the species of which are evergreen shrubs from New Holland, with bell-shaped corollas; *Browallia*, containing several tender annuals; and the medicinal *Franciscea* of Brazil.

SCROPHULARIACEÆ—FIGWORTS.

The Figworts, of which the common foxglove may be taken as the type, form rather an extensive order, consisting of about one hundred and seventy genera and nearly two thousand species. The members are herbaceous, rarely shrubby plants, with round or square stems; the leaves being simple and exstipulate, opposite or whorled, seldom alternate, and either sessile or with foot-stalks. The inflorescence is very variable, being axillary or united, usually in spikes, racemes, or in panicles; calyx inferior, persistent, and often unequal; corolla tubular or inflated, with a short limb, which is flat or erect, nearly equally divided or labiate; stamens definite, two or four; filaments free; anthers two-celled; ovary two-celled and many-seeded; style simple; stigma obtuse, rarely bifid; fruit a dry capsule.

Foxglove.

The following genera may be mentioned as illustrative of the order:—*Scrophularia*, weeds common in British ditches; *Digitalis*, the foxglove of our waysides and gardens; *Antirrhinum*, the well-known snapdragon; *Linaria*, the toadflax of our hedges and banks; *Euphrasia*, the meadow eyebright; *Veronica*, including the brooklime of our ditches, and the speedwells which abound in every waste place; *Rhinanthus*, the yellow rattle; and *Calceolaria*, *Buddlea*, *Mimulus*, and others, now favourites in every flower-garden. The form of the flowers in the different genera vary considerably, as may be seen by examining the foxglove, the speedwell, and calceolaria—plants at the command of every one. The stamens also present considerable differences: in the foxglove (*D. purpurea*) there are two long and two short; in *Pentstemon* there are five, the fifth being long and slender, and without an anther; in *Calceolaria* and *Veronica* there are only two. Various attempts have been made to subdivide the order—as, for example, into two sections, the one including the genera having four anther-bearing stamens, and the other those having only two-anthered stamens. Mr Bentham divides it into three sub-orders, according to the inflorescence, each of which are again subdivided into several tribes.

In their properties the members of this family present no great uniformity. The majority, however, contain a principle more or less acrid, purgative in some, and poisonous, as in the foxglove, unless taken in small doses. The meadow eyebright (*E. officinalis*) is slightly astringent and aromatic, without the deleterious qualities of the other genera. Cows are said to be fond of *Melampyrum pratense*; and Linnæus says the best and yellowest butter is made where it abounds. One or two species of Linaria and Calceolaria are named as yielding colours for the dyer.

LABIATÆ—LABIATES.

A very large natural order, remarkable for the uniformity of structure and properties which prevails among the members. The *labiate* or lipped corolla immediately suggests the mint, sage, thyme, dead-nettle, horehound, and lavender, with which every one must be less or more familiar. They are herbs or undershrubs, with quadrangular stems, and with opposite, divided or undivided, exstipulate leaves, replete with receptacles of aromatic oil. The flowers are in opposite, nearly sessile, axillary cymes, resembling whorls, as in the dead-nettle; sometimes solitary, as if capitate; calyx tubular and persistent; corolla bilabiate, the upper lip (*a*) being entire or bifid, the lower (*b*) three-cleft, the upper in æstivation overlapping the lower; stamens four, didynamous, the upper sometimes wanting; ovary deeply four-lobed, seated on a fleshy disk, each lobe containing one erect ovule; style simple; stigma bifid; fruit from one to four small nuts, enclosed within the persistent calyx.

Labiate.

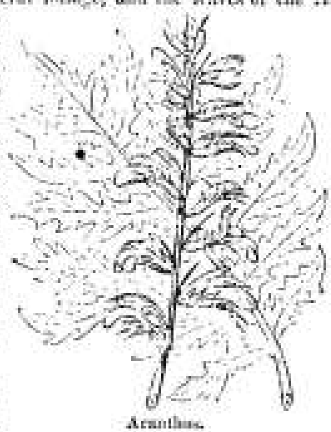
The following plants well exemplify the order:—*Lamium album*, the white dead-nettle of our wall-sides; *Salvia officinalis*, the common garden sage; *Rosmarinus officinalis*, the well-known rosemary shrub; *Thymus vulgaris*, the garden thyme; *Lavandula vera*, the sweet-scented lavender; *Mentha viridis*, spearmint, and *M. piperita*, peppermint; *Nepeta glechoma*, the ground ivy of our woods and ditches; *Marrubium vulgare*, the true medicinal horehound; *Ballota nigra*, black horehound, well known for its heavy oppressive smell; *Prunella vulgaris*, self-heal; *Ajuga reptans*, the common bugle of our woods and shady situations; with basil, marjoram, betony, hyssop, and other culinary or medicinal herbs. The order is sometimes known by the term *Menthaceæ*, taking mint as the type; and sometimes as *Lamiaceæ*, taking the dead-nettle; but we retain the older and better established one of *Labiatæ*. It is usual to divide the Labiates into twelve tribes, each embracing minor subdivisions or families.

Most of the Labiate order are medicinal, at least none of them are dangerous. The leaves are full of little pustules or receptacles of essential oil, which gives to the plants their cordial sudorific and antispasmodic properties. Many of them also possess bitter and tonic qualities in conjunction with those derived from the essential oil. The names of the genera above recited will at once recall to the mind of the reader all that is pleasant and valuable in the order.

ACANTHACEÆ—ACANTHADS.

There are nearly one hundred genera enumerated under this order, and upwards of seven hundred species of herbs and shrubs, principally inhabiting tropical regions. Leaves opposite and without stipules; inflorescence terminal or axillary; flowers in spikes with two or three bracts to each; calyx in four or five divisions and persistent—but in many of the species inconspicuous or obsolete, its place being supplied by the large bracts; corolla monopetalous and usually irregular, with the limb ringent or bilabiate, and deciduous; stamens two or four, and in the latter case didynamous; anthers one or two celled, sometimes bearded as in Acanthus, and bursting longitudinally; style simple; stigma one or two lobed; fruit a two-celled capsule, elastically two-valved; seeds supported on a filiform podosperm. The elastic dehiscent capsules, wingless seeds with hooked dissepiments, and imbricated flowers, are distinguishing features.

The genera best known are *Acanthus*, *Thunbergia*, *Ruellia*, and *Justicia*, sometimes taken as the representatives of tribes or sub-orders. The species of Acanthus are found chiefly in the south of Europe; they are plants with graceful foliage, and the leaves of the *A. mollis* is said to have furnished Callimachus with patterns for the capital of the Corinthian pillar. The corolla varies considerably in the different genera; being bilabiate in Justicia, funnel-shaped in Ruellia, and Campanulate in Thunbergia, the species of which are climbers.


Acanthus.

The properties of the order are little known. The Arabs use the leaves of an Acanthus by way of salad; *Justicia pectoralis*, boiled in sugar, yields a syrup used in the West Indies as a stomachic; and *J. paniculata* is said to be the basis of the famous French tonic *Drogue Amère*. A valuable deep blue dye is said to be obtained from one of the East Indian Ruellias.

DICOTYLEDONS.—II. MONOCHLAMYDEÆ.

The plants in this division have either no floral envelope, or have one only. In the former case, the pistil and stamens stand naked; in the latter, they are surrounded by a coloured calyx or perianth—there being no membrane corresponding to a true corolla. In treating the orders arranged under the section *Monochlamydeæ*, we shall use the term perianth, whether coloured or not, in preference to calyx, which refers more especially to an envelope which is exterior to the true corolla when present. The following are the Orders usually enumerated:—

Nyctaginaceæ—Nyctagos	Santalaceæ—Sandalworts
Amaranthaceæ—Amaranths	Elæagnaceæ—Oleasters
Phytolaccaceæ—Phytolaccads	Aristolochiaceæ—Birthworts
Chenopodiaceæ—Chenopods	Cytinaceæ—Cytinapes
Begoniaceæ—Begoniads	Euphorbiaceæ—Spurgeworts
Polygonaceæ—Buckwheats	Stackhousiaceæ—Stackhousiads
Lauraceæ—Laurels	Antidesmaceæ—Antidesmads
Myristicaceæ—Nutmegs	Urticaceæ—Nettleworts
Proteaceæ—Proteads	Ulmaceæ—Elmworts
Thymelaceæ—Daphnads	Piperaceæ—Pepperworts

Juglandaceæ—Juglands	Myricaceæ—Galeworts
Salicaceæ—Willowworts	Garryaceæ—Garryads
Betulaceæ—Birchworts	Empetraceæ—Crowberries
Corylaceæ—Mastworts	Coniferæ—Conifers
Platanaceæ—Planes	Cycadaceæ—Cycads

LAURACEÆ—LAURELS.

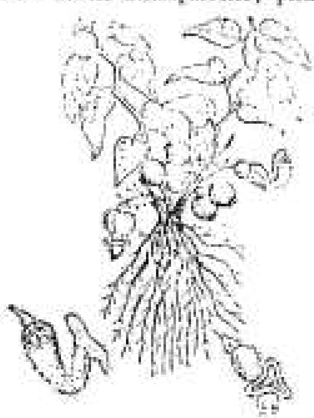
An important order, comprising above forty genera, and four hundred species. There are two sub-types—the one consisting of trees, with elegant foliage and aromatic properties; the other of herbs, which are leafless, twining in habit, and insipid. The arborescent species have exstipulate, alternate (seldom opposite) leaves, with inconspicuous flowers; the herbaceous are sometimes twining parasites. The perianth is from four to six-cleft, the limb sometimes obsolete; æstivation imbricate. The male and female flowers are distinct; the former have four, six, or eight stamens, opposite the segments of the perianth; the latter have four or more abortive stamens, furnished with glands, but without anthers, a one-celled, one-seeded ovary, with a simple style and an obtuse-crested stigma. The fruit is fleshy and indehiscent, naked, or covered by the enlarged and fleshy perianth. The two or four-celled anthers, with the valves curling upwards when ripe, like those of the berberry, and the filaments furnished with kidney-shaped glands at their base, are peculiar characteristics of the order.

The chief genera are—*Laurus*, the sweet bay; *Sassafras*, the sassafras-tree; *Persea*, the avocado pear; *Camphora*, the camphor-tree; *Cinnamomum*, the cinnamon-tree (all of which were at one time included under the genus Laurus); *Cassytha*, *Tetranthera*, and *Cryptocarya*. The true laurels have two anthers, and naked fruit; the cassia, cinnamon, and camphor have four anthers, and the fruit covered.

The arborescent Lauraceæ contain essential oil in abundance, which imparts to them a peculiar sweet, though strong penetrating odour, and a warm and pleasant taste; hence they yield some of our most grateful stimulants and spices. Cinnamon, cassia, camphor, benzoin, and sassafras, are products of the family; the roots of the red bay yield a violet dye; and a concrete oil, used in candle manufacture, is obtained from the fruit of *L. glauca*. The cogwood or Madeira mahogany is the wood of *L. chloroxylon* and *Indica*; and the Isabella wood of the cabinetmaker is the produce of *L. borbonia*, the red bay. The custom of crowning heroes and scholars with the leaves of the bay or laurel is well known to every reader of ancient history.

ARISTOLOCHIACEÆ—BIRTHWORTS.

There are only six or eight genera in this order, the members of which are herbaceous plants or shrubs, sometimes of climbing habit. The essential characters are—flowers hermaphrodite; perianth tubular, adherent with the ovary, and divided into three segments; stamens from six to ten, sometimes free and distinct, at other times adhering with the style and stigma; ovary three to six-celled; style short; stigma six-rayed; fruit capsular, dry, or succulent, three to six-celled, and many-seeded; seeds thin, flat, and of a dark-brown colour.



Aristolochia.

The chief genera are—*Aristolochia* the birthwort; and *Asarum*, the wild ginger of North America. Many of the species are natives of Europe; but they abound most in the tropical regions of America: *Arist. clematitis* and *Asar. Europæum* are the only two found in Britain. The genus *Asarum*, dividing, as it were, the representation of the order, the term *Asarineæ* is sometimes used indiscriminately with that which we have adopted.

The birthworts are heating and stimulating in their properties, and act chiefly on the skin and kidneys. The prepared root of *Arist. serpentaria* (Virginian snake-root) is used in ague, typhus fever, and in gout—being one of the ingredients of the celebrated Portland powder. The snake-root, as the name implies, is regarded as an antidote against serpent-bites; but whether it is or not, there can be no doubt that a drop or two of the juice, if introduced into the mouth of one of these reptiles, has the power of stupifying it, so that it can be handled with impunity; and a few drops swallowed, almost instantly causes death. The roots of the *Asarums* partake more of bitter and acrid properties, and have a disagreeable odour like that of the stapelias. *Asarum canadense* has an aromatic flavour, and is often used by the country people in lieu of the true ginger—*Zingiber officinale*.

URTICACEÆ—NETTLEWORTS.

This is an extensive order of plants, which, to the uninitiated, may appear very dissimilar. It is illustrated, for example, by the common nettle, the hop, the hemp, the pellitory of the wall, the bread-fruit-tree, the cow-tree, upas, mulberry, common fig, banyan, and India-rubber-tree, all of which, though exhibiting different habits and products, are not only strikingly alike in their essential characters, but also in their general properties. The order is much simplified by subdivision into two sections—namely, *Urticeæ* and *Artocarpeæ*—the former including the herbaceous species, as the nettle, hemp, and hop, with watery juice; and the latter the ligneous species, as the bread-fruit, mulberry, and fig, which have their juice milky. Bearing this distinction in mind, the following may be stated as the characteristics of the order:—Trees, shrubs, or herbs, with alternate leaves, usually covered with asperities or stinging hairs, and furnished with membranous stipules, which are deciduous or convolute in vernation; flowers usually monœcious, sometimes diœcious; perianth membranous, lobed, and persistent; stamens definite, distinct, inserted into the base of the perianth, and opposite its lobes; anthers turned backwards with elasticity when bursting; ovary superior, simple; ovule solitary, erect, or pendulous; stigma simple; fruit a simple indehiscent nut, surrounded by the membranous or fleshy calyx, as in the nettle and hemp—or a fleshy receptacle, either covered by numerous nucules lying among the persistent fleshy calyxes, as in the bread-fruit, or enclosing them within its cavity, as in the fig. 'The unisexual flowers,' says Dr Lindley, 'simple lenticular fruit, superior radicle and stipules, afford the essential characteristics of this order, which cannot well be mistaken for any except *Chenopodiaceæ*; and the plants of that order never have stipules, or rough or stinging leaves.'

The chief genera under the sub-order URTICEÆ are—*Urtica*, of which *U. dioica* is the common stinging nettle of our old wall-sides; *U. urens*, the smaller stinging nettle; and *U. pilulifera*, the Roman nettle of our gardens; *Humulus lupulus*, the cultivated hop; *Cannabis sativa*, the fibrous hemp of commerce; and *Parietaria officinalis*, the medicinal pellitory of the wall. The members of this section are widely scattered over the world, and increase apparently with the progress of civilisation. The chief genera of the sub-order ARTOCARPEÆ are—*Artocarpus*, of which *A. incisa* is the far-famed bread-fruit of the South Sea Islands; and *A. integrifolia*, the jack-tree of the East India Islands; *Galactodendron utile*, the cow-tree or palo de vacca of South America; *Antiaris toxicaria*, the upas-tree of Java, about which so many fabulous stories have been told: *Morus*, of which *M. nigra* is the common black mulberry; *M. rubra*, the red, and *M. alba*, the white mulberry, the leaves of which are so much esteemed for feeding silkworms: *Ficus*, of which *F. carica* is the common edible fig; *F. sycamorus*, the sycamore of the Scriptures; *F. Indica*, the spreading banyan; and *F. elastica*, the Indian-rubber-tree.

Hop.

The Urticeæ have watery juice, which is acrid and astringent, and the fibres of their stems are all less or more tenacious. The leaves of the hemp are narcotic; the hop has bitter, aromatic, and stomachic properties, and its effluvia are also said to be narcotic. The stinging property of the common nettle is well known, but the poisonous secretion is distinct from the juice. In the Artocarpeæ, on the other hand, the juice is milky, and on exposure to the air, becomes tough and elastic. Their fruit is edible, but their juice is generally acrid and poisonous; unless in that of the Galactodendron, which is wholesome and nutritious. The elaboration of a tough elastic product seems to be characteristic of the whole order—making its appearance in the stem of the hemp, in the inspissated juice of the Indian-rubber-tree, or in silk, the best of which is derived from silkworms which feed on the leaves of the mulberry. Hemp, hops, silk, caoutchouc, figs, mulberries, and bread-fruits, may be regarded as the most valuable products of the order.

BETULACEÆ—BIRCHWORTS.

A small order of trees and shrubs, abounding in the temperate and colder regions of the globe. They have alternate simple leaves, with the primary veins often running straight from the midrib to the margin, and deciduous stipules. The flowers are in catkins, unisexual, and monœcious; the males sometimes having a membranous lobed perianth. Stamens distinct, scarcely ever monadelphous; anthers two-celled; ovary two-celled; ovules definite, pendulous; style single or none; stigmas two; fruit membranous, indehiscent, by abortion one-celled; seeds pendulous, naked.

The chief genera are—*Betula*, the birch, and *Alnus*, the alder, the species of which abound in every northern country. The common white birch (*B. Alba*) is an elegant tree, thriving in almost any sort of soil, and becoming stunted and dwarfish only in the arctic regions, or at great elevations. The weeping-birch (*B. pendula*) is a still more graceful tree, grown in lawns and parks for its fine drooping branches and neat small foliage. *B. nana* is the dwarf birch of high and exposed situations, being found on the very limits of perpetual snow. *B. nigra* is the black birch of North America, the timber of which is used so much by cabinetmakers; and *B. papyracea* is the paper birch, whose bark is used by the Esquimaux and others in the construction of canoes. The common alder (*A. glutinosa*) is a quick-growing tree, found in swampy flats, and by the borders of streams; the hoary alder (*A. incana*) is seldom found south of the sixtieth parallel; the notch-leaved alders (*A. sinuolata* and *A. glauca*) are both American species.

The bark of the order is astringent and bitter, and has been used with effect as a febrifuge. A decoction of birch-bark is used by the Laplanders in the preparation of reindeer-skins; and the empyreumatic oil derived from it is said to be used by the Russians in tanning—hence the peculiar odour of their leather. The sweetish sap obtained by tapping the birch in spring is the chief ingredient in birch wine; the leaves, which, when young, are highly odorous, are also used in imparting dyes of various shades of yellow. The wood of several of the birches is used in furniture-making and turning, and makes no mean substitute for mahogany. The wood of the alder is soft and white, endures well under water, and is used by turners and veneerers.

CORYLACEÆ—MASTWORTS.

The Corylaceæ or Cupuliferæ are so named from the cup-like shape of the persistent involucre in which their fruit or nuts are placed—as, for example, the acorn. This cupule is called *cup* in the oak; but husk in the chestnut and filbert. It includes many genera of well-known trees and shrubs—as the oak, chestnut, beech, hazel, and hornbeam. Their leaves are alternate, simple, and stipulate; their vernation well-marked, and often rigid; flowers unisexual; the males in catkins; and the females in clusters or in catkins; the male flowers have from five to twenty stamens inserted into the base of the scales, or of a membranous perianth, generally distinct; in the females, the ovaries are crowned by the rudiments of an adherent perianth, seated within a coriaceous involucre (*cupule*) of various figure, and with several cells and several ovules, the greater part of which are abortive; ovules twin or solitary, pendulous; stigmas several, nearly sessile, and distinct; fruit a bony or leathery nut, of one cell, and less or more enclosed in the involucre.

The following are the most familiar genera:—*Quercus*, of which *Q. pedunculata* is the common British oak; *Q. sessiflora*, another British oak; *Q. suber*, the cork-tree; *Q. ilex*, the evergreen oak; *Q. rubra*, the scarlet oak of America; and *Q. phellos*, the willow oak, with long narrow entire leaves. *Fagus*, of which *F. sylvatica* is the common beech of our woods; and *F. ferruginea*, the bloody or copper-leafed beech. *Castanea*, to which belong *C. vesca*, the edible sweet chestnut; and *C. pumila*, the dwarf Virginian chestnut. *Corylus*, of which *C. avellana* is the common hazel nut or filbert; and *C. colurna*, the Constantinople nut. *Carpinus betulus*, the humble hornbeam of our hedges; and *Ostrya vulgaris*, the hop hornbeam. The hornbeams are by some botanists ranked under the Birch tribe, on account of the involucre not forming so complete a cupule as the other genera; but this seems too minute a distinction, as the involucre is not more leafy than it is in some of the filberts. The members of the family abound in Europe, Asia, and North America; more sparingly found in South America; and altogether absent from the south of Africa.

The bark in all the Mastworts is bitter and astringent, and is used for dyeing, tanning, or for medical purposes. Their timber is in general employed as a durable material for house and shipbuilding, and implement-making—as that of the oak, chestnut, and beech. In a few, the fruit is bitter and disagreeable; but in the majority it is farinaceous, and frequently contains an oily matter, used in domestic economy. Many of the lower animals derive their main subsistence from the acorns, beech-mast, chestnuts, and hazel-nuts of this order; and their fruit, as well as their bark and timber, is of the highest value to man. The gall-nut is an excrescence of the oak-leaf, caused by the puncture of an insect; it is used in medicine, and is the chief ingredient in ink and in black dyes.

CONIFERÆ—CONIFERS.

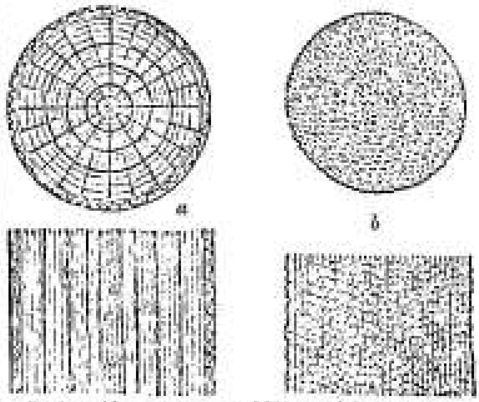
One of the most important, as it is one of the best defined, of the natural orders. Its members are trees or shrubs, with a branched trunk abounding in resin, and are familiarly illustrated by the Scotch pine, the spruce and silver firs, the larch, the cedar, the araucaria, the arbor vitæ, the cypress, the yew, and the juniper. The ligneous tissue of their wood is marked with circular disks; their leaves are linear, needle-shaped, or lanceolate, entire at the margin, and with the veins parallel to each other. The essential characters of the fructification are:—Flowers unisexual; males monandrous or monadelphous, each floret consisting of a single stamen, or of a few collected into a deciduous catkin about a common rachis; females in cones; ovary spread open, and resembling a flat scale, destitute of style or stigma, and arising from the axle of a membranous bract; ovules naked, in pairs on the face of the ovary, and consisting of one or two membranes open at the apex, and of a nucleus; fruit consisting of a cone formed of the scale-shaped ovaries, become enlarged and indurated, and occasionally of the bracts also; seed with a hard crustaceous testa. In speaking of the Coniferæ, it has been not inaptly remarked that 'the flowers are quite different from what is generally understood by that name, being in fact nothing but scales; those of the male containing the pollen in the body of the scale, and those of the female producing the ovules or incipient seeds at the base.'

Well-defined as the order obviously is, there are minor distinctions which warrant its subdivision into the following sections—namely, ABIETINEÆ, the true pines and firs; CUPRESSINEÆ, the cypresses; and TAXINEÆ, the yews. In the firs, the fruit is a cone, the scales of which open, and more or less recurve, when the seeds are ripe; in the cypresses it is also a cone, but rounder, and with fewer scales; and in the yews it is an open succulent cup, bearing the seed or nut in its centre. In other respects—as in their foliage, habit, resinous secretions, &c.—they closely resemble each other. Of the Abietineæ the following are very typical members:—The *Pinus sylvestris*, the Scotch pine; *Abies excelsa*, the spruce fir; *Picea nobilis*, the spruce fir; *Larix Europæa*, the common larch; *Cedrus Libani*, the cedar; and *Araucaria excelsa*, the Norfolk Island pine—all of which are evergreens, with the exception of the larch. The Cupressineæ are well represented by *Cupressus sempervirens*, the evergreen cypress; *Thuja occidentalis*, the American arbor vitæ; *Taxodium distichum*, the deciduous cypress; *Juniperus communis*, the juniper of our rocky glens; and *J. sabina*, the savin-tree. The Taxineæ embrace the common yew (*Taxus baccata*), the salisburias of our shrubberies, and a few others less common.

The high importance of this order is derived from its timber, which in all is straight, easily worked, and durable. It is also valuable for its resinous productions; several kinds of pitch, tar, turpentine, gums, and balsams being procured from the various species. The large seeds of some are said to be edible and wholesome; the berries of the juniper are largely used in the preparation of gin; and the main ingredient in spruce-beer is an extract from several species of Abies. Great tanning powers exist in the bark of the Larch; the savin, juniper, and others, possess stimulating and diuretic properties; and the leaves of the common yew are fœtid and poisonous, especially to cattle.

MONOCOTYLEDONS—ENDOGENS.

The Monocotyledons or Endogens include all those plants whose leaves have their veins placed parallel—as the palms, the grasses, the hyacinth, crocus, &c. Their stems have no distinction of pith, wood, bark, concentric circles, and medullary rays, like the Exogens (*a*), but is merely a confused mass of pithy matter, with intermingled bundles of ligneous fibre (*b*). Their seed contains an embryo, having only one seed-lobe or cotyledon: hence the term Monocotyledon. Their trunks increase from within, instead of by external concentric layers: hence also the term Endogen. They are divided into sections—PETALOIDEÆ and GLUMACEÆ. The former includes those having a perianth—such as the orchis, cane, lily, palm, &c.; and the latter those which are destitute of a perianth, but have a glume or husk instead, like the grasses, cereals, and sedges. The trees of this division are strictly tropical: the herbaceous species are found all over the globe.



Sections of Dicotyledonous and Monocotyledonous Stems.

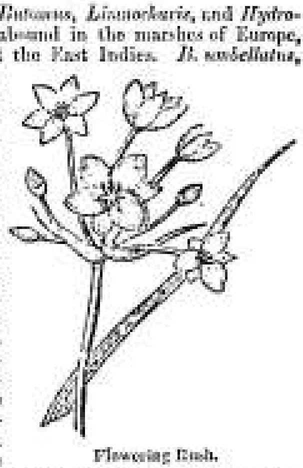
§ I.—PETALOIDEÆ.

Hydrocharidaceæ—Hydrocharads	Smilaceæ—Sarsaparillas
Alismaceæ—Alismads	Liliaceæ—Lilyworts
Butomaceæ—Butomads	Melanthaceæ—Melanths
Juncaginaceæ—Arrow-grasses	Pontederaceæ—Pontederads
Orchidaceæ—Orchids	Gilliesiaceæ—Gilliesiads
Musaceæ—Musads	Commelynaceæ—Spiderworts
Zingiberaceæ—Gingerworts	Palmaceæ—Palms
Marantaceæ—Marants	Pandanaceæ—Screwpines
Iridaceæ—Irids	Typhaceæ—Bulrushes
Hæmodoraceæ—Blood-roots	Araceæ—Arads
Hypoxidaceæ—Hypoxads	Naiadaceæ—Naiads
Amaryllidaceæ—Amaryllids	Juncaceæ—Rushes
Bromeliaceæ—Bromeliworts	Restiaceæ—Cordleafs
Dioscoreaceæ—Yams	Eriocaulaceæ—Pipeworts.

BUTOMACEÆ—BUTOMADS.

A small order of aquatic plants, having cellular leaves, furnished with parallel veins, and handsome umbellate flowers of a purple or yellow colour. Calyx three-sepalled, usually herbaceous; corolla three-petalled and coloured; stamens hypogynous, definite or indefinite; ovaries superior, three, six, or more, either distinct or united into a single mass; stigmas of the same number as the ovaries, and simple; follicles many-seeded, either distinct and rostrate, or united into a single mass; seeds minute, attached to the whole inner surface of the fruit. The order is nearly allied to the preceding, but differs in each carpel, having numerous seeds.

The genera are—*Butomus*, *Limnocharis*, and *Hydrocleis*, all of which abound in the marshes of Europe, South America, and the East Indies. *B. umbellatus*, the flowering rush, is common in our ditches and by river sides, growing from two to three feet high, with sword-shaped leaves, and umbels of a rose or purplish-white flowers. *Limnocharis plumieri*, a native of Brazil, has yellow flowers, and the apex of each leaf is furnished with a curious pore, apparently for the discharge of the superabundant moisture which constantly distils from the plant. All the members are very pretty


Flowering Rush.

plants; the common flowering rush being universally acknowledged as one of our handsomest native plants.

The order is said to possess acrid properties; and most of the species yield a milky juice. The rhizome and seeds of the flowering rush had once an officinal value as refrigerants and solvents.

LILIACEÆ—LILYWORTS.

A very extensive, and to the florist one of the most important of the natural orders. Taking the common white lily as the type, there is a great resemblance in all the Lilyworts, not only in their habits and forms, but also in their essential characters. Notwithstanding, botanists have somewhat perplexed themselves by subdivisions founded upon the minutest differences. Thus by some the order is termed *Tulipaceæ*—the tulip being taken as the type; by others it is made into three distinct orders—namely, *Asphodeleæ*, *Tulipeæ*, and *Hemerocallideæ*; while by others these are merely regarded as sub-tribes. According to the latter view, the Asphodeleæ would include the asphodel, onion, hyacinth, asparagus, &c.; the Tulipeæ—the common tulip, lily, fritillary, gloriosa, &c.; and the Hemerocallideæ—the day-lily, the aloe, and tube-rose. Sinking these distinctions in the meantime, and viewing the whole as one order, the following are the essential characteristics:—Plants with scaly or tunicated bulbs and stemless; or tuberous, creeping, erect, or arborescent; leaves not articulated with the stem, either sessile or with a narrow petiole. In some of the genera the flowers are erect and single, as in the tulip; in others they are erect but in umbels, as in the orange lily; and in others they are in racemes and drooping, as in yucca; or single and drooping, as in the fritillary; or with the segments curved back, as in the martagon lily. Perianth coloured, regular, and six-divided, occasionally tubular; stamens six, inserted into the segments of the perianth; anthers opening inwards; ovary superior, three-celled, and many-seeded; style one; stigma simple or three-lobed; fruit either a three-celled, three-valved loculicide capsule; or fleshy, and then occasionally tripartite. The seeds of the Asphodeleæ have a black, crustaceous, brittle testa; in the Tulipeæ and Hemerocallideæ the testa is brown and spongy.

Liliaceous.

The following plants may be mentioned as illustrative of the principal genera:—*Lilium candidum*, the white lily; *Tulipa sylvestris*, the wild tulip; *Allium cepa*, the onion; *Fritillaria meleagris*, the fritillary; *Hyacinthus orientalis*, the garden hyacinth; *H. nutans*, the harebell; *Asparagus officinalis*, the garden asparagus; *Muscari racemosum*, the starch hyacinth; *Erythronium dens-canis*, the dog's-tooth violet; *Phormium tenax*, the New Zealand flax; *Aloë*, the aloe; *Polianthes*, the tube rose; *Hemerocallis*, the day-lily; *Scilla*, squills; *Asphodelus*, king's spear—all of which are within the reach of every one's examination. The Lilyworts are found in every quarter of the globe, being more abundant, however, in temperate than in tropical climates, where they exist chiefly in arborescent forms.

The properties of the order, as may be expected, present considerable differences. All the Asphodeleæ contain a bitter stimulant principle in a viscid juice, as is exemplified by the onion, garlic, leek, and chives. The roots of some are purgative, as the aloe; while those of several lilies are eaten in Siberia, as potatoes. Gum-dragon is the styptic juice of *Dracæna draco*; New Zealand flax is the tough fibre of the leaf of *Phormium tenax*; squills is a well-known demulcent; and the succulent suckers of asparagus are largely eaten as a vegetable. Many of the species are cultivated solely for their fine showy flowers.

BROMELIACEÆ—BROMELWORTS.

This family consists of about a dozen genera, and more than one hundred species of plants with scarcely any stem, and sometimes parasitic in their habit. Their leaves are rigid, channelled, and often spiny or toothed at the margin. The perianth is tubular, and in two rows; the outer, or calyx, in three clefts, rigid, and persistent; the inner, petaloid and deciduous; stamens six, inserted into the base of the segments of the perianth; ovary free or cohering, and three-celled; ovules indefinite; style single; stigma three-parted, often twisted; fruit capsular or succulent, three-celled, and many-seeded.

The principal genera are—*Bromelia*, the pine-apple; *Agavé*, the American aloe; *Billbergia*, *Lyllua*, *Pitcairnia*, and the curious epiphyte *Tillandsia*, Spanish or Brazilian moss. They are natives of moist warm climates, such as Brazil, West and East Indies; but many of them, with a little care, might be cultivated in the south of Europe. All the above-named genera are common in our stoves and conservatories. The common pine-apple (*B. ananas*) was named by Linnæus after Olaus Bromel, a Swedish botanist; and it receives its English name from the circumstance of its fruit being covered on all sides with small triangular scales, resembling the cone of a pine-tree. The American aloe (*A. Americana*) is a very frequent plant in our greenhouses, remarkable for its thick leathery leaves and high flower-stalk, which sometimes reaches the height of thirty feet.

The order has several important uses. The pine-apple, so much esteemed for its fine aromatic flavour, is perhaps the most delicious fruit in the world. What is called the fruit is, in fact, the fruits of the same spike cohering into one mass, by means of their perianths becoming succulent; something similar to the cohesion which forms the strawberry. Several of the species are esteemed for their showy blossoms; the juice of others yields a vinous liquor; and the tough leaf-fibres of such as the Agave produce excellent cordage. Some of the Tillandsias, which hang their threadlike festoons from the trees of Brazil, are collected and used for stuffing mattresses, saddles, &c. making a pretty good substitute for horse-hair. Most of the genera yield a fine aromatic odour; and from their habit of retaining water in the sheathing axes of their leaves, are specially grateful to the traveller in the regions where they abound.

PALMACEÆ—THE PALM-TRIBE.

An important order of arborescent endogens, with lofty simple trunks, bearing a tuft of leaves or fronds on the summit, and only in one or two instances branched. The leaves are terminal, and large, with a plaited vernation; flowers small, with bracts, forming a mass or spadix, which is enclosed in a spathe bursting on the under side; florets bisexual or polygamous; perianth six-parted, and persistent, in a double row—the three outer segments often smaller, the three inner sometimes deeply connate; stamens inserted into the base of the perianth, usually six, seldom three, and in a few polygamous species indefinite; ovary one or three celled, or deeply three-lobed; ovules three, rarely one; fruit baccate or drupaceous, the flesh fibrous; albumen cartilaginous, either ruminate, or furnished with a central cavity.

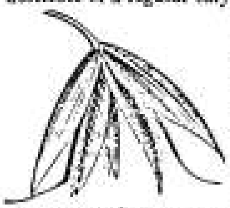
Palm.

The principal genera are—*Cocos*, the cocoa-nut; *Phœnix*, the date-palm; *Sagus*, the sago-palm; *Calamus*, the common cane; *Areca*, the areca-nut; *Borassus*, the cabbage-palm; *Ceroxylon*, the wax-palm; *Elais*; *Sabal*; and *Acrocomia*. They are strictly inhabitants of the tropics, to the natives of which they are undoubtedly the most useful order of vegetation.

The properties of the Palms are numerous and varied—wine, oil, wax, flour, sugar, salt, thread, utensils, habitations, and food, being obtained from some one or other of the species. The cocoa-nut, sago, date, areca, betel nuts, and palm-oil, are well-known products. *Coir*, which is worked into mats and cordage, is the dry fibrous pericarp of the cocoa-nut.

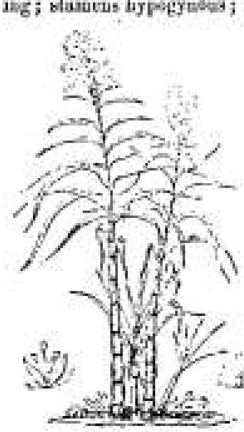
§ GLUMACEÆ.

The plants in this section of the Monocotyledons are destitute of a regular calyx and corolla, having instead green or brown scales to cover the stamens and pistil. The glume, or chaff of the oat (see fig.), is a familiar example of this kind of envelope. The Sedges (CYPERACEÆ) and the Grasses (GRAMINACEÆ) are the only Orders ranking under this sub-class. We can merely glance at the latter—naming a few of the genera which lie within the inspection of every reader.



GRAMINACEÆ—GRASSES.

One of the most important and valuable, as it is one of the most extensive, of the natural orders. According to the latest authorities, it comprehends two hundred and ninety-eight genera, and three thousand eight hundred species, familiarly illustrated by the common grasses of our pastures, by the bread-corns or cereals—wheat, barley, rye, oats, &c.—and by the sugar-cane and rice. Their rhizomes are fibrous or bulbous; their culms or stems cylindrical and hollow, except at the joints, where they become solid, the whole culm generally covered with a shining siliceous coating; leaves alternate, and though sheathing the stem, do not unite round it; flowers in spikelets or *locustæ*, and arranged in a spiked, racemed, or panicled manner. The essential characters of the fructification, according to Dr Lindley, are—flowers usually hermaphrodite, sometimes monœcious or polygamous, consisting of imbricated bracts, of which the most exterior are called *glumes*, the inferior immediately enclosing the stamens *paleæ*, and the innermost at the base of the ovarium *scales*: glumes usually two, alternate, sometimes single, most commonly unequal; paleæ two, alternate, the lower or exterior simple, the upper or interior composed of two, united by their contiguous margins, and usually with two keels, together forming a kind of dislocated calyx; scales two or three, sometimes wanting; stamens hypogynous; anthers feathery or hairy; pericarp usually undistinguishable from the seed, membranous; albumen farinaceous.



Sugar-cane.

The Grasses are scattered all over the globe, and are the most directly useful of all vegetation both to man and to the lower animals. The following well-known plants may be taken as illustrative of the order:—*Triticum vulgare*, common wheat; *Hordeum distichum*, common two-rowed barley; *Secale cereale*, rye; *Avena sativa*, common oats; *Zea mais*, maize or Indian corn; *Saccharum officinarum*, the sugar-cane; *Oryza sativa*, rice; *Bambusa*, the bamboo; *Phleum pratense*, cat's-tail grass; *Agrostis stolonifera*, fiorin grass; *Anthoxanthum odoratum*, sweet-scented vernal grass; *Dactylis glomerata*, cock's-foot grass; *Festuca pratense*, meadow fescue; *Lolium perenne*, rye-grass; *Briza media*, maiden-hair; *Alopecurus pratensis*, meadow fox-tail grass; and *Holcus lanatus*, woolly soft grass. Though allied in many respects to the Sedges, the Grass family are readily distinguished by their hollow-jointed stems, and leaves that sheathe, but do not completely surround, the stem like a tube.

As food for man and beast, the value of this order is too well known to require more than a passing notice. Wheat, barley, oats, rye, rice, guinea corn, millet, maize, and the sugar-cane belong to it, with the products of which every one is familiar. The straw or dried culms is used as fodder, litter, thatch, and as material for the manufacture of ladies' bonnets. All the Grasses—from the bamboo and sugar-cane to the common rye-grass—have a thin siliceous coating on their stems, which seems intended to furnish them with greater strength and durability than could have been procured by simple ligneous fibre.

CRYPTOGAMS, OR ACROGENS.

This class of vegetation is readily distinguished by none of its members bearing flowers—hence the term *Cryptogamia*, or *Flowerless*. They consist of cellular tissue only, and increase by simple additions of matter to the growing-point, or apex of the parts already formed—hence the term *Acrogens*. They exhibit, however, very different degrees of organisation,—the highest (*ferns*) having both stems and leaves, and peculiar sort of wood; the lowest consisting of simple-jointed threads, or even mere nucleated granules. Between these two extremes there are various conditions of stem and leaf—the two most frequently graduating into each other, and forming neither true leaf nor stem, but thin expansions, botanically termed *thalli*. The Cryptogams are divided into two sub-classes—namely, the FOLIACEÆ, or those in which the distinction of stem and leaf can be traced; and APHYLLEÆ, those which show no such distinction. None of the members have seeds like the vascular plants, but are reproduced by spores or little embryo plants, which arise from various parts of their structure. See VEGETABLE PHYSIOLOGY.

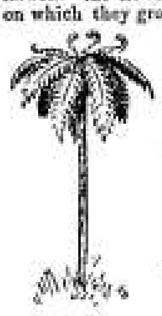
§ FOLIACEÆ.

Filices—Ferns	Characeæ—Stoneworts
Lycopodiaceæ—Club-mosses	Musci—Mosses
Marsileaceæ—Pillworts	Hepaticæ—Liverworts.
Equisetaceæ—Horsetails	

FILICES—FERNS.

In this order the different parts of the plant spring from a *rhizoma*, or root-stock; the fronds or leaves being either separate and independent, or uniting by their stalks so as to form a sort of trunk, as in the tree-ferns. The fronds are not leaves in the ordinary sense of that term; their veins are forked instead of being either reticulated or parallel. The fronds are usually pinnatifid, and more or less compound; sometimes nearly simple and entire; in their vernation they are circinate—that is, they unroll from the stem outwards. The reproductive organs or *sori* are brown membranous-looking spots, either upon the backs of the fronds, or on the margin, or wrapped up in contracted and deformed fronds. These sori either form under the cuticle near to some vein, in which case the raised portion of the skin forms what is called an *indusium*; or they are outside the cuticle, and naked; or they are arranged along the margin of the leaf, which curls over them, and supplies the place of the indusium. The sori contain a number of brownish grains, called *thecæ*, each being in reality a case containing a number of minute *sporules*, which are the true reproductive embryos.

It is usual to divide the Ferns into two sections—namely, the POLYPODIACEÆ and the OSMUNDACEÆ—the former having the sori either on the back or on the margin of the frond, and the former having apparently flowers—the flowers being merely sori with the leaves on which they grow shrivelled up around them. The former section is illustrated by the following genera:—*Polypodium*, the polypody, which has naked sori; *Aspidium*, the shield fern; *Cystopteris*, the bladder fern; *Asplenium*, spleenwort; *Pteris*, the common brake; *Nephrodium*, to which belongs the male and female ferns of our woods; *Adiantum*, maiden-hair; and *Scolopendrium*, hart's tongue, the frond of which is tongue-shaped, and simple. The latter section is represented by *Osmunda*, the flowering fern; *Botrychium*, the grape fern; *Ophioglossum*, the adder's tongue; and by the tree-ferns of Australia and New Zealand. The Filices are widely distributed, delighting in humid soil and shady situations—some growing parasitically on trees.



Tree Fern.

The fronds of the family generally contain an astringent mucilage, and are thus considered as pectoral and lenitive; the roots of some are used as anthelmintics and purgatives; and *Aspidium fragrans* has been employed as a substitute for tea. The young leaves and rhizomes of some are edible; and the fronds of the common brake, when burned, yield a considerable quantity of alkali.

§ APHYLLEÆ.

The orders under the Aphyllous, or frondless subclass of Cryptogams, are—

Lichenes—Lichens. Fungi—Mushrooms. Algæ—Seaweeds.

FUNGI—MUSHROOMS.

The Fungi, or Mushroom family, which are among the lowest forms of vegetation, are extremely diversified in their size, shape, colour, and consistence. The common field mushroom is one of the best known, and forms the type of the family; but the puff-ball, truffle, morel, as well as the mould on cheese and stale bread, the mildew on trees, the rust on corn, the substance called dry rot, and many other minute and yet unobserved appearances of a similar nature, are all fungi. They are strictly aphyllous, having neither fronds nor thalli; and their reproductive organs consist of sporules lying loose on the tissue of the plant, or collected in certain places which are distended by their aggregation. In the field mushroom (*Agaricus campestris*) the plant consists first of some filamentous thalli or spawn, which look like roots, then the stipe or stalk, surmounted by the pileus or cup. 'When the mushroom first appears, the stalk is covered by a thin membrane, called the veil, which unites the cup to the lower part; but as the mushroom grows, this veil is rent asunder, and it either entirely disappears, or only a small portion of it remains round the stalk, which is called the *annulus*, or ring. Under the cup are gills or lamellæ, which are of a dark reddish brown; and attached to these are the thecæ, containing the spawn or seed.' In some, the spawn is in the substance of the plant at the base; nor is the mode of growth the same in all. Many—as the moulds, &c.—are mere microscopic jointed filaments, or filaments surmounted by little ball-like receptacles which contain the sporules, or are mere spherical granules, which increase with astonishing rapidity, each granule containing a number of undeveloped granules.

Among the more familiar genera are—*Agaricus*, the mushroom; *Tuber*, the truffle; *Morchella*, the morel; *Boletus*, the puff-ball; *Puccinia*, the mildew; *Clavaria*, the yellow meadow fungus; *Tremella*, the jelly-looking masses found on decaying trees; and *Tubercularia*, the small, red, pimple-like fungus, also found on rotten sticks and trunks of trees. The Fungi are scattered everywhere—springing from the ground, yet without roots; under the ground, as the truffle; on all decaying organic substances; and even on living animals, as the *Achlya prolifera*, which looks like a whitish slough or slime on gold fishes, yet is a true rapidly-developing fungus, with a filamentous stipe crowned by a ball-like receptacle. Even what we call yeast is but a spherical fungus, having a nucleated development.

The plants of this order are not more diversified in form than in properties. Some are wholesome and palatable—as the mushroom, morel, truffle, &c.: others, similar to these in appearance, are deadly poisons. Many of the minuter fungi—as moulds, smuts, rusts, &c.—are noxious to the human system. Ergot forms a powerful and dangerous medicine. German tinder is prepared from a species of boletus, which, after being dried, is impregnated with nitre.

Such, according to our limits, is an outline of the Natural System of Botany; which, though as yet but partially developed, is infinitely more interesting and instructive than any artificial method, however elaborate and complete. Undeveloped as we must admit it to be, harsh and difficult as much of its nomenclature is, unnecessarily multiplied and complicated as its orders and tribes really have been, it has still the germs of truth and nature within it, and only requires a cordial and patient elaboration, on the simple principles of its great founder, to render it what it professes to be—an exposition of the system upon which Nature has proceeded in the creation of the Vegetable Kingdom. Our brief synopsis, as contained in this and the two preceding sheets, can at most but convey to the reader a very general notion of vegetable life and relationship, and only introduce him, as it were, to the technical phraseology and mode of procedure: for further acquaintance with the subject, we cannot refer to a more accessible source than the excellent suite of works recently published by Professor Lindley of London. There the inquirer will find, in a connected form, all that is necessary to be known in ordinary cases; there, if he is ambitious of proceeding further, he will find reference to the highest authorities, British and continental; and there, too, he may learn the best modes of practical investigation. To observe generally, to collect everywhere, to examine carefully, and to pronounce with caution, are the duties of the true phytologist; and the more attention to these, the sooner will the objects of a Natural System be accomplished. It is true that there are some difficulties at the outset—and where is the department of human knowledge without such obstructions!—but these overcome, and what a delightful field of intellectual enjoyment beyond! The beauty and variety of flowers, the fragrance and freshness which we are insensibly led to associate with them, have long been themes for the poet and moralist; but really not more so than the subject deserves. The endless forms in which plants appear, their adaptations to certain situations, the peculiar properties which many species possess, though all grow on the same soil, the wonderful metamorphosis which they undergo from seed to plant, and from plant and flower to seed again—not to speak of the amenity and beauty with which they invest the landscape, or of the utility they confer as articles of food, medicine, and clothing—are all subjects of never-failing interest to a cultivated mind. There is, perhaps, no pursuit which leads more directly to an appreciation of that wisdom and goodness which pervade creation, than the study of the vegetable kingdom, in which infinite variety, beauty and elegance, singularity of structure, the nicest adaptations, and the most pre-eminent utility, meet us at every step, and compel us to observe and learn, even when often the least disposed to inquiry or reflection. Take it even in the light of a mere recreation for an idle moment, it is at least an innocent and cheerful one: one that never interferes with the comfort of a neighbour, or brings to the cultivator a single feeling of mortification or regret.

ANIMAL PHYSIOLOGY—THE HUMAN BODY.

The external appearance of the human body is necessarily familiar to all. Its internal structure, however, and the manner in which its different functions are performed, are not understood as they ought to be by the generality of people. The more fully that we comprehend the structure of our frame, the more attentive shall we be to its preservation in a state of health, and the more capable of accomplishing that all-important object. The present treatise will therefore be devoted principally to a description of the human body, in language as popular as the subject will permit, and as concise, at the same time, as possible. Though chiefly directed to the structure and functions of the human body, notice will be taken, under the several sections, of the analogous structure and functions in the lower animals; so as to convey to the reader an outline of Animal Physiology in general, and thus prepare him for a more intelligent perusal of the succeeding numbers on SYSTEMATIC ZOOLOGY.

Zoological science places the human being in the class of *Mammalia*, or suck-giving animals, and in the order of *Bimana*, comprising the two-handed creatures of that class. An erect posture is the peculiar characteristic of man, and it is one which gives to his aspect that dignity becoming his high place in creation. By the adaptation of an erect structure, also, his hands are left disengaged, and ready for the numerous operations to which he is inclined by his judgment or urged by his wants. His general stature is between five and six feet. A combination of hard and soft parts forms the material of his frame, the soft portions being arranged, generally speaking, upon and around the more solid parts of the structure. These latter parts consist of a beautiful framework of bones, termed the *skeleton*, which naturally occupies the first place in our description. *Muscles* and *tendons*, which are the organs of locomotion; the *brain* and *nervous system*, or organs of sense, feeling, and intellect; the *lungs*, for respiring the air essential to the maintenance of the principle of life; the *stomach* and *digestive organs*, for the supply of nourishment; the *heart*, *blood-vessels*, and *absorbents*, for the circulation of vital fluids through the body—these and other important parts will fall to be described after the solid framework on which they rest has received its due share of our attention.

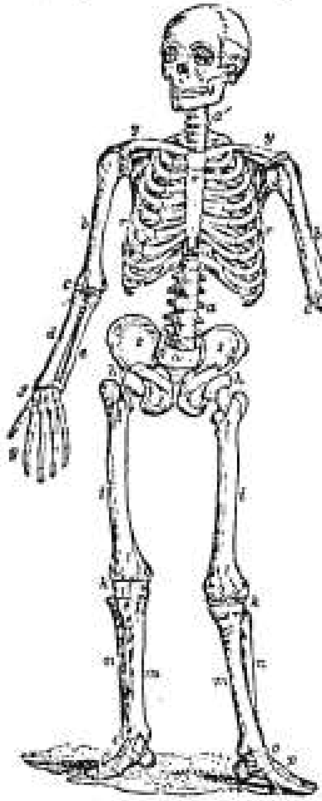
THE BONES.

The skeleton comprehends three main divisions—the head, trunk, and extremities—which consist, in all, of 251 bones, joined together in a manner combining great strength with ease and freedom of motion. The whole of the bones are composed of nearly the same materials—namely, earthy matter, chiefly lime, and gelatine or animal glue. According to Berzelius, 100 parts of human bones are composed of 51.04 phosphate of lime, 11.30 carbonate of lime, 2 fluoride of calcium, 1.20 soda and chloride of sodium, 1.16 phosphate of magnesia, and 33.30 animal matter, consisting of albumen, gelatine, and fat. This notable proportion of lime imparts to them the necessary hardness and solidity, while the animal matter cements or binds them together, and renders them not easily broken. Weighed *en masse*, a middle-sized adult skeleton ranges between 160 and 200 ounces, or from 10 to 13 pounds avoirdupois. Individually, the bones vary in solidity and weight, the heaviest in proportion to their size being those of the skull, the extremities, and the pelvis or under part of the trunk. The surface of human bone is for the most part smooth; and the interior, beneath a cake or coating of more condensed substance, is porous and spongy. The bones of the extremities are hollow, like pipes, by which arrangement they are rendered at once light and strong. The marrow is contained in the internal cavity. Compact as they are, the bones are nevertheless pervaded by blood-vessels, which, indeed, are essential to their growth and vitality.

The crown or summit of the osseous fabric is occupied by the cranium or skull, which is composed of eight bones, the *frontal*, the *occipital*, and the two *parietal*, constituting the greater part of the outward skull, before, behind, and laterally. The two *temporal* or temple bones, on the under part of each side, and the sphenoid and ethmoid bones, placed at the base of the skull internally, are the remaining bones of the head. The union of these bones is remarkably firm and strong in the adult being. In some cases, the osseous plates are joined by serrated or ragged edges, like the teeth of a saw. In other instances, they overlap each other, like the ridge of a house; the arrangement, in each case, being precisely the one best fitted to insure strength and stability in the particular part. Altogether, an arch of the most powerful kind is formed, for the safe protection of the important organ within—the *brain*. The bones of the face, situated below and before the cranium, are numerous. Among the facial bones are reckoned the two upper *maxillary* or jaw bones; two *malar* or cheek bones; two *nasal* or nose bones; two small bones, attached to the nose internally, called the *turbinated* bones; two *palate* bones; the two *lacrymal* bones, situated in the orbit; the vomer, or ploughshare bone, forming a part of the basis of the nose; and the single lower jawbone, or *maxillary* bone of the lower jaw.

The bones of the skull and face rest upon the top of the spine or backbone, which consists of twenty-four separate pieces, called *vertebræ*, firmly and curiously jointed the one into the other. The column of the spine is curved in several places, the most prominent being a curve forwards near the middle of the back. Seven of the vertebræ are called *cervical*, twelve *dorsal*, and five *lumbar*, from being situated respectively in the neck, back, and loins. Each vertebra has various projections and depressions, to admit of a firm union with those adjoining it; and, by the junction of the whole, a long hollow or canal is made, for the reception of the spinal marrow. In the annexed figure, the upper part of the vertebral column is marked *b*, and the lower *a*. The second of the vertebræ of the neck sends upwards a projecting pinion or tooth, which is received into a corresponding depression in the one above, thus forming the pivot upon which the head turns. A ligamentous band keeps the tooth-like projection of the second vertebra in the depression of the first; and nothing can better show how completely our life, during every instant of its duration, depends on the maintenance of every single part, however minute, in order: if this ligament, scarcely thicker than strong paper, were to give way, instant death, from pressure on the spinal marrow, would ensue. The bones of the spine rest upon the *pelvis* (*s s*), a hollow, basin-shaped cavity, which is formed of two large bones, and composes the lower part of the trunk, giving to it firmness and stability. The spine rests on it by means of the *sacrum* (*r*), a series of five imperfect vertebræ, consolidated into one piece in advanced life, which sink like a wedge between the pelvic bones of each side. The sacrum terminates in a loose osseous peak, called the *os coccygis*. The strong, hollowed, cup-like bones of the pelvis, are marked by large round depressions on the outer and under surface of each, which form sockets for the two upper bones of the leg.

At the top of the spine, immediately below the vertebræ of the neck, are situated on each side the collar-bones or *clavicles* (*p p*), which are long and narrow in shape, and pass in a semicircle or arch from the front of the chest backwards, or, in other words, from the *sternum*, *x* (breast-bone), to the top of the shoulders.



On the back of the ribs, at each side, lie the shoulder-blades or *scapulæ*, which are thin flat bones, of a triangular shape. They rest loosely on the back, having scarcely any attachment except by muscles to any of the neighbouring bones. By this means they have a free and easy motion, and also communicate the same property in part to the arms, the upper bone of which is attached, on each side, to the scapula. A very small cavity in the latter bone admits the round ball-like head of the humerus, giving to it the most unconfined play of movement, whether of a rotatory kind, upwards, downwards, or sideways. Nothing can be more beautiful than the whole arrangements for permitting the arm to perform the multifarious motions which man requires from it. The *humerus*, a single bone in each arm (*b b*), cylindrically shaped, is united at the elbow-joint (*c c*) to the two bones of the fore-arm, termed the *radius* (*d d*) and *ulna* (*e e*). One of these, the ulna, is attached to the humerus by a hinge-joint (like that of a common door), while the radius is connected to the same bone by a round button-like head, which, being slightly concave, receives a projecting knob of the humerus, and admits of rotatory movements being performed by the lower part of the arm. These peculiarities of structure are essential to the free use of the hand. At the wrist, the position of the radius and ulna is in some measure reversed, the radius forming with the *carpal* bones (*f f*) a joint like that of a door-hinge, while the ulna is in a measure left loose. The carpal or wrist bones are eight in number. They are of small size, and lie in two rows, being jointed together in a manner that combines great strength with a certain degree of mobility. In the direction of the points of the fingers, they are united with the *metacarpal* bones, forming the palm of the hand, and to which the *phalanges* (*g g*) or finger bones are attached. Each finger has three bones in it; the thumb, or opposing finger, has only two.

As has been said, the bones of the pelvis, on each side, are marked by deep cup-like concavities, which receive the heads of the thigh-bones, *h h*, *i i* (*femur*), the upper bones of the lower extremities. As was required by the different nature of the purpose to be served, the ball-and-socket joint of the leg is much stronger than that of the arm, and permits of much less freedom of motion. The *femur* or thigh-bone is a rounded cylindrical bone, terminating at the knee in a connection with the *tibia* (*m*), the principal bone of the inferior part of the lower extremity. The knee-joint is a hinge one, but permits of a slight rotatory motion when the leg is bent. The tibia has a smaller bone, the *fibula* (*n n*), placed by its side, and over the knee-joint is situated a small bone called the *patella* (*l l*), or knee-pan, to which the principal muscles that move the joint are attached, and which serves to protect the parts against injury. The tibia and fibula form a union at the ankle (*o o*) with the bones of the tarsus, which are seven in number, and constitute the heel or back part of the foot. These again are united to the *metatarsal* bones (*p p*), forming the body of the foot, and five in number. To these again are joined the *phalanges* of the foot, fourteen in all, two being attached to the great toe, and three to each of the others.

The *costæ* or *ribs* (*r r*) proceed from the vertebræ or backbone, and are twelve in number on each side. They bend round in a circular manner from their point of union behind, and seven of them, called the *true ribs*, are joined directly by gristle or cartilage to the breast-bone, while the remaining five terminate anteriorly in a common cartilage, which unites with the sternum below. Altogether, the ribs form a large hollow space for the reception of the lungs, heart, and other organs, and protect them from injury. The ribs move in an easy joint formed with the back-bone, and, with the intercostal muscles, contract and expand to suit the motions of the lungs.

These are the principal bones forming the skeleton of the human being. All animals have not this osseous framework; it is only found, and that in a modified degree, in a certain number of classes—namely, in quadrupeds, birds, reptiles, and some fishes, all of which, from the principal feature in their structure, are called vertebrated animals. Some of the other tribes of beings have their framework, corresponding in purpose to bones, on the outside of the body, in the form of a coat of mail. This is the case with shellfish, with the crustacea, and with many insects that have a hard external covering. It is only in the skeletons of the higher vertebrata, however, that we find a real analogy to the framework of the human being. In such cases not only are the bones of the same form and construction, but of the same number also; and where we do not find them of the same number separately, several will be discovered to have been atrophied at an early stage of existence as unnecessary to the functions of the full-grown animal, or compacted into one mass. Thus comparative anatomy detects in the fore-leg of the horse, the wing of the eagle, and the paddle of the whale, the same amount of parts as are separately exhibited in the arm of man.

THE MUSCLES.

The soft fleshy substance of the body, which gives plumpness and form to the whole, is the muscular part, or *muscles*. These are the instruments of motion. And when we consider the various positions which the body and its members assume, the agility and quickness with which the most intricate movements are made, the ceaseless play of the heart, the heaving of the lungs, and the singular rapidity of articulation and speech, we need not be surprised that these muscles, upon which all such movements depend, should be many in number, and deemed important agents in the animal economy.

The muscles are of a reddish brown colour; they are composed of accumulated threads or fibres, arranged sometimes in layers, sometimes in a straight position, and sometimes obliquely. They are of an elastic nature, somewhat like a piece of India rubber, and, at the impulse of the will, are lengthened and shortened alternately. A muscle is generally thick or swelled out in the middle; it gradually gets thinner towards the extremities, and in many instances passes at one or both ends into a tendon, or tough white substance, which is attached to a bone, and serves the same purpose as a rope or cord, to fix the muscle to the point from which it is intended to act. These tendons are most numerous about the joints, especially the larger joints, where they allow of free and unrestrained action, and yet occupy little space in situations where a large swelling muscle would have been inconvenient. About the larger joints, such as the knee, elbow, and shoulder, there are also numerous glands, which pour out an oily substance, that serves at once to lubricate the joints, and facilitate the play of the tendons.

There are from four to five hundred muscles in the human body, all necessary for performing the various movements and operations of the complicated machine. On each side of the backbone there are several layers of strong muscles, which are fixed by tendons to every projection of the numerous bones composing the spine. These muscles keep the trunk of the body erect, and also permit of the various motions of the back. There are a multitude of small muscles about the face, head, and eyes, whose various action imparts that expression to the human countenance which indicates the prevailing feelings and passions of the individual. The tongue is also supplied by intricate muscular fibres, giving to it that amazing volubility of action by which the vast number of sounds composing language are expressed. Many are attached to the lower jaw; but two in particular, the temporal muscles, proceed upwards through an arch formed by a projecting arm of the temple-bone, and are fixed to the tendons of the head. These two muscles are the most powerful in moving the jaws in the operation of chewing the food, and are very large in several animals of prey. Another flat muscle inside the cheek is called the trumpeter-muscle, because it assists in blowing from the mouth and in sounding wind instruments. The chest is supplied with numerous muscles, which move the ribs upwards and downwards in the action of breathing. A large flat muscle, called the diaphragm, stretched across the trunk from side to side, and separating the hollow of the chest from that of the belly, also contributes mainly to the process of breathing. The arm and hand are rolled inward and outward by a set of muscles, which are placed on the outer and inner sides of the respective bones; thus, the outside muscles act in a contrary manner to the inside, and reverse motions may be alternately performed. The muscles of the fore-arm are fixed to the scapula or shoulder-blade, to the chest, and to the clavicle, at the upper end, and to the bone of the arm at the other. The fingers are moved by muscles situated in the fore-part of the arm, and have long slender tendons, by which they are attached. Two beautiful provisions of nature are here observed: at the wrist, a circular ring of tendinous substance binds down the long tendons, which would, in their various motions, otherwise start up from their places. This ring at once keeps them in place, and permits their free and unhampered play. The other provision is seen in the construction of the tendons of the fingers. There are two principal muscles which move the joints of the fingers, and two sets of tendons, which are inserted, the one into the middle bones of the finger, the other into the third row of bones, or the extremities of the finger. In order to preserve their free action, and to make them lie in the most convenient manner, there is a loop or slit in the shorter tendon, by which the other passes through to its insertion in the point of the finger. By this means the longest and strongest muscle moves the extremities of the finger, where the greatest power is wanted, without impeding the action of the other. The muscles which move the lower extremities are thicker and more powerful than those of the arms. Several large muscles, acting in opposition to each other, are situated around the thigh-joints, and move them. They are fixed, one end to the trunk of the body, some pretty far up, especially two, which are spread upon the front of the abdomen or belly, on each side of the spine; while the other ends are attached to the thigh-bone. Several thick muscles, also, are situated at the back of the trunk. Two large muscles compose the *calf* of the leg, and join to form the tendon of *Achilles*, which is fixed to the heel-bone; these muscles act powerfully in bending the ankle, and in supporting the body in walking. The foot and toes are moved by several long slender muscles, situated in the leg, which have tendons attached to them, and terminating on the toes, exactly like those of the hand and fingers.

The pelvis and lower limbs of man differ greatly from those of all other animals in their superior proportional strength, and in the number and fulness of the muscles. This was necessary, as man has been evidently intended by nature for the erect position. In the monkey tribe, whose general form approaches nearest to that of man, the narrowness of the pelvis or hip-bones, and the smallness of the muscles of the lower extremities, clearly show that they were not destined by nature for the erect attitude; in fact, all animals of this class are furnished with *four hands or paws*, the hinder pair exactly resembling those in front. When they attempt to walk on the hind extremities, they cannot put the sole to the ground, but press on it edgeways. By the nice balancing of the muscles, and the great force which they exert, man is enabled to stand erect, and to maintain a firm position, or move forward at pleasure, notwithstanding that the body diverges from the perpendicular line of the centre of gravity. The head is also balanced upon the neck by means of strong muscles, whose constant though unobserved exertion is necessary to maintain it in its position; for in young children, when the muscles are as yet weak, and in persons asleep, the head has an inclination to droop, and in the dead body it falls down on the shoulder or breast. The muscles of the neck, therefore, may be said to exercise a power in some degree involuntary, or not under the command of the will, as the majority of the muscles of the body are. But there are other muscles still more distinctly removed from under the guidance of the will. The heart is nothing else than a hollow muscle, which contracts and expands without the consciousness of the being; and, in like manner, the muscles which perform the act of respiration are not moved by the will.

This division of the muscles into two classes—*voluntary* and *involuntary*—shows, as perfectly as anything could do, the care with which our frame is constructed. Had those muscles on which respiration and the action of the heart depend, been placed under the control of the will, their functions would have been liable to be impeded at every turn by circumstances. Now, these organs cannot cease to act for the most trifling interval without fatal consequences. The arrangement, therefore, which renders their operation involuntary, is one to be admired as essential to life and comfort.

THE BLOOD—BLOOD-VESSELS.

The blood.—The blood is the medium by which all the solid and fluid parts of the body are supplied with nourishment. In its composition, therefore, will be found the majority of the substances of which the body is composed. The blood consists of a solid coagulable matter, called *fibrin*; of a series of *red globules* which form the colouring matter; and of *serum*, or whey-like matter, which gives the whole the necessary fluidity. From the heart, the centre of the circulation, the blood is conveyed through the body by vessels called *arteries*, and is brought back to the same part by *veins*. The purpose of its thus making the circuit of the whole body, is to supply the necessary materials for increasing the bulk and repairing the daily waste which takes place by perspiration and the perpetual operation of the numerous excretory organs. The blood is restored to its nutritious state by the chyle, a juice formed in the stomach and intestines from the digested food; this chyle reaches the heart by one of the large veins called the left subclavian; from the right side of the heart it goes along with the venous blood to the lungs, and there it is mixed with the oxygen, or vital portion of the atmospheric air, by which process it is converted into bright red arterial blood. In short, there are two distinct circulations of the blood in the system. By the one, the blood is conveyed and distributed over all parts of the frame, imparting, at every pulsation of the heart from which it issues, new life and nourishment to the whole. After traversing the body, it returns to the heart, deprived of its nutritious properties, and changed in colour from a bright to a dark red. Here the second circulation, which is through the lungs, commences. The blood is poured from the right side of the heart, which has divisions for the purpose, into large vessels which carry it to the lungs, and, spreading out into countless branches, penetrates and permeates their whole substance. Collected again by other vessels of equal number and extent, it is conducted by them to the left side of the heart, to be propelled anew through the frame, restored to its bright red hue, and repossessed of all its vivifying qualities. Both these changes are effected in the lungs. The chyle, which may be called the essence of our food in a liquid state, is conveyed from the stomach through the chest by a duct, which empties itself into one of the veins, immediately before the blood is transmitted through the lungs. It is in these organs that the chyle is thoroughly mixed up with the circulation; and it should be remembered, that this chyle is the only benefit, the only real food, extracted from all the substances received into the stomach, the remainder being entirely useless and excrementitious. From the chyle comes the material of the bones, of the fleshy or muscular parts, of the brain and nervous cords, of the hair, nails, enamel of the teeth, and, in short, of every different structure of the system. The average quantity of blood contained in an ordinary-sized person, is calculated at about 30 lbs. weight. The coloured globules of blood do not enter into the smallest vessels of the body, but only the thinner part of it, which has no colour; thus, in the eye, there are numerous blood-vessels, but these are so minute as not to admit the red parts of the blood; and this is a necessary provision of nature, in order that these organs may retain their pure transparency for the purpose of vision. In inflammation of the eyes, when these vessels are much enlarged, the red globules sometimes enter, and the eyes are then said to be bloodshot. What is called the pulse, is the flow of the blood through the arteries, which is caused partly by the impulse of the heart's contractions or beatings, and partly by the contractions of the coats of the arteries. The rate of pulsation in a person in the prime of life, is from 65 to 75 beats in a minute. In childhood the pulse is much quicker—from 100 to 140 beats; and in old age it again becomes slower than the medium standard. In fevers, inflammations, and other diseases of excitement, the action of the heart is increased sometimes to from 100 to 140 pulsations in a minute.

Blood-Vessels.—These consist of the heart, with its arteries and veins, that branch out through every part of the body, and carry the blood, by a constant circulation, through them. The heart is placed in the left side of the chest, a cavity divided into two parts by a thin membrane running perpendicularly down the centre, and supported below by the diaphragm. It is of a round or conical shape, with the base or broad part uppermost, and the point slanting downwards and towards the front surface of the chest. It is of a thick muscular substance, with hollow cavities inside, and numerous cords or pillars of fleshy or tendinous substance stretching through these to give them support. In man and all the more perfect animals that breathe air through the lungs, it is double, or has two distinct sides, each performing separate offices. In fishes, again, the heart is single; in insects there is no proper heart, but a vessel that runs along the back, somewhat like an artery, through which the fluid corresponding to blood circulates through their bodies; other animals, still more simple in structure, have no trace of heart or blood-vessels. For these ends, the heart in man has two sides, a right and a left; and each of these sides contains two hollow cavities—the one called an auricle, from its fancied resemblance to the ear; the other a ventricle, or belly. The manner in which the circulation of the blood is effected may thus be described in detail:—Two large veins, one from the upper part of the body, the other from the lower, enter the right auricle of the heart, and carry the blood, which has made the round of the body, into this cavity. Here it is of a dark purple colour, and it is called venous blood, from its coming from the veins. From the right auricle it is sent, by a sudden contraction or forcing together of the two sides of the cavity, into the right ventricle, immediately below the auricle, and communicating with this by a small opening furnished with a valve; by the right ventricle contracting, it is conveyed by the pulmonary arteries into the lungs, the two large cell-formed substances on each side of the chest, surrounding the heart. After passing through the lungs it is returned by the pulmonary veins to the left auricle of the heart; from this it is sent into the adjoining left ventricle; and, by a powerful contraction of this muscular cavity, it flows out by the great artery of the heart, the carotid, which distributes it through every part of the body, again to be returned by the veins: and thus the round of circulation is continually going on.

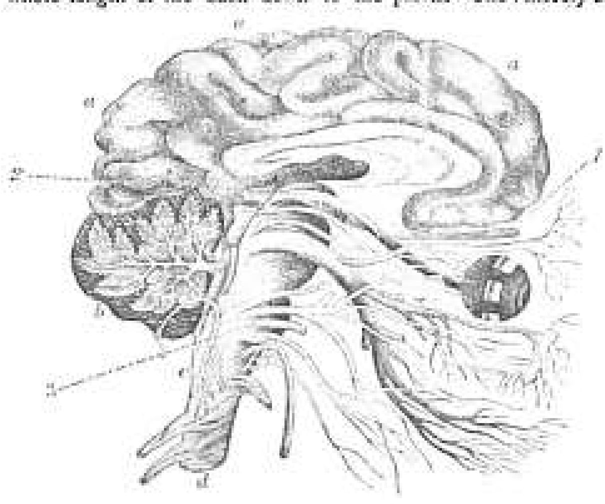
The heart being an extremely thick muscle, the force with which it contracts is very considerable. The left ventricle of the heart, too, although somewhat smaller, is much thicker and more muscular than the right, it having to send the blood through the whole of the body. A beautiful provision is observable in the heart, to prevent the flowing back of the blood into its different cavities during their alternate pulsations. In the passage of communication between the left auricle and ventricle are placed valves, which, when the ventricle contracts to send the blood through the aorta, close accurately, so as to prevent a reflowing into the auricle. There is the same provision between the right auricle and ventricle, and also at the mouth or commencement of the aorta and pulmonary arteries, and the veins which communicate with the right auricle. Some of these valves are of beautiful structure; they are composed of three flaps that join accurately over each other; and to prevent their being pushed by the impetus of the blood beyond their proper position, they have little tendinous cords attached, of exactly the length required. In the child before birth, as it cannot breathe, and therefore the lungs are not used, there is a small hole or communication between the right and left auricles, by which the blood from the veins flows directly through to the arteries, and thus avoids going to the lungs; this hole closes up whenever the child begins to respire. The aorta, or great artery of the body, after it leaves the heart, passes upwards in the form of an arch, when it gives off the carotid branches to supply the brain, and face, and arteries to the arms and chest. It then bends downwards, and gives off branches to the stomach and other viscera; and when it comes to the lower part of the belly, it divides into two main parts, which become the arteries of the pelvis, thighs, and legs. The arteries of the body are composed of three coats or coverings, the principal one being a thick muscular ring, which encircles the artery, and which contracts and expands so as to assist in sending the blood onwards. The principal trunks of the arteries lie deep in the fleshy parts of the body; but their ramifications are so numerous and minute, that they pervade every particle of the human structure—bones, gristle, and every other texture. These extreme branches of the arteries being so minute, anatomists have had great difficulty in tracing the exact point at which they pass into veins. That they do so, however, is undeniable, and is partly seen on the surface of the brain. The veins are another system of vessels, which return the blood from the extremities of the body to the heart. They are larger and more flaccid than the arteries, and are distinguished from them by having no pulsation. A large vein generally accompanies the corresponding artery, but the great proportion of the veins lie more towards the surface, and are easily distinguished, swelling out under the skin. The numerous veins from the lower extremities join into one trunk in the belly, which vein, after passing through the liver, as will be afterwards described, joins the right auricle of the heart, the blood from the upper half of the body joining also by another similar vein. In the veins of the extremities that hang downwards, and are apt to be gorged with blood, there are inserted numerous valves, at short distances, which prevent reflux of any kind.

THE BRAIN—NERVES AND NERVOUS INFLUENCE.

The brain, as already mentioned, is contained in the cranium. It is a soft mass of matter, enclosed in certain protecting membranes beneath the bones of the skull. As the organ by which mind acts, and chief seat of the nervous energy, the brain may be described as the most important and dignified of man's bodily parts, and well deserves the most careful investigation. The brain is divided by strong membranes into two main sections—the cerebrum or proper brain, which lies in front beneath the brow and on the top and sides of the head, and the cerebellum or lesser brain, which lies behind. Both are longitudinally divided into halves or hemispheres, and also into lesser parts called lobes. The annexed figure offers a lateral representation of the different parts of the brain, as it lies beneath the skull, with its beautiful and minute radiation of nerves proceeding to the eye and other external instruments of the organs of sense.

The cerebrum or principal part of the brain is indicated by the letters, *a a a*. The cerebellum, distinguished by the letter *b*, terminates below in the *medulla oblongata*, *c*, the cylindrical pulpy cord by which a union is formed between the brain and *spinal marrow*, *d*. The latter part is the long cord of soft matter formerly mentioned as lying in the canal formed by the range of the spinal bones. It is round, of the thickness of the finger, of the same kind of substance as the brain, and formed of smaller nervous cords, running parallel to each other: it runs along the whole length of the back down to the pelvis. The nerves are small whitish-looking cords, which proceed from the brain and spinal marrow, and spread out in innumerable branches to every part of the body. A large branch of a nerve generally accompanies every large artery, and every important part of the body has a branch of a nerve sent off to it. The nerves for supplying the organs of smell (1), of seeing (2), of hearing (3), together with the great sympathetic nerves, which give branches to the heart, lungs, stomach, and other important viscera, proceed directly from the brain. The nerves of motion and sensation sent to the various parts of the trunk and extremities, take their origin, with a few exceptions, from the spinal cord. Two sets of nervous branches proceed from the cord on each side, corresponding nearly to the junction of every vertebral bone; and it is found that a branch of these nerves imparts motion, and the other sensation or feeling. The brain has a covering of three thin membranes; the outward one strong and thick, the inner extremely thin and delicate. The nerves, which are soft and pulpy inside, have also a thin external covering which protects them. The nervous branches are never seen or felt in the living body, and what are vulgarly called nerves, are the tendons of the muscles, the erroneous title being given chiefly to those about the wrists, fingers, and ankle-joints. Their great numbers and minute divisions are manifest, however, because we cannot prick any part of the body with the sharp point of a needle, without wounding some of them, and thereby causing the sensation of pain. When the nerves are injured in their powers by disease, the sense of feeling in the part is entirely lost. The brain in the lower animals is not generally nearly so large, in proportion to their bulk, as in man; and the cerebrum, or upper brain, is often smaller in them than the cerebellum, or lower brain. In many classes of the inferior animals there is no distinct brain, but only nerves running along their bodies, and joining into knots or ganglions. The nervous system of insects and worms is of this description. In the polypus, and some other similar animals, a distinct nervous system can scarcely be traced.

It may be proper here to make some observations on the functions of the brain, considered abstractly from its anatomy. Man surpasses all other animals in the height and proportions of the forehead, and in the comparative mass of brain in the upper part of the skull. In the human head the lower parts of the face bear a smaller proportion to the forehead than in the brutes. The face is placed in nearly a perpendicular line with the forehead, instead of projecting outwards into a snout, as in the lower animals. The brute face is merely suited for the purpose of animal wants and for defence; the jaws are long and narrow, supplied with thick, strong muscles, and short teeth; there is not the elevated nose, which in man forms a distinguishing feature—the arched eyebrows—the exquisitely formed lips, and the rounded chin; above all, there is not that play of varied expression, that air of intelligence, and that indescribable emanation of a rational mind, that ray of divinity, at the appearance of which the most wild and ferocious of the brute creation are awed and subdued. But, besides, the Creator seems to have allotted characteristic external signs to express the passions of the mind, that in social life man might not easily impose on his fellow-man; for the various muscles of the face express the several passions of the mind so faithfully, that they may be even represented in painting. This is said to be the natural expression, and would appear to be understood even by animals; for a dog, on looking to the countenance of his master, easily recognises the mute expressions either of commendation or dissatisfaction. From the action of these muscles being so often repeated,



The Brain.

physiognomy arises; the action of the prevailing muscles fixes an enduring expression on the features; and thus traces of frequent anger often remain in the countenance after the passion itself is gone off. With the power of speech and reason, man has also the means of expressing his feelings and passions by laughter and weeping, manifestations which are not found in the lower animals. Weeping proceeds from a deep emotion of the mind, and seems an effort of nature to relieve the system of grief. It usually begins with deep inspirations of the lungs, after which follow short alternate inspirations and expirations, and it is finished with a deep long-drawn expiration, which is immediately followed by an inspiration. When moderate, it certainly relieves the distress arising from grief. Laughter has its rise from some ludicrous ideas impressed upon the mind, and would seem to arise directly from a sort of titillation conveyed to the branches of certain internal nerves, probably those of the diaphragm; immediately to this succeeds a number of imperfect inspirations and expirations, which seem to be checked by the contraction of the glottis in the throat or larynx. Laughter in a moderate degree may be conducive to health, as it gives impulse to, and ultimately promotes, the circulation; carried to excess, however, it may prove dangerous, from accumulating too much blood in the lungs. Sneezing consists of one deep inspiration, succeeded by a powerful single expiration, and seems to consist of a convulsive effort of the muscles of breathing to throw off some cause of irritation in the sensitive membrane of the nostrils. The common hiccup is a spasmodic action of the muscles of the stomach, caused by something irritating the stomach itself. Some of the causes by which our mental happiness is either increased or diminished, proceed entirely from the bodily sensations. Any gentle stimulus applied to a nerve seems to cause a feeling of pleasure; strong stimuli, or any causes disturbing seriously the natural condition, produce pain. Itching is akin to pleasure, and in both cases the flow of blood is increased into the part in which either pleasure or titillation is perceived; but when further increased, it degenerates into pain, or excessive sensations in the nerves. Anger violently excites the motion of the spirits, increases the motion of the heart, the frequency of the pulse, and the strength of the muscles; forces the blood into the extreme vessels; and even sometimes bursts the smaller vessels themselves: passion also increases the secretion of bile. Grief weakens the strength of the nerves and action of the heart, retards the pulse, destroys the appetite, and frequently produces paleness, looseness of the bowels, indigestion, and those slow or lingering diseases that take their rise from an interruption of the secreting glands, and a disease of their structure. Fear diminishes the force of the heart, weakens the muscular motions, relaxes the whole system, and, if long continued, causes a general sinking of the body. Excessive terror often increases for the moment the muscular strength, even to convulsions; excites the pulse, interrupts the course of the blood, and in not a few instances has produced sudden death. Love, hope, and joy, promote all the salutary actions of the body, gently quicken the pulse, promote circulation; increase the appetite, and aid the cure of diseases. Excessive and sudden transports of joy, however, often prove fatal, by increasing the motion of the blood, and exciting a fit of apoplexy. Shame, in a peculiar manner, retains the blood in the face, as if the veins were obstructed; when felt in an extreme degree, it has also been known to prove the cause of sudden death.

THE LUNGS OR BREATHING APPARATUS.

In the highest part of the cavity of the chest, on each side of the breast-bone, the lungs are situated. A membrane passing from the breast-bone to the back, divides them into two portions, the right lung and the left lung. The right lung consists of three sections called *lobes*, the upper, middle, and lower; the left lung, rendered smaller in bulk by the presence of the heart in the same cavity, has only an upper and a lower lobe. The lungs have a dark bluish appearance, a familiar example of which is afforded in the *lights* of sheep, that part generally appended to the heart and wind-pipe. Inside they are composed of an immense number of cells, which alternately inflate or collapse as the lungs are filled and emptied of air. When an inspiration is made, and the lungs are filled with air, these cells become expanded; and the blood sent from the right side of the heart, and spread over the cells, is exposed through an extremely thin membrane to the air. An important change, as formerly alluded to, here takes place on the blood: from being of a dark purple colour, it immediately changes to a bright scarlet, having absorbed or taken up all the oxygen, or vital part of the air, and parted with a corresponding volume of carbonic acid gas or fixed air, which it had acquired in its circuit through the vessels of the body. So essential is the matter imparted by the air to the blood for sustaining animal existence, that the breathing cannot be suspended even for a very short period without extinguishing life. It is probable, too, that the heat of the body is generated, and constantly kept up, in some way or other, by means of this process of breathing, and the change which the blood undergoes. We know, at least, that the evolution of carbonic acid cannot go on, in ordinary chemical processes, without an accompanying discharge of heat; and hence it is presumed that the vital warmth, derived by the body from the blood, may be in this way produced. The lungs, like every other internal organ, are covered with a thin transparent membrane called the *pleura*: this membrane, as well as the substance of the lungs themselves, is liable to inflammation; and hence the name of the disease called pleurisy. The trachea or windpipe, the communication between the mouth and lungs, is a hollow tube, having a series of cartilaginous rings passing round it, to prevent the possibility of its being compressed either by external means, or from the food in the act of swallowing, and, in consequence, the breathing obstructed. It takes its rise from the bottom of the mouth, and passes down in front of the neck, where its strong cartilage may be seen and felt. At its lower part it divides into two branches, one going to join the right section of the lungs, the other the left.

Lungs for the breathing of air are only found in the higher classes of animals. Fishes are furnished with gills, those comb-like substances which lie within a flap on each side of the head; over them a stream of water is constantly sent by inhaling it at the mouth in a similar manner to breathing. The air, which is always present in considerable quantities in water, is thus absorbed by the blood-vessels while ramifying over the gills, and all the purposes of breathing are answered. In insects there are no lungs, nor do they breathe by the mouth, but along the sides of their bodies, by means of numerous holes with small tubes or spiracles, leading to a longer middle tube, by which the air enters and mixes with their fluids. When we descend lower in the animal scale, even this substitute for breathing ceases, and probably the vital air is absorbed by such animals by simple pores or openings in the skin.

THE TEETH.—DIGESTING APPARATUS.

The first process performed in connexion with the supply of nourishment to the body is that of masticating the food, and this is the office of the teeth.

The Teeth.—These are placed in the upper and lower jaw, to which they are attached by roots, which sink into the porous sockets of the jaw, somewhat in the same manner as a nail is fixed in a piece of wood, though they are retained in place chiefly by the softer parts around. The teeth are composed of bony matter, covered externally with a thin coat of an extremely hard substance, called enamel. The teeth are furnished with nerves and blood-vessels, and have thus vitality like the rest of the body, although possessing it in a less perfect degree than most other parts of the structure. Hence they are very liable to disease and decay. In decaying teeth a blackish spot is first perceived upon the outer crust or enamel; this substance gradually gives way, and then the bone below proceeds to rapid decay. The irritation of the air, and particles of the food, inflame the nerves and soft pulpy parts inside, and thus the excruciating pain of toothache is produced. The first set, or temporary teeth, begin to make their appearance in the child about the fifth or sixth month, and towards the end of the eighteenth month the whole set of temporary teeth, consisting of twenty, have generally cut through the gums. These teeth continue till about the sixth or seventh year, from which time, till about the twelfth or thirteenth year, they gradually fall out one by one, and are succeeded by the second or permanent teeth. The roots of the temporary teeth are much smaller, and sink less deep into the jaw than their successors. The rudiments of the second set of teeth begin to form early in cavities below the others, and, gradually growing and pressing upwards, displace them. The number of the permanent teeth is thirty-two, consisting of sixteen in each jaw. The four front teeth are called the incisors, and have one long root; on each side next to these is one eye or dog tooth; then there are placed two small grinders on each side, having double roots, and three large grinders, or molar teeth. The last of these is called the wisdom tooth, from its making its appearance latest in the jaw, from the seventeenth to the twentieth year, or even later. By this change and gradual succession of teeth, we have a beautiful provision of nature for permitting the jaws to increase in size, and, at the same time, for preserving the relative positions and regularity of the different teeth; for had the first teeth of childhood been permanent, it is impossible that the jaw could have increased in growth without deranging the order and position of the whole.

The teeth of animals differ according to the kind of food on which they live. In the carnivora, or flesh-feeders, the teeth are sharp-pointed, and adapted for tearing their prey to pieces; in the graminivora, or those that live on grasses and other herbage, the teeth are of a rounded form, with broad surfaces, and the grinders are furnished with several layers of the hard enamel, following each other in succession, with a slight layer of common bone interposed; so that, when the grinder is worn down by the friction of chewing, it is not rendered useless, but a new layer of the enamel is presented at the worn-down surface. Some animals, as the hare, rabbit, beaver, and mouse, have the front teeth of a chisel shape, with enamel only on the outer side of them. These animals are called gnawers, because they chew or gnaw down their food in this particular manner; and by the inner soft part of the tooth being liable to be worn down, while the outer is harder, the enamel is thus always kept with a sharp edge. Some animals have large projecting tusks for defence, as the elephant, wild-boar, &c.; others, as fishes, are provided with teeth more for holding fast their prey than for mastication. Many have no proper teeth at all, as birds, worms, and other soft formed animals. Man is characterised by having all his teeth set close to each other in a half circle; they are of a medium form, between that of carnivorous and herbivorous animals; the front teeth are adapted for cutting; the canine are sharp, though not of undue length; and the grinders are suited for masticating vegetable and farinaceous matters, as nuts, &c. In short, the form of the teeth of man evidently points out that he is adapted to live on a mixed kind of diet, or a conjunction of vegetables and flesh.

Stomach.—Behind the windpipe, taking its rise also from the bottom of the mouth, lies the oesophagus, or tube which passes into the stomach. This tube expands at the top into what is called the pharynx, forming the whole of the upper part of the throat immediately behind the tongue. Into this cavity the windpipe opens, and, to guard against any particle of the food or drink passing into the windpipe instead of into the passage to the stomach, there is a little tongue or valve which closes accurately over the mouth of the windpipe every time food or drink is swallowed. When the substances have passed, the valve again springs open, and admits of free breathing. To show how accurately and precisely every part of the human machine performs its duties, a celebrated writer has instanced this same valve, which, in a multitude of persons dining together, not one time out of a hundred in any one individual instance is at fault. When a drop of fluid or particle of food does by chance insinuate itself into the windpipe, so sensitive is this tube, that a convulsive cough is excited till it is again expelled. There is another little tongue or flap attached to the roof of the palate, and seen above the tongue when the mouth is opened. This, which guards the passage to the nose, is not, however, to be confounded with the other, which is farther down the throat, and invisible. The oesophagus, or gullet, passes down through the chest, traverses a ring in the diaphragm, that large muscle which stretches across the lower ribs, and which assists so materially in breathing. Immediately below this muscle, on the left side, is situated the stomach, which is partly sustained in its place by being attached to the oesophagus, or tube from the mouth. The stomach is an oval bag of considerable size, occupying a slanting position immediately below the heart, with its right side overlapped by the left edge of the liver, and extending to the lower end of the breast-bone. The stomach has three coats—an external membranous one, a muscular, and a soft villous inner covering. The upper passage, by which this bag communicates with the oesophagus, is called the *cardiac* opening; the lower, where the first gut commences, is called the *pyloric* orifice.

Digestion.—One of the most important operations in the animal economy, is that of digestion, whereby the various substances used for food are dissolved in the stomach, and undergo changes, by which they are formed into matter fit for entering into the composition of the different parts of the body, to nourish its growth, and supply the daily waste which takes place in the system; for such is the constitution of animal bodies, that the substances of which they are composed are liable to constant waste; the solid parts are worn down, and a large quantity of fluid is constantly given off by the exhalent vessels, both from the skin and the surface of the lungs. This is manifest in the sweat and the vapoury exhalations constantly passing off by the mouth; and there is also an imperceptible perspiration regularly proceeding from the surface of the body, which has been computed to amount to several pounds in the course of a day. It must be evident, therefore, that if this waste was allowed to proceed but for a very short period, the body would soon be reduced to a state of complete decay. A constant supply of new material is therefore daily needed, to replace that which is wasted; and thus it has been supposed that a human body changes its whole materials many hundred times from the period of its birth till death; and that an individual, as regards his mere corporeal structure, is not at all the same at the period of manhood to what he was when a boy, nor in old age what he was in his prime. Although this change then is complete, even to the bones and most solid parts of the frame, it is brought about so gradually, and with the regular and minute substitution of one particle for another, that it is never perceptible. Man has been called, with relation to his diet, omnivorous, from his being adapted to live on every kind of food, whereas most other animals are confined to one particular description. The carnivorous animals live on flesh alone, the graminivorous on grass and green herbs, and the granivorous on grains and other smaller seeds. These animals never change their respective diets; nor, from the construction of their teeth, stomachs, and intestines, were they ever intended to do so. But in man it is plainly evident, from his anatomical structure, that he was intended to feed on every sort of food promiscuously, or that he could adapt himself to either animal or vegetable fare, as habit or necessity impelled him. Man also differs from brutes in resorting to the arts of cooking, whereby the food is put into a state more fitted for digestion, and for yielding a sufficiency of nutritious aliment. The food being received into the mouth, is broken down and masticated by the teeth. It is here also reduced into a soft pulp by the saliva, which flows into the mouth by the salivary glands; and thus being sufficiently broken down and softened, it passes into the stomach. The stomach has numerous glands situated on its inner coat or surface, which secrete a peculiar fluid called the gastric juice, which is clear and colourless, with little taste, or smell, or sensible qualities. On this fluid depends the important office of digestion. It has the power of coagulating substances in the stomach, of preventing the contents of the stomach from passing into a state of fermentation or putrefaction, and of dissolving the whole into one homogeneous mass. When the stomach is first filled with food, it appears to remain there for a short period without undergoing any change; gradually, however, successive portions of the food, as they come into contact with the gastric fluid, are dissolved; till at length, in a shorter or longer period, the whole is collected into a thin greyish paste, called chyme. In the upper or left division of the stomach, it would appear, from some recent observations, that the food is freed from its superabundant moisture, which drains off by some undiscovered means to the blood-vessels, and from thence to the kidneys. The chyme then, as it is gradually formed, moves to the other extremity of the stomach, called the pyloric, where it passes out to enter the intestinal canal. It would appear, also, that the pylorus, or lower mouth of the stomach, has a sensitive power, whereby it freely permits the digested chyme to pass out, but refuses exit to the undigested matter. The chyme having passed into the first part of the intestines, or duodenum, is then mixed with the bile from the gall-bladder, and with the pancreatic juice. Both these substances, especially the bile, seem essential for the conversion of the chyme into proper alimentary matter, but their peculiar action has not yet been satisfactorily explained. That the liver and bile ducts are of the utmost importance, however, cannot be doubted, from their magnitude, and the care with which they are supplied with numerous vessels, and from their being universally present in a great proportion of animals. The chyme having passed through the duodenum, and having been mixed with the bile and pancreatic juice, now changes its appearance and properties, and becomes the chyle, or nutritious matter destined to supply the various parts of the system with nourishment. The digested mass is passed gradually along the course of the small intestines, urged forward by what is called their *peristaltic* motion, which is effected by a successive contraction of their fibrous coats. Here the minute mouths of the lacteal vessels, opening on the inner surface of the small intestines, take up the chyle, and carry it, as has already been described, to the receptacle of the chyle, and then by a duct running up the chest along the spine, called the thoracic duct, it joins the blood-vessels. The refuse of the aliment which has not been taken up by these lacteal vessels passes on through the large intestines, and at length is ejected from the body. Digestion is not brought about, as has by some been supposed, by any mechanical means, as by the grinding powers of the coats or sides of the stomach, nor by heat alone, nor fermentation, nor by the simple resolution of the food into a fluid; but it is evident that it undergoes a series of chemical actions in the stomach and bowels, whereby its nature and properties are completely changed; and thus animal and vegetable substances, however different, are reduced to one peculiar kind of fluid, the chyle, which, though it may be found to vary slightly according to the kind of food, is, in its general properties, always the same. The gastric juice varies in different animals. In those which feed on vegetable matter, it dissolves these substances only; whereas grain and vegetables pass through the stomach of a purely carnivorous animal without undergoing any change. The gastric juice has this singular property, too, that although it readily dissolves dead animal matters, and reduces them in a short time to a thin pulp, it will not usually act on the living fibre; so that, after death, the coats of the stomach have been found dissolved into holes, by the same juice, which, in the living healthy body, had no such effect.

A stomach of some kind or other is found in all animals; for it is by this organ that nutrition and growth are solely promoted. There are some very simply formed animals whose whole body consists of an oval hollow bag, or stomach, with a simple outlet for the mouth to take in nourishment, and no other organ whatever. The common polypi have simply a mouth and hollow stomach, with several tentacula, or arms, by which the creature seizes the worms and grubs on which it feeds; these it swallows, abstracts their juices, and then voids the remainder from its mouth. The common leech has its whole body divided into a number of small cells, like a piece of honey-comb; and these receive the water, and sometimes blood, on which it feeds. Flesh-feeding animals have a simple bag for a stomach, and their food is easily and soon digested. Those animals, again, that feed on grass, which is of more difficult digestion, have three and four stomachs, into which the food successively passes after it has been masticated or chewed a second time in the mouth. This is the case with cows, sheep, deer, &c. Birds that feed on grain have first a sap-bag, or crop, into which the food enters, and remains for a considerable time, mixed with a juice somewhat like saliva; here it is softened and rendered moist, preparatory to its passing into the true stomach, or gizzard, which is an extremely strong muscular bag; in this, with the assistance of a number of sharp-pointed pebbles, which such birds always swallow, it is ground down and acted on by the gastric juice. This compensates for the deficiency of teeth in fowls. Crabs and lobsters have no teeth in their mouths; but in their stomachs will be found three or more teeth, which assist in grinding down the tough sea-weed on which they feed. By domestication, the qualities of the gastric fluid may be so changed, that animals accustomed to live entirely on flesh will exist and thrive on a vegetable diet. This is the case with dogs, and many birds. All these peculiarities in the natural history of animals illustrate, at least directly, the uses of the digestive organs in the human being.

THE LIVER, &c.

The Liver.—Opposite the stomach, on the right side, lies the liver, a large flat substance, of a dark brown colour, divided into two lobes. The liver has a round, convex upper surface, and is hollow or concave below; it is also thick and solid at the back part, and its edge becomes thinner towards the front, where it lies over a portion of the stomach and bowels. It is suspended in its place by several ligaments attached to the surrounding parts. In the under side of the liver, in a small hollow, is situated the gall-bladder, a small oval bag which contains the bile. A tube from this bladder, called the bile-duct, passes into the upper portion of the bowels, carrying the bile there. The liver is supplied by several branches of an artery in the usual way that the other organs are, but it has also a peculiarity which no other organ of the trunk possesses. The large veins, which return the blood from the lower part of the bowels, before going to the heart, enter the substance of the liver, and there spread into innumerable branches throughout its whole surface. From this venous blood the bile is supposed to be secreted, and after having yielded this substance, the vessels collect again into one large trunk, and join the large vein which carries the blood to the heart. The liver weighs, on an average, from three to four pounds weight, and the quantity of bile which it secretes, taking into account its large supply of blood, must be very considerable. The greater proportion of animal beings are provided with an apparatus of some kind or other for preparing a supply of bile, and in many the liver bears a large proportion to the other contents of the belly. In some animals, as the horse, the gall-bladder is awanting, there being merely a duct to convey the bile into the intestines. In the lowest classes of animals, all traces of liver or gall-ducts disappear.

The Spleen.—This substance is situated below the stomach, on the left side, betwixt it and the ribs. It is in shape a flat oval, and of a dark iron colour. No duct or opening has been discovered proceeding from it, nor has its use been as yet accurately ascertained. It possibly serves to relieve the stomach of its surplus quantity of blood while this organ is distended with food; and the splenic vessels have also been held by some to contribute to the secretion of the gastric juice. The spleen, it is remarkable, has been frequently cut out from living dogs, without causing any apparent derangement in the health or digestion of these animals.

The Pancreas.—This substance, known under the name of the sweet-bread, is a large oblong gland (or *secreting* organ), lying across the back part of the belly, extending between the spleen and the middle of the liver. This gland pours out a substance something like the saliva or spittle of the mouth; and by means of a small duct or canal, empties it into the upper bowels, along with the bile from the gall-bladder, both these substances aiding in digestion, and the preparation of the nutritious fluid to be afterwards mentioned.

Lacteal Vessels.—These are innumerably small tubes, proceeding from the ileum or small intestines, along their whole course, and spreading along the mesentery, where they form an immense number of small knots, or glands, by joining together. These are the vessels which take up the fluid chyle, or milky-like substance, after it has been digested and properly prepared in the stomach and bowels. From these mesenteric glands, the chyle is conveyed by these ducts or canals to another large gland, situated in the loins, on the right side of the aorta, and immediately below the diaphragm, called the receptacle of the chyle. From this receptacle the thoracic duct arises, and passing upwards by the side of the aorta, or great artery of the body, it joins the left subclavian vein, lying under the left clavicle or collar-bone, and thus pours the whole of the chyle into the general circulation.

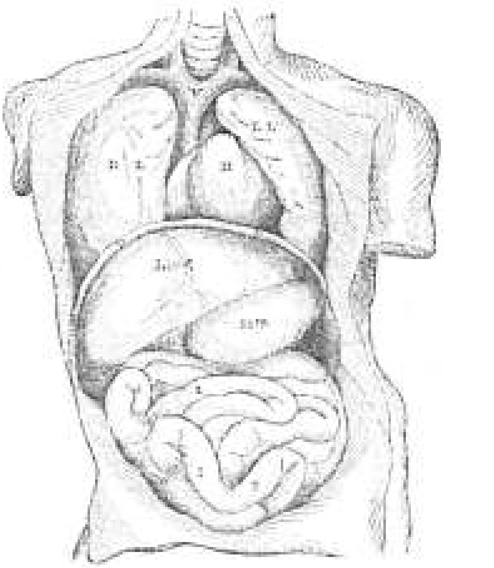
The Kidneys.—These are situated in the loins, one on each side of the back-bone, about one-third up the spine. They are in shape somewhat like a French bean, and their internal structure consists of a number of minute porous tubes. They each at the middle hollow part receive a large artery, and their use is to filter from the blood the superabundant fluid, and salts and juices unnecessary for the system, and transmit these, by means of two small tubes, called the ureters, to the urinary bladder. These tubes enter the back part of the bladder in a slanting direction, which serves the purpose of valves, preventing a flowing back of the fluid when the bladder is full. The bladder is situated in front, immediately above the bone of the pelvis, called the pubis.

The whole cavity of the belly is lined by a thin membrane, called the peritoneum, which is double, being reflected from the sides of the cavity over the whole of the intestinal organs. This peritoneum is liable to inflammation, in the same manner as was mentioned of the pleura, which produces a very violent disease. The coats of the intestines, too, are also subject to the same affection. Dropsy may arise from water being formed between the two folds of the peritoneum.

The Lymphatic Vessels.—These are another distinct set of vessels spread over all the inner cavities of the body, and also throughout the skin, on which they open by innumerable small mouths. Their office appears to be to take up from the blood a thin lymph, which they convey into the receptacle of the chyle and thoracic duct, and also to exhale or carry off from the skin the superfluous moisture of the body. This moisture forms the sweat, and several pounds of fluid are daily drained off from the body in this manner, even when little or no bodily exercise is taken, for perspiration continually goes on insensibly. These vessels are composed of a series of extremely small tubes, and, joining and interweaving, form numerous glands, especially in the groin, armpits, and neck; when swelled by disease, they harden and enlarge, forming knots like a pea or bean. But they are no less numerous on the surface of the inner cavities of the body as on the skin; they are found in the brain, on the surface of the lungs, where they give out a large proportion of vapour at every expiration of the breath, and in the abdomen or belly. It is a disease or sluggishness of these vessels, whereby they do not perform their necessary duty of taking up all the superabundant fluids, that causes accumulations of water in the chest, belly, and legs. The branches of the lymphatics of the lower half of the body join the receptacle of the chyle; those of the upper part enter the thoracic duct just before the latter pours its contents into the subclavian vein.

THE BOWELS.

From the lower or pyloric orifice of the stomach, the duodenum, the first portion of the intestinal canal, takes its origin. This gut passes below the liver and receives the bile-duct, and the duct from the pancreas, when it terminates in the jejunum, which again passes into the ileum, or principal portion of the small intestines. These are of great length, and occupy a great part of the abdomen, being folded and twisted backwards and forwards in many intricate windings. At the end of the ileum, the colon, a large gut, makes an arch upward towards the right side, and across the belly, and descending at the back part, ends in the short bag, called the cæcum, which joins the rectum, the termination of the intestinal canal. The whole length of the intestines in man is generally about six times that of his average height, or from thirty to thirty-six feet. In all animals that feed on vegetables, the intestines are of great length; whereas, in those that derive their nourishment from animal food, they are of much shorter proportions. Two membranous substances, called the omentum and mesentery, run along nearly the whole length of the intestines, and serve as a means of their attachment and proper suspension in their places. The bowels have three coats—an external one, common to them with the other viscera, a muscular coat, and an internal mucous covering.



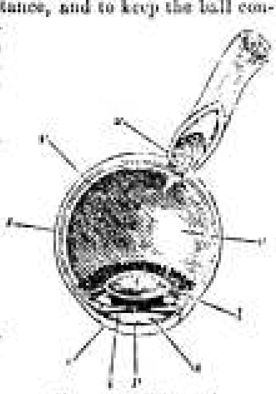
Organs of the Chest and Abdomen.

R L, the right lobe of the lungs; L L, the left lobe; H, the heart; V, the great arteries; D D, the diaphragm, a muscle separating the chest from the lower regions; Liv., the liver; Stm., the stomach; G, the duodenum, or beginning of the small intestines; I I, the intestines or bowels.

THE SENSES.

Man possesses five senses—sight, hearing, smell, taste, and touch—each of which acts through the medium of appropriate instruments, and all regulated by and acting in connection with the brain.

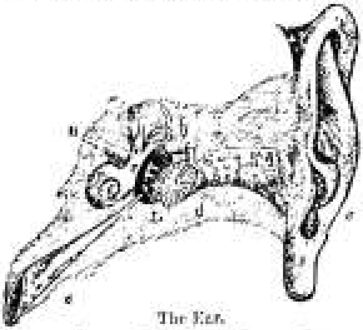
Sight—the Eye.—The eye is the exterior instrument of sight, and is a most beautiful and ingeniously constructed object. The eye may be compared in its structure to a telescope, the purpose of both being to collect the rays of light proceeding from the surface of bodies, to concentrate these rays, by means of a refracting lens, into a focus, and, therefore, to form a very small image or picture of the object before them. The human eye is placed in a large hollow or socket in the upper bones of the face, surrounded by fatty substance, and the various muscles necessary for moving the eyeball and eyelid. At the upper and outer angle of the eye-socket is placed a gland, which secretes the tears that serve to moisten the delicate surface of the eye, to wash off any dust or other substance, and to keep the ball continually wet and transparent, for the purpose of perfect vision. The tears, after spreading over the eyeball, collect at the inner angle, where, at each corner of the eyelid, both above and below, there is a small aperture visible, which carries the tears down a passage into the nose. The edges of the eyelids are also supplied with glands, which pour out a mucus that prevents them from adhering together; and these, when irritated and inflamed, are often the seat of disease. The membrane which covers and imparts the white colour to part of the eyeball in front, is called the sclerotic coat (s). The middle transparent part of the eye in front is called the cornea (c), which is filled with the aqueous humour (a) of the eye. Immediately behind the cornea is seen a circular fringed-like substance (i), which varies in colour in different individuals, being blue, black, hazel, &c.; hence it is called the iris, or rainbow curtain. This iris has the property of opening and closing, according to the quantity of light which falls upon the eye; and thus the pupil (p), a black circle contained within the iris, is enlarged or lessened. Behind the iris is situated the crystalline lens (l), in shape resembling the small lens or ground glass of a common telescope, but of unequal swell on each side, being more flattened before than behind. This lens is contained within a capsule, or thin covering of delicate membrane. A familiar example of the lens of a fish's eye is presented every day in that white globular substance found in such eyes after boiling. The heat coagulates the lens, which is of the same nature as the white of an egg; and in the fish it is nearly a circular body, to adapt the animal's vision to the dense medium of water. The lens is the substance which receives the rays of light entering the eye, and refracts or bends them inwards, whereby they are collected into one point upon the back chamber of the eye or retina, and thus a minute picture of the object seen is formed. If a bullock's eye is taken when fresh, and a hole cut in the skin covering the back part, and then presented to the light with a piece of white paper put opposite the hole, a representation of the objects in front of the eye will be distinctly traced on the paper. When through disease the lens becomes of an opaque white colour, and will not transmit the rays of light, the affection is known as *cataract*, producing blindness. The fluid filling the lens is called the crystalline or vitreous humour (v). Behind the lens is the back chamber of the eye, filled with a fluid, called, from its thickness, the *crystalline* humour. Over this back chamber the retina (r) is spread out like a lining or covering. It is covered over with a black pigment, the better to prevent the intermixture or reflection of the rays of light. On this membrane the optic nerve (o), which comes from the front part of the middle brain, and enters the eyeball at the back part, spreads out in numerous branches; and here the small images of the outward objects presented to the eye are painted in miniature. All these objects are painted on the retina in a reversed position, or turned upside down, the same as happens in a common microscope; and how they are perceived in their upright position through the medium of sensation, is a curious question, not easily admitting of explanation. Each eye, too, forms a distinct impression of every object; and yet things are not seen double, but both eyes combine to give one impression to the brain or seat of perception. Besides the numerous muscles which roll the eyeball in various directions, to adapt it to the various positions of vision, there seems also a power, in the cornea or front portion of the eye, whereby it can flatten or become more convex according as the object viewed is at a greater or less distance from the eye; thus adapting itself to the focus of vision in a similar manner as the joints of a telescope are drawn out or pushed inwards. When the cornea is, from its natural form, of too rounded or convex a structure, distant objects are always seen imperfectly, hence causing what is called nigh-sightedness; on the other hand, when it is too flat in form, near objects are then seen indistinctly. This change occurs generally to the cornea as old age approaches; hence spectacles, or artificial rounded lenses, to aid the flatness of the eye, are in such cases made use of with the desired effect. From the different densities of the three humours composing the eye, the refraction, or breaking of the light into the various coloured rays, is avoided. This for a long time was a great objection to telescopes, till different kinds of glass were joined together in the lenses, thus imitating the resources of nature in the eye. The eyes are supplied by two large optic nerves proceeding by separate trunks from the brain; they join together for a short space within the cranium, where they again separate, and each entering an opening at the back part of the orbit, spreads out into branches over the retina. Sometimes these nerves lose their power of sensibility, and total blindness is occasioned without any perceptible disease of the eye: this is called *amaurosis*.



Human Eye Dissected.

All the higher classes of animals are possessed of evident organs of sight. Birds have, in general, very acute vision, especially birds of prey, to enable them to distinguish their victims at a great height in the air. They have also a third eyelid, or transparent membrane, which covers the eyeball when they are darting suddenly through the air, and which thus protects the delicate organ of the eye from injury, at the same time that it allows the transmission of a sufficient quantity of light. Fishes have eyes of a somewhat different form from land animals, to adapt their vision to the denser medium of water, through which the rays of light pass. Insects have great numbers of small eyes clustered together, like the facets of a gem. Many of the inferior animals, as shellfish, worms, &c. have no perceptible organs of vision.

Hearing.—The ear is the instrument of this sense. The outer part or conch (c) of the ear is formed so as to collect and transmit the currents of air into the passage (m) which leads to the tympanum or drum (t). This passage is defended at its mouth by a number of small hairs growing up in it; there is also a waxy substance constantly secreted, which keeps the whole moist, and is an effectual bar to the entrance of insects or other offensive substances. At the inner end of this winding passage is the thin membrane or drum (d), which is stretched out on four small bones (b), and which, by its vibrations, conveys through the medium of the nerves the sensations of sound. There are also attached to these small bones several muscles, which, by their contraction and relaxation, modify the tension of the thin membrane, and prevent sounds from acting too strongly on it, or render it tighter, in order to be even sensible to feeble vibrations. Behind the cavity of the tympanum or drum, there is another passage which leads from the ear to the mouth, called *the Eustachian tube* (c), the object of which is most probably the same as the holes in the common drum, to allow the air to escape from behind, and thus promote the vibration of the membrane of the tympanum; for it is found, that if such holes are not made in a drum, little or no sound will be produced; and in the human body, when this tube, leading to the mouth, is choked up by the inflammation of a common cold, deafness is produced. There is another cavity called the vestibule of the



The Ear.

ear (r), covered over also by a thin membrane; on this membrane the nerves of hearing are expanded, and convey the sensations of sound to the brain by a, the auditory nerve. The sense of hearing is very acute in some animals, especially those that live by prey. In the lower orders of beings the sense is wanting, but is compensated in a considerable degree by the extreme acuteness of feeling, or touch, which is so diffused over their bodies as to make them sensible of the least agitation in the air by which they are surrounded.

Smell.—The nose is the instrument of smell, and is of comparatively simple structure. The bones forming its inner cavity are of a spongy nature, or rather are composed of a number of very thin plates, covered with a soft membrane, over which the branches of the nerves of smell are minutely exposed. The effluvia proceeding from bodies, and which imparts their peculiar odour, must pass in a stream or current through the nose before the odour is perceptible. If the air is perfectly still, and no current allowed in the nose, by suspending the breathing through that organ, the strongest smells will make no impression. In some animals the sense of smell is acute and powerful, beyond the conception of human beings; thus a dog, by the acuteness of this sense, will distinguish the footsteps of his master amid those of a hundred other people, and can thus trace him for miles, although he has been a long while out of sight; pointers also scent game at a great distance. On the other hand, this sense seems entirely denied to many of the lower animals.

Taste.—The sense of taste is nearly allied to that of smell. The nerves of taste are spread over the upper surface of the tongue, and are raised up in innumerable small points or *papillæ*, like the pile of velvet. No other part of the mouth is endowed with the property of tasting except the tongue, as may be proved by touching any part of it with a piece of salt or sugar, when no sensation of taste will be communicated until the tongue has come in contact with the part so touched. That the taste or flavour of many bodies is heightened by the accompanying effects on the organ of smell, is evident; because, if the nose is stopped up so as to prevent the exercise of its functions, many substances having different flavours will taste alike. This is the case with the various kinds of wines, but especially with the ardent spirits. The tongue and whole cavity of the mouth and throat are kept moist by the saliva, or spittle, which continually flows into them from repositories placed around the cheeks and under the tongue, called salivary glands, which communicate with the mouth by means of small ducts. This saliva flows in greatest quantity during meals, and may even be excited by the sight of food when the appetite is good. It is of essential service in moistening the food, and preparing it for the process of digestion in the stomach. The sensation of taste is in all probability diffused among every class of beings, however low in the scale of existence, although it is probable many animals possess little of it in their mouths, especially when these are formed of hard horny substances, as in many insects, in the lobster, crab, &c. and where any organ corresponding to a tongue is wanting.

Touch.—The sensation of touch is diffused more or less over every part of the body, but is most perfect at the points of the fingers, which in man are generally used to examine the figure and texture of bodies. For this purpose they are furnished with a large supply of very minute blood-vessels and nerves. It would appear that there are different nerves that convey the sensation of touch, distinct from those which are the nerves of motion; and that these proceed in pairs from the spinal marrow; and that, moreover, the sensation of heat or cold may be perceived very distinctly, in cases where the pricking of a needle or contact of other bodies is never felt. The sense of touch may be said to belong to every animated being, and is one great characteristic of animal life. Vegetables possess a peculiar kind of vitality, and show what is called irritability of their fibres; but they have no sensation, properly so called. It is probable, however, that sensation is not by any means equally acute in all animals; some feel more intensely than others; and it is a happy provision of nature that it should be so. The lower insects and reptiles, from their structure and habits, are continually exposed to injury; and did they feel it as acutely as the larger animals, the degree of animal suffering throughout nature would be excessive. Many animals bear the loss of limbs with impunity, and some have even the power of restoring those lost members in a very short time. It is probable that, according to the perfection of the nervous system, is the acuteness of animal sensation.

On thus reviewing the different parts of the human body, it will be observed that most of its organs are double. On a line being drawn in the middle, on each side will be found parts which are exactly similar to the corresponding side. This is the case with the brain, which is a double organ, having two series of nerves proceeding out from each side of it to go to the respective sides of the body. There are two eyes also, each reflecting a distinct image on the retina; yet the nerves communicate so that only one impression is conveyed to the sense. The arms are double, to suit the various purposes for which they are employed, and so are the lower limbs an essential requisite for the support of the body, and for progressive motion. The lungs, too, may be said to be double, having two distinct lobes; and it sometimes happens that one of them is entirely shrunk or diseased, and yet the important office of respiration is still carried on. The stomach, the liver, and some of the other viscera of the abdomen, are, however, single, their several offices being common to the whole body.

THE HAIR AND NAILS.

The hair grows out from the skin somewhat in the manner of a vegetable production. Hairs are fixed by roots in the skin, from whence, by a series of minute vessels, they draw nourishment, and continually increase in length. They possess no sensibility, however; and, unlike the other parts of the frame, may be cut off without producing the least pain. Hair is of different colours in different individuals—is fair in those of light complexion, and deep black in the swarthy. As old age approaches, and even in many young persons, where there is a particular disease in the hair, or dryness in the skin, this colour changes to grey and white. The colouring matter of the hair is contained in the centre, which is of a hollow form, and consists of an oily substance, in which carbon or charcoal, in minute particles, is more or less mingled. The nails are somewhat like hair in their production and composition; they are, like hairs, insensible to the touch, and may be cut or pared without producing pain. They receive nourishment from the blood-vessels of the extremities, and have a constant growth or renewal of their substance. Nails serve as a defence to the tender parts of the fingers; in animals they form formidable weapons of attack. The horns of cattle are exactly of the same nature as nails, and are chiefly composed of animal gelatine.

The manner in which the various secretions take place in the system, that are to form hair, nails, wax for the ears, blood, perspiration, &c., cannot but excite our admiration; for the whole is a chemical process of the most perfect kind, and such as art possesses no power to imitate.

THE SKIN.

An external compact membrane or skin covers the whole body. The outer skin, or cuticle, is unprovided with any blood-vessels or nerves, and consequently is insensible; in this manner it is well suited for a protection to the parts beneath; it is pierced by innumerable minute pores, which are the mouths of the exhalant vessels: it is thicker in the palms of the hand and soles of the feet than in any other parts of the body. Below the outer skin is a thin membrane, called the *rete mucosum*, which, assuming different hues in different nations, gives rise to the variety of colour in the human race. Some have held this membrane to be double, but this is not established. In Europeans it is white, passing into yellowish brown; in native Americans, of a copper colour; in Negroes, of a deep black. The common belief is, that climate has the effect of modifying the colour of the skin, as the black skin only occurs in tropical regions, and it is found that there it is a protection against the scorching influence of the sun's rays. Negroes will remain cool and comfortable exposed to a sun which would be intolerable to a white-skinned person. Their free perspiration seems to be of great service. Immediately below this network is the *cutis*, or true skin, an extremely sensible membrane, so thickly studded with minute blood-vessels and branches of nerves, that the smallest-pointed needle cannot prick it without touching many of them. On the points of the fingers, lips, and other parts of the body, these vessels are very numerous; and hence these parts are endowed with exquisite feelings of touch. Below the skin is situated the cellular membrane, which is a network, whose interstices are filled with fat, and it thus serves to fill up the spaces between the muscles, and to make up the shape, and preserve the symmetry, plumpness, and beauty of the whole frame. In cases of emaciation, this fatty matter is sometimes entirely taken up by the absorbent vessels—as after a tedious fever or other lingering disease—when the rough outlines and indentations of the muscles, and the projections of the bones, become painfully apparent.

SLEEP.

The various functions of the body are divided into voluntary and involuntary. When we eat we perform a voluntary motion, but digestion is performed without the action of the will, or is involuntary. The whole interior functional operations are involuntary, and go on whether we are awake or sleeping.

As a constant supply of food is necessary to repair the waste of the grosser parts of the body, so sleep is essential for the repose and renovation of the finer and more subtile nervous energy. Mere rest alone will not recruit the animal frame, but sleep, or a profound oblivion of feeling and sensation, and of every external circumstance, seems essentially necessary at every periodical revolution of the day. Toward the close of a day of exertion, the muscular powers which have been employed in motion, and in sustaining the body erect, begin to suffer particularly; the eyes become dim and heavy, and the eyelids close involuntarily; the lower jaw falls down; the circulation of the blood through the lungs is sluggish, hence frequent yawning is caused; the head nods forwards; all external objects affect us less and less; the thoughts become confused; and at last the profound oblivion of sleep ensues. We are unconscious of the exact moment when we pass into sleep, but occasionally it happens that immediately afterwards we are awaked by a convulsive start, which is caused by the sudden breaking in of the powers of volition, when as yet but newly and imperfectly lulled to rest. Sleep is quite essential to existence. Deprive a person of sleep, and the body sinks under the privation more rapidly than under famine. Indeed, no circumstances, however urgent, will prevent the approaches of sleep for any length of time; and under the severest calamities, and even while in the hour of battle, or when suffering from extreme fatigue, or cold, or hunger, sleep steals upon us to steep the senses in oblivion. Healthy sleep is so profound as to resemble, in all that regards self-consciousness, death itself. Sometimes, however, the mind exerts its activity, though it is but a partial exertion; and hence dreams, or thoughts of sleep, are made up of all incongruous associations, such as thoughts of the past day and incidents of long bygone years; scenes of actual experience, and others totally imaginary, being all mixed up and jumbled together. In sleep the heart continues to beat with regularity, and the circulation of the blood is carried on throughout the body; the lungs perform their functions, the stomach digests, and the bowels, and all the glands for secretion, carry on their operations; in short, every thing is carried on connected with the sustenance of the body and the existence of the vital powers; but for the most part all other powers, such as those over which we have a control in our waking hours, are at rest. This is not always the case, however, as walking during sleep, or somnambulism, is a peculiarity to which some individuals are liable. Dreams are most common when the sleep is imperfect or too long continued, and thus they occur frequently towards morning, or through the night, if the stomach is loaded and oppressed with food, or the mind harassed and deeply impressed with cares and solicitudes. In a state of health and serenity of spirits, the most profound and most refreshing sleep is during the first period of the night. When asleep, the circulation and breathing are both somewhat slower than when awake, hence the animal heat becomes diminished; and this is the reason why more clothing is required in bed than during the day. This is the reason, too, why a person lying down to sleep out of doors, or on a sofa, with the usual allowance of clothes, feels chill and uncomfortable on awaking. Digestion, too, would appear to go on less vigorously during sleep; and hence the impropriety of going to bed with a full stomach. During the night and darkness is the most natural and obvious time to select for repose, and it is only the absurd encroachments of fashion that have well nigh turned day into night. By going early to bed, the damps and colds of night are avoided, which is of essential consequence, especially for the delicate. There is also a natural connexion of the functions of the body with the periods of day and night, which makes sleep taken in the first part of the night peculiarly refreshing. The absence of every irritation of the head and other parts of the body—the perfect rest of the mind and external senses—have also great influence in promoting sleep. Again, a variety of causes which weaken and debilitate the body, incline to sleep; such as great losses of blood, cooling medicines, purgatives, coldness of the atmosphere; and narcotics, such as opium and tobacco, drinking largely of wine or spirituous liquors, by first causing great excitement, and afterwards a corresponding debility of the system, also predispose to profound and lethargic sleep. Injuries of the head, by pressing on or otherwise interrupting the functions of the brain, also induce sleep; and great corpulency, by retarding the return of blood through the veins, and thus keeping up a pressure upon the head, is generally accompanied by a disposition to sleepiness.

The period required for sleep, by different individuals, depends much upon temperament and peculiarities of constitution, as well as on mode of life and habit. While some cannot sleep beyond five, six, or seven hours, others, again, cannot well do with less than eight or nine hours. Children sleep more than half of their time, and require it, and thrive under it; while adults need much less repose. On a general average, eight hours has been reckoned a good allowance. Certainly sleep beyond this does no good, and often does harm. In order to enjoy grateful and uninterrupted sleep, it is necessary that due exercise shall have been taken during the day; that temperance in food and drink shall have been observed; that strong tea or coffee, which have a stimulating effect on the system, shall not have been taken within an hour or two of going to bed; and that there has been no supper, or a light one. It is true, gluttony and intoxication produce sometimes deep sleep, but it approaches more to an apoplectic stupor than the calm repose of the temperate.

THE SEXES.

In almost all animals the sexes are distinguished by a difference of form and texture of their bodies; and in many a superior gloss of colour in the hair or fur, or a superior brilliancy of the plumage, very generally characterises the male of the species. In most animals, too, the males are of superior size, and endowed with greater muscular strength. In the human species man is marked by a larger and more muscular body than the female; his chest is square and capacious, and particularly at the shoulders, whence it tapers gradually downwards; his bones are large, and his joints firm and sinewy; his muscles are round, tense, and conspicuously marked; his limbs thick and fleshy, and his arms powerful; his skin is firm and tense, and his hair strong, crisp, and often curly. The female figure, again, is smaller, less powerful, and, in every respect, more delicately formed; the bones are less projecting, the muscles softer, less conspicuous, and more smoothly blended one into the other; the shoulders are narrow and rounded; the greatest breadth of the body being at the pelvis, from whence it gradually tapers upwards; the skin is soft and delicate; the hair smooth, and of a silken appearance. The mental qualities and dispositions differ somewhat also. Man is commanding, resolute, daring, adventurous, addicted to deep and abstract thought, as well as to high and imaginative speculations. Woman is gentle, submissive, timid; with a mind, perhaps, little inferior in compass to man, she is more commonly distinguished for acute penetration, nice and delicate discrimination, refined and chastened taste, and elegant and playful fancy. It was the opinion of Plato, that, with regard to the mind, there is no natural difference between the sexes, but in point of strength. "When the entire sexes are compared together," says he, "the female is doubtless the inferior; but in individuals, the woman has often the advantage of the man." With warm and tender attachments, pure morals, and high religious feelings, she is admirably calculated for the sacred charge of watching over and training up the young, and of instilling into their tender and susceptible minds the beautiful lessons of early wisdom—of faith, truth, and charity. All nations, as they have advanced in civilisation, have uniformly increased in that respect and refined attention which is due to the softer sex; and one of the most powerful minds and of the most splendid endowments has been the foremost to appreciate those superior qualities which are to be found in a gentle and unsophisticated female. The late Professor Dugald Stewart thus introduces a quotation from a well-known traveller, which affords a just and beautiful estimate of the tender disposition of woman:—"From the greater delicacy of their frame, and from the numerous ailments connected with their temperament, combined with their constant familiarity with distresses which are not their own, the sympathy of women with the sufferings of others is much more lively, and their promptitude to administer relief, wherever it is possible, is much more eager than in the generality of men. To the truth of this remark every day's experience bears witness; and, from the testimony of travellers, it appears that the observation extends to women in all the different stages of society."

TEMPERAMENTS.

There are certain conditions of the bodily frame which evidently give rise to varieties of the human constitution, and which have been called temperaments. These have been peculiarly the object of attention to Dr Spurzheim, and others of the phrenological philosophers. As their views on this subject seem to us of a very clear order, a passage is here extracted from one of the journals devoted to that science. "Dr Spurzheim," says the journalist, "recognises four primary or cardinal temperaments, to which he considers all individual cases may be advantageously referred, either as pure, or much more frequently as consisting of two or more combined. I shall first give Dr Spurzheim's brief description of them, and shall afterwards enlarge upon each in detail.

1. 'The lymphatic, or phlegmatic temperament, is indicated by a pale white skin, fair hair, roundness of form, and repletion of the cellular tissue; the flesh is soft, the vital actions are languid, the pulse is feeble, and the whole frame indicates slowness and weakness in the vegetative, affective, and intellectual functions.

2. The sanguine temperament is proclaimed by a tolerable consistency of flesh, moderate plumpness of parts, light or chestnut hair, blue eyes, great activity of the arterial system, a strong, full, and frequent pulse, and an animated countenance: persons thus constituted are easily affected by external impressions, and possess greater energy than those of the former temperament.

3. The bilious temperament is characterised by black or dark hair, yellowish or brown skin, black eyes, moderately full but firm muscles, and harshly-expressed forms. Those endowed with this constitution have a strongly-marked and decided expression of countenance; they manifest great general activity and functional energy.

4. The external signs of the nervous temperament are fine thin hair, often inclining to curl, delicate health, general emaciation, and smallness of the muscles, rapidity in the muscular actions, vivacity in the sensations. The nervous system of individuals so constituted preponderates extremely, and they exhibit great nervous sensibility.'

The pure lymphatic temperament is characterised by a pallid complexion, soft skin, mostly free from hairs, the hair flaxen, the pulse weak and low; a general tendency to corpulence, and a deficiency of expression in the face. Instances of pure lymphatic temperament are more rare than of either of the others, and perhaps are never to be found, except amongst females and habitual invalids, when past middle age, who, from the want of exercise, have lost all trace of some other temperament which they may have possessed in youth. The mental characteristics of the lymphatic temperament are soon told; an insurmountable tendency to indolence, an aversion to exertion of either body or mind, form the hopeful traits. It is, therefore, obvious that the restraining faculties, Cautiousness and (in some of its manifestations) Secretiveness, are the only organs with the operation of which it will correspond; while all the other propensities, and the intellectual faculties, will be enervated and restrained by it.

It has been generally supposed that the sanguine constitution is produced by the perfection or redundancy of the circulatory system; and it seems such a natural supposition, that it is difficult for us to allow its proper force to the fact, that individuals of other temperaments are frequently found who can bear loss of blood, by phlebotomy or otherwise, as well as those of sanguine constitutions, and in many instances much better. There is, however, one anatomical peculiarity which appears always to attend the sanguine. The skin is much less disposed to transpiration than the bilious or nervous; and, in consequence, Dr Prichard, in a work lately published, considers that individuals possessing it are much better calculated to bear cold than others. The Fins, who, as a nation, are decidedly sanguine, bear extraordinarily cold winters much better than their more bilious neighbours the Laplanders. Dr Prichard adds, that as the sanguine temperament is very rare in those warmer countries, near the spot where man was first placed by his Creator, he considers the sanguine temperament as the result of a natural adaptation to external circumstances, analogous to the white hares and other animals of northern regions; but, if this is the case, it is difficult to imagine how it is that Laplanders should continue tawny, while the Fins, situated farther south, are fair. The most striking moral feature of the sanguine temperament appears to be a tendency to enjoyment of the present time, with little inclination to regret the past or to dread the future; and, in general, to look at either past or future no more than is necessary to happiness. The bilious temperament is characterised by a decided cast of features, complexion inclining to brown, dark eyes, and black or dark brown hair, with the muscles firm and well marked, and the figure, in general, expressive of vigour, with every motion significant and decided. In combination, it is frequently traced in a slight yellowness of the skin, which can only be detected by comparison, or an extraordinary acute perception of colours; for example, you may frequently find two persons, particularly ladies, the one with dark hair and eyes, the other with flaxen hair and blue eyes. The complexions of both would be denominated fair; on observing them near each other, however, it will be seen that the fairness of the dark-haired one differs considerably from the clear snowy whiteness of the sanguine.

With respect to the nervous temperament, it manifests itself in a remarkable quickness to learn and readiness of comprehension, but little tendency to sensual gratification, and an extraordinary power of passing from one subject to another."

MAN ADAPTED TO LIVE IN ALL CLIMATES.

Man has this superiority over other animals, that he can inhabit almost every region of the globe, and there exhibit a greater or less degree of civilisation. He is found under the scorching sun and amid the arid plains of Africa, as well as in the frost-bound regions of Spitzbergen; and not only is he found to endure under these extremes, after a gradual naturalisation of ages, but he can even move from one country to another, and undergo a vicissitude of climate with comparative impunity. Thus we see, even from our own country, emigrants going forth, and naturalising themselves amid the cold regions of the north, onward to the very verge of the equator. The Esquimaux and the Canadian savage will prosecute their usual employments of the chase in a temperature where mercury freezes into a solid mass, and where even brandy congeals to ice in apartments containing fires; while the African negro, again, feels quite at his ease in a burning climate, where the thermometer in the shade ranges from 90° to 100°, and upwards. Man has an equal facility in adapting himself to the pressure of the atmosphere attendant on low or elevated situations. In Mexico, he is found living in elevated regions, from 6000 to 8000 feet above the level of the sea; and the hamlet of Antisana, in Quito, is 13,500 feet above the level of the ocean. On the contrary, we find almost all animals only adapted to live in the regions in which they are naturally found; and if they are removed from such localities, they seldom enjoy the natural period of their lives. Even the dog and the horse, the domesticated companions of man, degenerate and change their natures under extreme varieties of temperature; and the monkey tribe, which, in the structure of their bodies and in the substances on which they feed, approach the nearest to man, become sickly and diseased, and never propagate their species, when removed into any of the colder regions of the globe. In order to enable man thus to subsist in regions having such a diversity of natural productions, he is endowed with the power of feeding on and digesting every possible variety of food—he is, as compared to other animals, in respect to diet, omnivorous. We thus find the Greenlanders and inhabitants of frozen regions living almost exclusively on the fat and flesh of land and sea animals, the only species of food which the barren and ungenial nature of the climate affords, but one, nevertheless, which, from its stimulating and nourishing nature, is the very best for enabling them to live under such an extreme depression of temperature. The inhabitants of hot countries, again, will be found living on rice, fruits, and other vegetable substances, which the warm and genial soil produces in abundance, and which, from their nature, are less heating and stimulating than an animal diet. In the intermediate and temperate regions, a mixed diet of animal and vegetable food is preferred. Much discussion has arisen whether man be more a flesh-feeding or herb-eating animal; experience demonstrates that he is equally adapted to become both—that he will live on an almost purely animal diet, as well as on one purely vegetable; although, were we strictly to compare the form of his jaws and teeth, and the general structure of his intestines, with those animals that live on nuts and other fruits, and farinaceous or mealy substances, as, for instance, the monkeys, the near approach of these to the human structure would indicate to us that at all events a farinaceous diet is the most suitable to his natural organisation. We thus find among all civilised nations that bread, and the grains and mealy roots, in some shape or other, have always a preponderance in every meal. But the art of cooking, which man resorts to even in the first dawnings of civilisation, enables him to change the nature of his various food, and to render it more suitable both for digestion and the purposes of nourishment, and thus gives him a wonderful superiority over all the rest of the animated world. Indeed, it is by this improved mode of preparing his food, perhaps, as much as by original strength and perfection of frame, joined to the other comforts of civilisation, that he is enabled to brave the vicissitudes of climate, and to prolong his life to a longer period than the great majority of other animals.

Man has been formed with a naked skin, with the evident intention that he should clothe himself by his own labour and ingenuity. Almost all the larger and more perfect animals have a covering of hair, of feathers, or of down, which is at stated periods renewed, and in some animals in greater length and abundance at particular seasons, to suit the variations of temperature. But man can always adapt his clothing to the climate he inhabits, or to the varying alterations of the seasons; and he can at all times, by his own industry, vary or renew his suits. Man, too, builds for himself a comfortable habitation, to protect him from the inclemency of the weather, and is not contented with a burrow under ground, or the casual shelter of the woods and coppices, as is the case with the animals of the forests. It is true the architecture of bees, and some other animals, is curious, ingeniously combined, and admirably suited to their necessities; but in comparative taste, splendour, or even convenience, how far are all these surpassed by the houses, and temples, and cities of mankind! Though man is naturally defenceless and unarmed, how soon does his ingenuity enable him to obtain a mastery over the beasts of the field and forest, and furnish him with weapons of defence against all his enemies! How soon does his ingenuity enable him to improve and cultivate the soil—to drain marshes, cut down woods, level mountains—to select and cultivate the best species of grain, and the most wholesome and nourishing vegetables, for food—to invent tools and engines, by which he acquires a command over the sea and land, by which he erects bridges, constructs machinery, and launches the towering vessel upon the wide ocean! And, lastly, with what skill he constructs instruments of art and of science, by which he can examine and investigate the most minute objects of nature, as well as bring within his sphere of observation the distant worlds and systems of the universe!

INFANCY—MATURITY.

At the moment of birth, the infant begins to exercise an independent existence, whereas before it formed a part, and was nourished by the vessels of its parent. A general similarity takes place in the embryo growth of most animals, and the familiar instance of the chick in the egg may be taken as an example. The egg is composed of a centre part or yolk, and of the albumen, or white part surrounding it. In this white part, a small darker speck may be seen floating, from whence the first rudiments of the chick are derived. In a few days after the hen has sat on the egg to impart to it the necessary heat, a small whitish spot will be observed, which is the first rudiments of a brain; in a few days more, vessels will be seen spreading out from a central heart, and forming a network all around; gradually an appearance of a head is seen, with indications of brain and spinal marrow; the eyeballs next are formed, then the several parts of the viscera, the projections of the wings and legs, and lastly, the skin and rudiments of the future feathers. During these periods of incubation, the chick has been nourished by the yolk of the egg, which has gradually been absorbed by its vessels for this purpose. At last, when its growth is perfected, and the whole contents of the egg converted into the materials of its body, the little animal begins to pick a hole in the shell, and, by repeated efforts, bursts from its shelly prison, and assumes an independent life.

The infancy of man is of much longer duration, and of a much more helpless nature, than the same state in other animals. A child cannot walk till it is at least twelve months old; and even for a considerable time after that period, it has to be fed and tended with the utmost care; whereas, after a very short time, the young of most animals are able to provide for themselves. A great many, a few minutes after birth, are able to walk about, to search for and distinguish the teat of their mother, and to pick up the food that is suitable for them: and having remained under their maternal protection for a short space, they leave their parents, and never know or distinguish them more. It is very different with the infant: during a long and helpless period of childhood, it is tended by a fond mother, who anticipates all its wants; while it, on the other hand, watches her smiles, and imitates her most minute actions; and thus a reciprocal bond of union is established, by which not only every species of knowledge and experience is acquired for the conduct of after life, but those moral feelings and sympathies implanted which constitute the great boast and solace of human society.

Man proceeds from infancy to maturity by a slower and more gradual expansion of the bodily structure than any other animal; and this may be one reason of his superior organisation, his greater fitness for supporting labour and fatigue, and the longer period to which his life is extended. From infancy, upwards, the mental powers also gradually expand. This is also different from animals; for in them the faculty of instinct at once is perfected, and never afterwards increases or undergoes any change. In childhood, the mental faculties are constantly active, and on the alert to catch new information, inquisitive to know everything, and imitate every gesture. The facility with which children acquire the knowledge of words, and in a few months master a language, is very astonishing, when we reflect for a moment how much time and pains it takes a grown-up person to become a proficient in any unknown language: and our astonishment will be heightened when we consider that, in the case of children, they have not only to acquire the words and their proper applications, but even to master the articulation of sounds, with all their infinite combinations.

The age of puberty, or that period when boyhood terminates, and manhood commences, varies somewhat in different climates, according to their high or low temperature; the mean period may be reckoned about fourteen years; and between twenty and twenty-five, the growth of the body generally terminates.

About the age of thirty, man may be said to be in his full vigour, with his mental and bodily powers completely developed. Females arrive earlier at a state of maturity than males: in warm climates they are full grown as early as their tenth or twelfth year; in more temperate regions, about their fifteenth or eighteenth year. The proportion of male children born to that of females is as 21 to 20; there is thus a small superabundance of males; but, from various causes, it so happens that there is generally rather a superabundance of females actually existing in society. Among these causes may be mentioned the greater hardships and labours to which men are exposed, the effects of war, and, on the whole, the longer life enjoyed by females. This regular proportion of male and female births throughout mankind in all ages, and in all parts of the world, shows the admirable design and precision of an unerring nature.

OLD AGE—DECAY.

We have seen that there is, within the animal frame, a system of operations by which a constant supply of nourishment is afforded to make up for the daily waste and decay, and that every part is constantly undergoing a renewal. To view a man in the full vigour of life, then, we might suppose that, excepting accidents, he was calculated to go on, in the course of existence, for an indefinite period. The principle of life, however, seems to have limits set to its duration, beyond which it fails to keep in healthy motion the animal faculties. The apparatus of life is evidently destined but to last for a certain time. Old age creeps on apace, and the vital flame burns fainter and fainter, till at last it sinks in the socket, and is seen no more. The commencement of decay is perceptible even in youth itself. The child at first grows quickly, from the soft and yielding state of all its vessels; but gradually these begin to thicken and get harder—a greater proportion of earthy matter is adding to the bones. The extremities grow large, while the heart itself does not increase in an equal degree; hence the circulation becomes less and less quick, till the period of full growth. When the growth of the body can proceed no farther, a degree of fatness not unfrequently occurs. This proceeds from the superabundant nourishment produced from the food, which, from the impetus or force of the circulation being more lessened by the greater extension and resistance of the body, accumulates in the cellular textures and by the sides of the extreme vessels. In every part of the body, the induration produced by approaching age becomes conspicuous—in the bones now wholly brittle, in the skin, in the tendons, in the glands, in the arteries, and in the brain itself, which gets firmer and drier. Moreover, the arteries continue to get denser, narrower, and even shut up in their minute branches. At the same time the nerves become more and more callous and insensible to the impressions of the senses, and the muscles to irritation; thus the contractile force of the heart, and the frequency of its pulsations, are diminished, and consequently every force which impels the blood into the ultimate vessels. The quality of humours is diminished in the denser body; the moisture which lubricates the solid parts everywhere manifestly decreases. Nor is the quantity of humours only diminished; they themselves likewise become vitiated. They were mild and bland in children; they are now acrid, salt, and fetid, and loaded with a great quantity of earthy matter. This circumstance of the superabundance of earthy matter is evident in the gouty concretions in the joints of old people, in the frequency of stone, and in the arterial tubes, and even the heart itself, being frequently converted into real bone. The rigidity of the whole body, the decrease of the muscular powers, and the diminution of the juices, constitute old age, which sooner or later comes upon all men—sooner, if subjected to violent labour, or addicted to pleasure, or fed upon a too scanty or unwholesome diet; but more slowly, if they have lived quietly and temperately, or if they have removed from a cold to a moderately warm climate.

There are three obvious divisions of human life—a period of youth, including the period before the age of 30; of maturity, from 30 to 50; and of old age, commencing about the period of 50 or 60. The Psalmist speaks of the age of man being, in his time, only threescore years and ten, or in rare cases fourscore years, which may be reckoned the average limit of human existence. After the period of 50 or 60 years, varying of course in different constitutions, the marks of old age begin to make their appearance. The skin becomes more lean and shrivelled; the hair changes to a gray colour, or baldness occurs; the teeth drop out, and in consequence of this, the lower parts of the face, about the mouth and jaws, incline inwards; the muscular motions of the body become less free and elastic—this is especially seen in walking, old people generally treading on the whole base of the feet, and hence having a shuffling gait; the blood circulates slowly; the animal heat is diminished; the pulse occasionally intermits, and the whole energies of the animal frame become lessened; the eyesight begins to fail, and dulness gradually comes over all the senses; the memory undergoes a remarkable change—while recent events pass through the mind and make no impression, the occurrences of early life continually suggest themselves, and are minutely called to remembrance.

Although seventy years is usually the extreme duration of human life, yet a small proportion of those born ever reach even this; a few rare instances occur where one hundred years or upwards are attained. The famous Parr lived to the age of 152 years; he married at the age of 120, and, when 130, was able to thrash, and to do every description of farmers' work. He was at last brought from the pure air and the homely diet of the country into the family of the Earl of Arundel, in London, where he drank wine and lived luxuriously. The sudden change of diet and circumstances, however, proved quickly fatal to him. Henry Jenkins, another poor man, lived to the astonishing age of 169 years, and retained his faculties entire. Some time ago, a statement appeared of the ages of the resident pensioners of Greenwich Hospital, which contained at the time 2410 inmates. Of this number, 96 had attained to or passed the age of 80; one only was above 100; 15 were 90 or more; and 60 were 80 or upwards. About 42 of the 96 were of aged families, and in some of this number both parents had been aged. Longevity has in a great number of cases been found to be hereditary. Eighty of the 96 had been married; 79 were in the habit of using tobacco in some form or other, and 48 had drunk freely; 29 were entirely without teeth; 52 had bad, and 14 good teeth. But the oldest man in the house, who was 102, had four new front teeth within the five preceding years. The sight was impaired in about one half, and hearing only in about a fifth part of the number.

Old people are not generally inclined for much exercise, nor is it suited to their stiff joints and impaired vigour; for the same reason, they cannot endure much cold. Cheerful company, especially the company of the young, is peculiarly grateful to old people. Innocent amusements and recreations are also of great consequence, and the mind should be exercised in some useful or amusing pursuit. Cities, or at all events constant and agreeable society, are favourable to the condition of old age. In lonely secluded country places, the mind sinks prematurely into a total gloom and blank, for want of sufficient stimulus and variety to keep up the vigour of thought and play of ideas. Few deaths occur from what is commonly called old age, or a gradual and simultaneous decay of all the functions. It may be said to happen when the powers gradually decay, first of the voluntary muscles, then of the vital muscles, and lastly of the heart itself; so that, in an advanced age, life ceases through mere weakness rather than through the oppression of any disease. The heart becomes unable to propel the blood to the extreme parts of the body; the pulse and heat desert the feet and hands, yet the blood continues to be sent from the heart into those arteries nearest to it, and to be carried back from them. Most commonly, however, some one part gives way, and disease gradually coming on, cuts off the lingering flame of existence. Thus the body, after having grown up to maturity, and flourished in its prime, sinks to the earth, and moulders into the elements of which its several parts are composed.

CONCLUSION.

The admirable structure of the body of the human being—its superiority in every respect to that of the lower animals—afford a most perfect proof of design in the all-wise Creator, and is one of the most striking instances of the impossibility of our formation being the result of blind chance. Paley, after going over a great number of examples of this kind of design in a Creator, proceeds to state that, in all "instances wherein the mind feels itself in danger of being confounded by variety, it is sure to rest upon a few strong points, or perhaps upon a single instance. Amongst a multitude of proofs, it is one that does the business. If we observe in any argument," he continues, "that hardly two minds fix upon the same instance, the diversity of choice shows the strength of the argument, because it shows the number and competition of the examples. There is no subject in which the tendency to dwell upon select or single topics is so usual, because there is no subject of which, in its full extent, the latitude is so great, as that of natural history applied to the proof of an intelligent Creator. Perhaps the most remarkable instances of mechanism in the human frame are—the pivot upon which the head turns, the ligament within the socket of the hip-joint, the pulley or trochlear muscles of the eye, the epiglottis, the bandages which tie down the tendons of the wrist and instep, the slit or perforated muscles at the hands and feet, the knitting of the intestines to the mesentery, the course of the chyle into the blood, and the constitution of the sexes as extended throughout the whole of the animal creation. To these instances the reader's memory will go back, as they are severally set forth in their places; there is not one of the number which I do not think decisive; not one which is not strictly mechanical; nor have I read or heard of any solution of these appearances, which in the smallest degree shakes the conclusion that we build upon them.

"The works of nature require only to be contemplated. When contemplated, they must ever astonish by their greatness; for, of the vast scale of operation through which our discoveries carry us, at one end we see an intelligent Power arranging planetary systems, and, at the other, concerting and providing an appropriate mechanism for the clasping and reclasping of the filaments of the feather of the humming-bird. We have proof not only of both these works proceeding from an intelligent agent, but of their proceeding from the same agent; for, in the first place, we can trace an identity of plan, a connection of system, from Saturn to our own globe; and, when arrived upon our globe, we can, in the second place, pursue the connection through all the organized, especially the animated, bodies which it supports. We can observe marks of a common relation, as well to one another as to the elements of which their habitation is composed. Therefore one mind hath planned, or at least hath prescribed, a general plan for all these productions. One Being has been concerned in all."

ZOOLOGY.

ZOOLOGY is that branch of Natural History which treats of the beings composing the *Animal* Kingdom. The life of every animal presents to intelligent observation a number of facts, which may be considered individually or in groups, according to their nature and character. Thus we might consider *structure* alone—that is, the animal body as composed of bones, muscles, blood-vessels, &c.—the department of science which is termed ANATOMY; or we might examine the *actions* and *functions* of these organs—in fact, the history of the living being—which is termed ANIMAL PHYSIOLOGY. In pursuing either of these, we might restrict our inquiries to a single animal, though, from the evident relationship of all animated existence, it would be highly disadvantageous to do so; but in SYSTEMATIC ZOOLOGY, the purpose is altogether different. It discovers that the several beings included in the Animal Kingdom may be regarded not only in their individual aspect, but in their relations to each other; that they form parts of one great plan, as harmonious in itself as that of a beautiful building made up of a vast number of subordinate parts; and that whilst the diversities of form and aspect seem almost infinite, they are evidently subordinate to certain general principles, which produce not only the manifest conformity, but the apparent departures from it. The grand aim of the scientific zoologist being to discover this plan—the plan upon which Nature has proceeded in the creation of animal life—he employs *classification* as a means by which to facilitate his acquaintance with the vast number of beings that claim his attention.

CLASSIFICATION.

On looking at the variety of animal forms around us, the mind naturally associates together those which have the greatest general resemblance, and separates these (although differing in some degree amongst themselves) from those with which they have greater dissimilarity. It is by pursuing this plan, from one stage or degree of resemblance and difference to another, that classifications are formed; and these will be correct according to the amount of knowledge upon which they are founded, respecting not only the external form, but the internal structure of the objects they include. At one time it was customary to divide animals into five classes—*beasts, birds, fishes, reptiles, and insects;* but the investigations of Cuvier and other modern naturalists have shown that this is an imperfect arrangement, though the most easily recognised by the uninstructed observer.

Experience teaches that the offspring of any kind of animal is similar to its parents, though slight variations may be often traced between them. A succession of beings having this general conformity is called a *race*. Now, the first object which the naturalist has to determine is, whether two races—such as the Negro and European races of man, or any two breeds of dogs—*might have* had a common origin. If he finds reason to believe that their differences are not greater than may be accounted for by the influence of accidental causes, and especially if he finds one race never producing the form of another, he considers them as springing originally from a common stock, and as of one *species;* but if he cannot thus account for their differences, he regards them as of different species. This division of all existing animal forms into species, is that on which the naturalist has to found his subsequent classification; and it is necessary to take great care to avoid errors arising from variations in the forms of animals at different periods of their existence. Thus the tadpole and the frog, the caterpillar and butterfly, would be referred not only to different species, but to different classes, were we not aware that they are only different states of the same animal; and many birds have been erroneously regarded as of distinct species, which belonged to the same, but presented varieties of plumage, depending upon age, sex, and period of the year. Again, in the dog and other domesticated animals, the difference between *breeds* is so great, that the naturalist would unquestionably rank them as distinct species, were he not induced to believe by other evidence that they had all a common origin. A number of species, differing from each other in trivial points, but having a strong general resemblance, are said to belong to one *genus*. The genera most nearly allied are united into one *family;* several families into an *order;* and several orders into a *class*. The class, therefore, contains a very large number of species, many of them differing widely from each other, but all agreeing in some prominent and important character. The classes composing the Animal Kingdom are usually arranged under four groups, on account of their correspondence in certain general particulars, and their difference in others: these are called *sub-kingdoms*. The four sub-kingdoms, as defined by Cuvier, are—VERTEBRATA, ARTICULATA, MOLLUSCA, and RADIATA.

VERTEBRATA.

The Vertebrata derive their name, very appropriately, from a feature of their organisation specially connected with that superior intelligence which forms their leading characteristic. This is the internal skeleton, which, while it appears at first sight as only a frame for the support of the muscles, is in reality formed with a more immediate reference to the nervous system, of which the chief parts (brain and spinal marrow) are contained in the head and vertebral column. The Vertebrata have red blood, which is propelled through the system by a muscular heart. The animal powers of sensibility and spontaneous motion are highly developed in them; and in accordance with these, a complete symmetry or correspondence between the two sides of the body is observed externally. But this symmetry does not extend to the organs of vegetative life, which are irregularly disposed in the cavities which they occupy.

The Vertebrated animals are divided, again, into four *classes*, of very distinct character, and occupying different grades of organisation—the MAMMALIA, BIRDS, REPTILES, and FISHES.

CLASS I.—MAMMALIA.

The Mammalia (so called as possessing organs for suckling the young) are regarded as constituting the highest group in the Animal Kingdom; being gifted with the most complex organisation and highest intelligence. In subdividing them, it has been found that certain external features, as the teeth and forms of the extremities, are of special convenience for distinction, because these indicate in a great measure the habits and general character of the animal. This is a principle from which some remarkable results have arisen—Cuvier having determined the whole character of certain extinct species from seeing only a few teeth. In following it, however, naturalists must be admitted to have decided some points of classification in a manner which will not ultimately be approved of. One highly essential distinction of a different nature—the being born with a placental envelope or otherwise—separates the mass of the Mammalia from a group chiefly resident in Australia—the pouched animals, &c.—which are wanting in this peculiarity, besides being marked by some other conspicuous features of inferiority. The next great distinction is the possession of claws or hoofs, the latter being animals (*Ungulata*) of generally innocent character, which live upon vegetable food, hence provided only with cutting and flat-grinding teeth, while the former (*Unguiculata*) are carnivorous and destructive animals, possessing in their claws and sharp molar and canine teeth the means of catching and tearing their prey. A peculiar arrangement of the incisors for gnawing gives to a group of comparatively weak animals the name of Rodentia. Another group is distinguished by the want of fore-teeth. With these slight indications of Cuvier's principle for classifying the Mammalia, we proceed to consider the following orders into which the class is usually divided:—

1. Bimana.	5. Carnivora.	9. Pachydermata.
2. Quadrumana.	6. Cetacea.	10. Ruminantia.
3. Cheiroptera.	7. Rodentia.	11. Marsupialia.
4. Insectivora.	8. Edentata.	12. Monotremata.

I.—Bimana.

Man, the *two-handed animal*, is the sole species forming this order. Regarded as a member of the Animal Kingdom, he is distinguished by his erect position, thus leaving the two anterior extremities to be used solely for prehension, which is not the case in any other species. The hand of man is adapted to a far greater variety of purposes than that of the monkeys, to which it bears a resemblance. Its power consists chiefly in the size and strength of the thumb, which can have its tip brought into opposition with that of any of the fingers; and all these are capable of being moved separately. In none of the monkeys can the thumb be opposed to the fingers with any degree of force, and in many their tips cannot be brought into contact: so that, though admirably adapted for clinging round bodies of a certain size, such as the small branches of trees, their hands can neither seize very minute objects nor support large ones. To the hand of man some have attributed his superiority; but it may be safely said that he owes this to his mind and its instruments conjointly. The hand would be useless without the mind to direct it; and mankind, if handless, would soon be reduced to a very subordinate kind of existence, if not speedily extinguished altogether.

Possessed of so remarkable a means of executing that which his mental ingenuity devises, man is less provided, in regard both to acuteness of sensibility and to muscular power than many other Mammalia. His swiftness in running is inferior to that of other animals of his size. The smallness of his face, compared with that of the cranium, shows that the portion of the nervous system connected with the external senses is less developed in him than in most other creatures. Accordingly, he is surpassed by many in the acuteness of his sensibility to light, sound, &c. But he stands alone in the power of comparing his sensations and drawing conclusions from them. Moreover, although none of his senses are very acute in his natural state, they are all moderately so, which is not the case in the lower animals; and they are capable (as is also his swiftness of foot) of being much improved by practice, especially when circumstances strongly call for their exercise.

This improvability is one of the most remarkable characteristics of the bodily as well as the mental constitution of man. It is from a gradual advance in both that the civilised races now enjoy so much of comfort, and of means of still further elevation. In the processes by which these are attained, we observe a remarkable difference between the character of man and that of his fellow-creatures. The arts of which these are capable are limited, and peculiar to each species; and there seems to be no evidence of a power of invention, or of construction for any purpose, beyond that to which the original and instinctive powers are adapted. Hence it would appear that there is no proof of any species or race among the lower animals ever making an advance towards an improvement or an alteration in its condition; and where a particular adaptation of means to ends, of actions to circumstances, is made by an individual (as is often the case where a certain amount of intelligence or rationality exists), the rest do not seem in the least to profit by it.

Man is as much distinguished, then, from the lower animals, by his mental as by his corporeal endowments. Yet they are not of a *kind* altogether different from that which we may elsewhere see. In common with the inferior tribes, he possesses strong instinctive propensities, which are kept under control, however, in a well-balanced mind. But when the reasoning powers are undeveloped, as in early childhood and idiocy, the exclusive sway of the instincts is obvious. The more violent passions and emotions are nearly akin to these; and whilst they give great activity to the operations of the mind, it is requisite that they should be duly restrained by the intellect and will. This power of internal regulation is one of the most striking characteristics of the human mind above that of animals, which possess, like it, reasoning faculties, often to no mean extent, and are actuated by emotions and moral feelings. One of the most important aids to the use and development of the human mind, is the power of producing articulate sounds, or language; of which, as far as we know, man is the only animal in possession. There is no doubt that many other species have certain powers of communication amongst individuals; but these are probably very limited, and of a kind very different from a verbal language.

The more we study the physical and mental constitution of man, the more are we led to the belief, that it is in the adaptation of the whole to a great variety of circumstances that its great perfection consists. There seems scarcely any condition in which he cannot support himself. He is capable of sustaining the lowest as well as the highest extremes of temperature. His diet is naturally of a mixed kind; but he can support himself in health and strength on either animal or vegetable food exclusively. At the same time, it is by the demands which his peculiar condition makes upon the exercise of his ingenuity, that his mental powers are first called into active operation; and, when once aroused, their development has no assignable limit. [For a detailed inquiry into the characters of the different races of mankind, see PHYSICAL HISTORY OF MAN.]

II.—Quadrumana.

The order Quadrumana, which takes its name from the peculiar conformation of the extremities of the animals composing it—all four of them having one of the toes opposed to the rest, like the thumb of man to his fingers—are remarkable for their facility in climbing, which they gain by the *grasping* power conferred upon them by the possession of *four hands*. Their anatomical structure clearly shows that the upright position is not natural to them; and it is certain that, though they may be taught in a state of captivity to walk erect like men, they usually support themselves by their anterior as well as their posterior limbs. It may be observed that those species which approach the nearest to man rest upon the outer side of the foot only, and not upon its sole, when quitting his position; and that they are very insecure in it. And to those which are intermediate between the higher Quadrumana and the succeeding orders, the maintenance of the erect position without support for any length of time is impossible. It might be supposed that the possession of 'four hands' is a character which raises the animals possessing it above two-handed man; but a little reflection will show that this is not the case, since the hand even of the highest Quadrumana is very inferior to that of man in complexity of structure and in the variety of movement to which it is adapted, whilst that of the lower shows but a slight advance upon the foot of the Carnivora. A corresponding series of gradations may be traced in the aspect of the face; for whilst, at one end of the series, the muzzle (at least in the young animal) is not much more prominent than it is in some races of man, at the other it nearly resembles that of other Mammalia. Nevertheless, throughout the order, a certain degree of resemblance to man may be perceived in the gestures as well as in the general aspect of these animals. All of them, like man and the Carnivora, possess three sorts of teeth: the canines, in the full-grown animal, are much more developed than in man; and there are intervals between them and the other teeth, which are not present in his jaws, but which exist in all the other Mammalia.

The Quadrumana may be divided into three families—the Simiadæ, or Monkeys of the old world; the Cebidæ, or American Monkeys; and the Lemuridæ, or Lemur tribe, which supply the place of monkeys in Madagascar and some parts of Africa and India. This restriction of distinct types of structure to different portions of the surface of the globe is not a little remarkable, and may be traced even in the subordinate divisions:—

1. The Simiadæ must be regarded as the types of the order; and amongst these the *Apes* manifest, in the most striking manner, the peculiar characters of the group. These are distinguished from the other subdivisions, in part by the absence of a tail, but also by the want of the cheek-pouches and of the callosities, or hard spots on their haunches, destitute of hair, which the monkeys and baboons possess; and further, by the predominance in length of the fore feet or arms over the hinder ones. The most remarkable species of this group are the *chimpanzee* and *orang-outang*; the former a native of equinoctial Africa, and the latter of the peninsulas and islands of Eastern Asia. Contrary to the general opinion, it is in the first of these that the greatest number of points of resemblance to man are to be found. Both these animals attain considerable size when full grown; probably in their native climate the former rising to five feet, and the latter to seven; but no living specimens of such sizes have ever been seen in this country. In both, there is a remarkable difference between the young and the adult form of the skull—the young bearing the greatest resemblance to that of man; whilst in the adult, the muzzle is so much prolonged, and the canine teeth are so much developed, as to give the face much of the aspect exhibited by that of the baboon.

Orang-Outang.

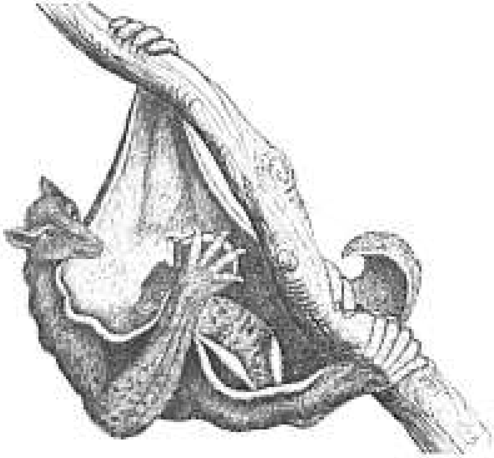
The *Monkeys* of the old world are distinguished (in addition to the characters which separate them from the ensuing family) by the possession of cheek-pouches, callosities, and a tail, which separate them from the apes; the tail is longer than in the baboons, the muzzle less protuberant, and the aspect less ferocious. The true monkeys are also remarkable for the shortness of the arms in proportion to the legs, which causes some species to walk on all-fours with difficulty, climbing being their usual mode of locomotion; but, by common observers, they are still more noticed for the beauty of their colouring, their activity of movement, and gentleness of demeanour. Their character is greatly changed, however, by confinement. They are found in almost all the tropical countries of the old world, and particular genera have a peculiar local distribution. Many of them live in societies, chiefly inhabiting the woods, but committing great devastations on any cultivated ground in the neighbourhood. In several species, the aspect of the head is extremely grotesque, as are also the attitudes of the animal. The number of species is altogether considerable. Their food seems to be rather vegetable than animal; and in one genus this is distinctly indicated by the structure of the teeth and of the stomach. One genus, restricted to Africa, is destitute of thumbs on the anterior extremities, and the deficiency is partly supplied by the great development of the tail, which is not, however, prehensile, as in the American monkeys.

The *Baboons* have usually a short tail, or none at all; but there is much variation in this respect. They are rather distinguished from the apes and monkeys by the protuberance of the muzzle, and the ferocity of aspect which is partly dependent upon this; the canine teeth are generally large and strong. The baboons have also a large bag connected with the organ of voice, by the resonance of which the power of their loud and discordant cries is greatly increased. In a state of captivity, the baboons exhibit less docility than any others of the order. They are by no means devoid of intelligence; but they do not seem capable of being steadily attached by kindness, and generally exhibit an alternation of moody sullenness and violent outbreaks of passion. Their resentment of injuries is often manifested for a long time afterwards.

2. The Cebidæ, or monkeys of the new world, differ from those of the old not only in the number of their grinders and the disposition of the nostrils, already mentioned, but in the entire absence of the cheek-pouches and callosities, and also in the conspicuous character, and the importance as a member, of the tail, which is usually prehensile in these monkeys, and capable of being twisted round branches so firmly, as entirely to support the animal. In general, the thumbs of the anterior members are not opposable; and they are sometimes scarcely developed at all. The Cebidæ are generally of smaller size than the Simiadæ, none of them attaining nearly the dimensions of the chimpanzee, orang, or mandril; they are also less malicious, more easily tamed, and susceptible of a more constant attachment; but they seem to possess less intelligence. They are found in very large numbers in the woods of South America, where they chiefly subsist on vegetable food, to which their teeth show a peculiar adaptation. The largest of them are the *Myceti*, or howling monkeys, which derive their peculiar powers of voice from a sort of hollow drum connected with the larynx. They are shaggy animals, about the size of a fox. The *Ateles*, or spider-monkeys, are remarkable for the length and prehensile power of their tails, and for the absence (in some species entire, in others nearly complete) of the thumb; whence they are called four-fingered monkeys.

3. The Lemuridæ have in many respects the aspect of the American monkeys; but the muzzle is much prolonged, resembling that of insectivorous or carnivorous animals; the teeth also are modified for animal food, presenting sharp tubercles, locking into each other; and the grinding motion of the lower jaw is reduced, so that its action possesses more of the scissors-like character of that of the animal-feeders. The four thumbs are well developed, and opposable; the claw-like aspect of the nail of the first hind finger has been already noticed as one of the most easily recognised characters of the family. The canines in the lower jaw have the character of additional incisors; and the first molars resemble the ordinary canines. The total number of teeth in each jaw is eighteen, as in the American monkeys. The *true Lemurs* are distinguished by their very large and handsome tails, which are elevated when the animals are in motion, and not trailed after them. They average the size of a large cat, but have longer limbs. They are nocturnal or twilight animals, passing the day in sleep, rolled up in the form of a ball; at night they rouse themselves, and spring with the greatest activity in search of their food, which principally consists of fruits. These are entirely confined to Madagascar, where at least thirteen species are known to exist, differing but little from each other except in colour. On the other hand, the *Galagos*, which are found in the neighbourhood of the River Senegal, are pre-eminently insectivorous.

The *galeopithecus*, or flying lemur, so much resembles the bats, as to have been placed with them by many naturalists. It is, however, a *lemur* in all its essential characters, but it has its limbs connected by thin skin, which they stretch out, as the framework of an umbrella



Galeopithecus, or Flying Lemur.

supports its covering. By this singular structure the animal is supported in the air, as by a parachute; but it has not the power of sustaining a continued flight, though it can leap a distance of a hundred yards with a gradual descent. Like the bats, it feeds on insects, and sleeps with its head downwards, suspended by its hind legs. It is a native of the Indian Archipelago.

III.—Cheiroptera.

The order Cheiroptera is perhaps the most distinctly circumscribed group of the whole class Mammalia; for all the animals composing it agree in the possession of a pair of wings, formed by an extension of the skin over the very elongated fingers of the fore legs, and connected also with the hind legs, by which they are adapted to raise and sustain themselves in the air, and also to propel themselves through it by regular continued movements, in precisely the same manner as birds. Now, although in other groups we may observe a tendency towards the same adaptation, it is never carried farther than to give to the animal possessing it the power of partially supporting itself in the air, so as to prolong its leaps, as is the case with the flying squirrel, the flying lemur, and flying opossum. None of these animals can really *fly*, like bats and birds.

We see in the bats a very interesting modification of the whole character of the mammal, to enable it to lead the life of a bird, just as in the whale tribe we see a similar adaptation to the life of a fish. The insectivorous bats bear a strong analogy to the swallow, in the character of the food itself as in the mode in which they obtain it—by the rapid pursuit of insects on the wing; the chief difference in habit being the time at which they respectively go forth in search of their prey.

The whole structure of the Cheiroptera is obviously adapted to the fulfilment of the object which is the distinguishing character of the group. All the bones of the upper extremity, as well as those which give attachment to its muscles, are very largely developed. The member itself, although consisting essentially of the same parts as in man, has its aspect greatly changed by the extraordinary prolongation of the finger bones, upon which chiefly the skin of the wings is stretched. This skin is extremely thin, and is generally devoid of hair on both sides. It extends not only between the fingers, but from the last finger to the posterior extremity, and from this to the tail, where one exists. This expansion of the tail probably serves as a rudder, enabling the animal to change its course rapidly in pursuit of its insect prey—an idea which is supported by the fact, that in the bats which feed on vegetable substances, or on animals which require less activity of pursuit, this part is either wholly wanting, or is much circumscribed in extent and power.

The four fingers of the anterior extremity being involved in the expansion of the membrane, only the thumb is left free; this is of moderate length, and is furnished with a crooked nail, which is of great use to the animal in climbing and making its way along the ground. The toes of the hind feet are short, and furnished with claws, by which the bats suspend themselves from the trees or walls on which they rest, hanging with the head downwards. They walk with slowness and difficulty when placed on the ground; the wings are folded up; and they rest upon the hind feet, and upon the claw of the thumb, by which they crawl forwards, pushing on first one side and then the other. But they can climb up perpendicular surfaces with considerable agility. The expanded skin of the wings appears to be endowed with a sensibility of a peculiar kind, enabling the animals to perceive their proximity to solid bodies without the assistance of sight. That they have a very acute perception of this kind, was long ago shown by the experiments of Spallanzani, who found that bats deprived of sight, and, as far as possible, of hearing also, were still capable of directing their flight with security and accuracy, finding their way through passages only just large enough to admit them without coming in contact with the sides, and even avoiding numerous small threads which were stretched across the room in various directions—the wings never, even by accident, touching them. It is probably through the vibrations of the air, which will differ according as the wing strikes it in the neighbourhood or the absence of any solid body, that the knowledge of the proximity of such is communicated to the delicate and expanded organ of touch. The use of this curious power to animals intended to execute rapid and varied movements in the dark, and amongst trees, buildings, &c. is sufficiently evident.

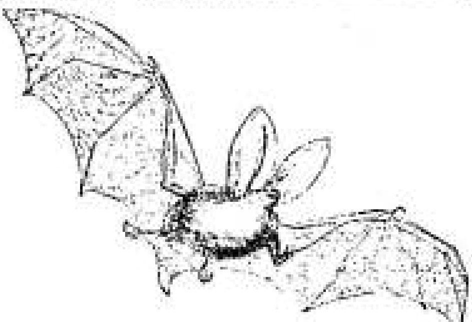
This tendency to a great extension of the skin is manifested in other parts of the body. In many bats, especially of the insectivorous kind, the external ear is enormously developed; being, in the long-eared bat of this country, nearly as long as the body. In the frugivorous bats, it is of ordinary size. The organ of smell, too, in many of the insectivorous bats, is furnished with curious leaf-like appendages, formed of the integument doubled, folded, and cut into the most curious and grotesque forms. The group in which these are most remarkable, is one which avoids the light of day even more than others: the animals composing it exist almost constantly in the darkest recesses of caverns; and it is probable that, by this peculiar conformation, they gain increased power and delicacy of the sense of smell, which in part compensates for the inutility of the organs of vision.

The families composing this order may be arranged under two principal divisions, which are strongly contrasted with each other in regard to the nature of their food, the conformation of their teeth and digestive system, and the peculiarities of structure which are connected with the mode in which food is obtained. One of these groups, which may be regarded as typical of the order, is *insectivorous*; the molar teeth are furnished with pointed tubercles, as in the order Insectivora; and the stomach and digestive system are evidently adapted to animal food. The other group is probably *omnivorous*, like many of the monkeys—feeding chiefly on fruits, but pursuing small birds, or large insects, that may be obtained without much difficulty; their molar teeth have flattened crowns, adapted for bruising and grinding their food; and the complex structure of the stomach and intestinal canal shows its adaptation to a vegetable diet. The proportional length of the intestine, in specimens of these two groups, is a remarkable illustration of this difference of adaptation. In the great bat of this country, belonging to the former group, it is only twice the length of the body; whilst in the frugivorous *pteropus* of the tropics, it is seven times.

The insectivorous group may be distributed into four families:—1. RHINOLOPHINÆ: in these, the nose-leaf is of complicated structure, and is membranaceous; the index or forefinger has but one joint; the wings are large and broad, as in the *horse-shoe* bats of our own country. 2. PHYLLOSTOMINÆ, which have the nasal appendage simple and fleshy, and an index-finger of two joints. 3. VESPERTILIONINÆ, which are destitute of nasal appendages, and have a single joint in the forefinger. 4. NOCTILIONINÆ, almost exclusively confined to tropical countries, also destitute of nasal appendages, but have two joints in the index-finger.

To the second family belongs the celebrated *vampyre*, of the bloodthirsty propensities of which such marvellous stories have been told. The wound inflicted by its teeth is very small; but its tongue is endowed with a peculiar power of suction, by which a considerable amount of blood may perhaps be drawn. There are no well-authenticated accounts of the death of any animal having been occasioned by this creature; and the story of its fanning its victim with its wings to keep him cool, and render his sleep more profound, is probably a fiction.

The family *Vespertilionidæ* includes most of the bats of temperate climates. At least thirteen species exist in this country, the largest of which is the mouse-coloured bat, the expansion of whose wings measures fifteen inches; but this is of rare occurrence. A more common one is the noctule, or great bat, which is but little smaller; this is often met with in considerable numbers, seeking its retreat sometimes in the hollows of trees, at others under the roofs and eaves of houses. Probably the most abundant is the long-eared bat, which is easily distinguished by the character implied in its name. Its ears are folded downwards during



Long-eared Bat.

hybernation or profound sleep. It is easily tamed when in confinement, and may be brought to considerable familiarity, so as to eat from the hand. It has an acute and shrill, but not loud cry.

The frugivorous or omnivorous group contains but one family, the PTEROPINÆ, which is widely diffused throughout warm climates, and contains some of the largest species of the order. It is not improbable that the fabulous harpy may have had its origin in some of these. None of them have the tail much developed, and in many it is entirely absent. The *pteropus Javanicus* is a very characteristic example of this family. It is probably the largest of the bats—its expanded wings measuring five feet across. It is extremely abundant in the lower parts of Java, and uniformly lives in societies. They suspend themselves from trees during the day; and, from their motionless aspect and contracted bodies, they might be mistaken for parts of the tree, or for fruit suspended from its branches. When night comes, they begin to move, and go in search of food to the forests, villages, and plantations, in all of which they do great mischief, attacking indiscriminately almost any kind of fruit, of which they devour a large quantity. In their turn, they are eaten by the human inhabitants of some of the countries where they abound, who consider them as delicacies. The flesh of the common roussette of the Mauritius has been compared to that of the hare and partridge.

The Cheiroptera, inhabiting temperate climates, all remain in a torpid state during the winter. Some of them make their appearance, however, in mild days; but as casual revivals during the season of repose are injurious to them, they usually betake themselves to places of which the temperature is not readily affected by external vicissitudes. The office of this group in the economy of nature, is evidently to assist in restraining the too rapid multiplication of insects, and to keep down the luxuriance of tropical vegetation.

IV.—Insectivora.

The order Insectivora forms a group which has been considered as intermediate between the Cheiroptera and the Carnivora. Like the greater part of the first-named of these orders, the animals composing it are formed to live upon insect food; their molar teeth are beset with pointed conical tubercles, adapted to crush the hard envelopes of their prey; and they are for the most part, like the bats, nocturnal animals—like them, too, passing the winter of temperate climates in a state of torpidity. But they are completely destitute of the wing-like expansions which enable those animals to rise into the air in search of their prey; it is *their* function to seek it upon the ground, or even by burrowing beneath it. Hence, in their general organisation, they more resemble the Carnivora; but they retain the clavicle (collar-bone) of the higher orders, which, in the Carnivora, is reduced to a ligament; and this affords, in the burrowing species, a very important attachment to the powerful muscles by which their anterior members are put in action.

It is remarkable that, as far as yet known, no species of this order exist in South America or Australia. In the former continent, their place seems to be supplied by the Edentata, of which many species are similar in their food and habits; and in New Holland, they are replaced by numerous small Marsupialia, having the same general adaptation of their structure to insect food and to an underground residence.

This order may be divided into four families, which are characterised by their habits, as well as by their external form and internal structure:

1. The TALPIDÆ, of which the common English mole is a very characteristic example. The whole structure of this animal is beautifully adapted to the subterranean life which it leads, and to the mode in which it seeks its food. A very short arm, attached to a large shoulder-blade, supported by a stout clavicle, and provided with enormous muscles, sustains an extremely large hand, the palm of which is always directed either outwards or backwards. The hand comes to a sharp edge below, and though the fingers are scarcely perceptible, the nails which terminate them are long, flat, strong, and sharp. This forms a most admirable spade, by which the earth is at the same time dug away and thrown behind the animal. The sternum (breast-bone) possesses, in common with that of bats and birds, a ridge or keel, for the attachment of the large pectoral muscles which are necessary to endow the anterior member with the required power. To pierce and raise up the ground, the animal employs its pointed head, of which the muzzle is greatly prolonged, and terminated by a little bone which serves as a lever. This prolonged snout is also used as an organ of prehension, for by it the food is seized and conveyed to the mouth. The hinder part of the body is feeble, and the animal advances above ground so awkwardly, as to convey the impression of pain; but when placed in its gallery, or in a tube of the same size, it pushes itself forwards by its hind feet with great activity. The arrangement of the hairs composing the fur is such, that they will lie smooth in any direction; by which provision, the surface is prevented from offering any impediment to the motion of the animal either forwards or backwards.

The mole has been supposed to be deficient in the sense of sight, the eyes being so small, and so hidden behind the hair, that their existence was long denied; it has been ascertained, however, to be tolerably sharp-sighted. (There is a species inhabiting the south of Europe, very closely resembling the common mole, which is certainly blind; the eyelids of which are totally closed.) The sense of smell is extremely acute, and its organ largely developed; it is probably that to this almost entirely the mole is ordinarily indebted for the perception of its food, of its enemies, and of its mate. At the same time, it appears to be assisted by that of hearing, which is certainly acute, although aided by no external ear. The burrows of the mole are of a beautifully complicated construction, and are formed with the utmost art. Its food chiefly consists of earth-worms and the larvæ of beetles. When hungry, however, it will attack mice, lizards, frogs, or small birds, that may fall in its way; and it is said that if two moles are confined together, they will fight until one is vanquished, and that the victor will then devour his fellow. Besides these forms of animal matter, vegetable substances, especially the roots of plants, and the smaller roots of trees, are found in the stomach of the mole; but it may be doubted whether it eats these as food, or whether it does not simply tear them for the purpose of extracting the larvæ and worms, which may be entwined among them.

Much controversy has taken place as to whether moles are on the whole injurious or beneficial to the agriculturist; some parties maintaining that they injure crops of various kinds by the destruction of their roots, and dig up and scatter the plants in ploughing their superficial furrows, besides rendering the ground dry and sterile, by their subterranean roads; whilst others point to their destruction of earth-worms and grubs, and to the lightening of the soil produced by their operations, in proof of their beneficial character. The truth probably lies between the two extremes; the animal being neither prejudicial nor useful to the extent attributed to it by its enemies and friends respectively; but pretty certainly counterbalancing its mischief by the good it effects.

2. The SORICIDÆ, or *Shrews*, in which all the feet are formed for running. These animals are usually small, but are very numerous, and widely diffused. The fur is short, soft, and silky, and the tail long; so that the common shrew bears a strong general resemblance to a mouse, except that the snout is long and slender. The shrews, though they do not actually burrow, retreat during the winter, and for their ordinary repose, into holes; they feed, however, on the surface, or in the water, several of them being partially aquatic, diving with facility after aquatic insects, and remaining without difficulty a long time under water.

3. The ERINACEADÆ, *Urchins* or *Hedgehogs*, remarkable not only for the conversion of the hair into sharp spines, but for the great development of the muscular envelope of the body immediately beneath the skin (especially on the back), which in most other animals is scarcely perceptible. By this they are enabled to roll themselves into a ball, presenting a panoply of defensive weapons to their enemies. In its natural state the hedgehog is nocturnal, remaining coiled up in its retreat by day, and moving about all night in search of food. Its run is quick and shuffling, and as it were by starts. Insects, worms, slugs, and snails, form the usual food of the hedgehog; but it will also devour frogs, toads, mice, and even snakes, and has been known to feed on eggs and vegetable substances. It is easily rendered familiar with man and with other animals. Other species of this family connect it with the previous and succeeding groups, the spines not differing so much in size and strength from hairs, and the power of rolling up the body being absent.

4. The TUPAIDÆ, or *Banxrings*, the last family, is a very remarkable one. It is confined to the Indian Archipelago, and has not been long known to exist. Their teeth chiefly resemble those of the urchins, with a slight tendency towards the lemurs; and, like this last group, their eyes are large and prominent. They are covered with hair, which is soft and glistening, but not fine in texture, and have a long bushy tail. Contrary to the habits of other Insectivora, they ascend trees with the agility of a squirrel; from which animal, however, their pointed muzzle renders them easily distinguishable, even at a distance. They are readily tamed, running freely through the house, and coming of themselves at every meal for fruit or milk.

V.—Carnivora.

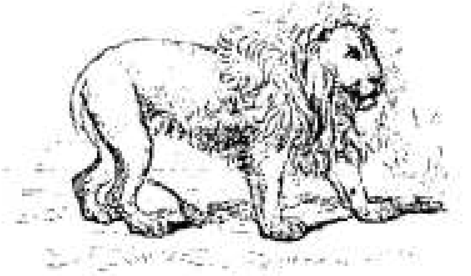
The animals composing the order Carnivora are, like the four previous orders, separated from the other Mammalia, possessing distinct fingers, by the presence of three kinds of teeth; and from these orders they are distinguished by characters which point them out as especially formed for the pursuit and destruction of large animals. They possess in the upper and lower jaw six incisor teeth; a large, strong, and pointed canine tooth on each side; and molar teeth, which are evidently formed for cutting and tearing rather than for bruising or grinding. The form of these teeth varies, however, in the different genera, in accordance with their several habits. These molars consist of three kinds: the anterior, immediately following the canines, which are always more or less pointed, and are termed *false molars*; the next class, formed especially for cutting the flesh upon which the animals feed, are termed *carnivorous teeth*; and the posterior are tuberculated, with flattened summits.

The proportion which these different classes bear to each other in number and development, accords with the degree of the carnivorous propensity of the animal, and furnishes important characters in the subdivision of the order. The more the surface of the molar teeth is raised into points and edges, and the more the action of the jaws is restricted to the scissors-like movement by which these edges are made to meet and pass each other, the more purely carnivorous is the regimen of the animal: this is well seen in the Cat tribe. On the other hand, the more the molar surfaces are flattened, and the greater the lateral grinding motion of which the jaws are susceptible, the greater is the probable admixture of vegetable food: this is seen in the bears. The general structure of the body, and especially that of the extremities, is modified in a corresponding manner, in accordance with the habits and propensities of the animal. In all, the toes are furnished with claws, which are peculiarly sharp in the cats, and are in them kept ready for use within a sheath, from which they can be projected at the will of the animal. The stomach of the Carnivora is very simple in its form, and the intestines are short, in accordance with the easily-digested character of their food.

The whole bony and muscular system exhibits a similar modification. Thus, whilst the powerful, yet active and flexible, movements of the purely carnivorous animals are adapted only to the pursuit and destruction of living prey, the more sluggish habits of most of the Bear tribe, their peculiar mode of progression, and the modified structure of the skull, teeth, and limbs, are all equally applicable to the mixed nature of their food. The difference in the conformation of the extremities, and in the mode of using them, is very striking in these two antagonised groups. In the former, the ends of the toes only touch the ground, the heel being considerably raised into the air; in this way the limbs can be used to much greater advantage in running and springing: the animals possessing this conformation are termed *digitigrade* Carnivora. In the latter, the whole foot rests on the ground—a structure more favourable to the maintenance of a firm position, but preventing great activity of progression: these are called *plantigrade* Carnivora. There is a third very remarkable variety of conformation in the extremities of this order; and this is exhibited in the Seals. Here the anterior as well as the posterior feet are formed for swimming, being spread into fin-like paddles; and the whole arrangement of their organs, as well as the general configuration of their bodies, admirably adapted to the pursuit and capture of their scaly prey.

The Carnivora may be subdivided into five families, each containing a well-known form. 1. FELIDÆ, or *Cat* tribe. In these the destructive power is most highly developed. They are characterised by their short powerful jaws, their retractile claws, and the peculiar adaptation of their teeth for cutting. They have but one small flattened molar tooth above, and no corresponding one below. 2. CANIDÆ, or *Dog* tribe. These, like the cats, are digitigrade; but their claws are not retractile; and they have two flat tuberculated molars behind the great flesh-cutter. 3. MUSTELIDÆ, or *Weasel* tribe. These are mostly semi-plantigrade, a portion of the sole touching the ground. They are distinguished by their long slender bodies, and by the presence of only one tuberculated molar. 4. URSIDÆ, or *Bear* tribe. These are the only true plantigrade Carnivora. Most of them possess several tuberculous teeth. 5. PHOCIDÆ, or *Seal* tribe. These are at once distinguished by the adaptation of their form and structure to a residence in water; and of their teeth for seizing and holding the slippery bodies of fish, and crushing them before they are swallowed.

1. The *Cat* tribe includes a large number of animals very closely resembling each other in structure and aspect—so closely, indeed, that many of the species can only be distinguished by their size, and by the markings of their skin. They all agree, too, in the mode of catching their prey, which is, to steal upon it unawares, and seize it with a sudden spring, in which they expend their energy, often slinking off when once baffled. It is very difficult to subdivide the family, on account of the strong general resemblance of its members. Most of them are sufficiently well known to render any peculiar description of them unnecessary. It may, however, be remarked, that some species are found in almost all tropical and temperate countries, and that those of different parts of the globe *represent* each other in a remarkable manner. Thus the *lion* and *tiger* are inhabitants of Africa and tropical Asia; in America they are replaced by the *puma* and *jaguar*, which are confined to that continent. In the same manner, we find the *panther* and *leopard* spread over tropical Asia and Africa; the ounce inhabiting the Asiatic mountains; the *caracal* in Turkey and Persia; and the *lynx* of Northern Europe. These are represented by the *ocelot* in South America, the *lynx* of Canada (differing from the European species), and other less known species. The Felidæ, like the noble falcons, will only eat the flesh of animals they have themselves killed, except when in a state of domestication or confinement, or when compelled by hunger.



Lion.

2. The family of CANIDÆ includes a much larger number of different forms, some of which approximate to the Cat tribe, and others to the weasels and bears. This tendency to variation from a typical form is most remarkably shown in the races of the common dog, which are believed to have all had the same origin, although the commencement of most of them is entirely unknown. The animals of this family agree in their greater or less adaptation to a mixed diet. Although animal flesh naturally constitutes the principal food of all, they do not attack living animals with a degree of boldness proportional to their strength, and many of them feed upon carrion, sometimes even when it is much putrefied. The *wolves*, *foxes*, and *jackals*, are the animals which most nearly approach the dog; and with the first of these it is regarded by many naturalists as being really identical.

The *Hyænas* constitute a group remarkably distinct from the true Canidæ, and yet bearing enough of their characters to require to be associated with them. They are more purely carnivorous than the dog tribe, and approach in the deficiency of tuberculated molars to the cats. But they differ from these not only in general aspect, which is much more nearly allied to that of the dog, but also in the absence of the retractile power of the claws, and in their propensity to feed on carrion. The teeth are peculiarly adapted for crushing bones, and their jaws are shorter than those of the dog, but longer than those of the Felidæ. In many other points of structure, the hyænas are intermediate between the two groups. They are peculiarly ferocious animals, combining the persevering *doggedness* of the one tribe with the furious bloodthirstiness of the other. Their habits are nocturnal—more so than those of most other Carnivora. Hyænas are now chiefly confined to Africa and the south of Asia; but there is no doubt, from the abundant remains of them which are preserved to us, that they must have formerly lived in large numbers in this country, and in other parts of Europe. With the Hyænas may be associated the *civets*; and the *ichneumon* of Egypt, which restrains the multiplication of crocodiles by feeding on their eggs.

3. The MUSTELIDÆ are the most *bloodthirsty* of all the Carnivora; but they are not so much adapted for devouring *flesh* as are the Felidæ. These animals, on account of the length of the body and the shortness of the limbs, which permit them to pass through very small openings, are called *vermiform*. All the members of this family are semi-plantigrade. The *weasel* of this country is a very characteristic example of the family; it is one of the most sanguinary of any, but confines itself chiefly to small animals, destroying large numbers of mice, rats, moles, &c. The *ferret*, which is an allied species, is bolder, having been known to attack man; and the *polecat* is a great enemy to the farmyard, game-preserve, and warren. All these animals have a strongly and disagreeably odorous exudation from a pouch under the tail; but it is most disgusting in the last. The *Otters* constitute an aquatic form of this family, having the same general aspect and dentition with the weasels, but being readily distinguished from all other genera of the family by their webbed toes and horizontally flattened tail. They subsist on fish.

4. The true plantigrade Carnivora, constituting the family of URSIDÆ, participate in the comparative slow motion and nocturnal life of the Insectivora; and like them, too, the species which inhabit cold countries pass the winter in a dormant state. In the *Bears*, the cartilage of the nose is elongated and movable, somewhat resembling that of the Shrews. These animals possess a great facility, from the structure of the sole, of rearing themselves up on their hind feet; and this may be especially noticed in such as are, like the bears, fruit-eaters, becoming carnivorous only from necessity; they are thus enabled to climb trees in search of food. The bears are the largest of the family; and some species of them are pretty widely diffused over the globe. The *racoons*, which resemble bears in miniature, with the exception of the greater length of the tail, are confined to the new world.

The *Badgers*, *Taxels* or Badgers of America, and the *Wolverines*, form a tribe connecting the Bears with the Mustelidæ. The *badger*, for example, is only semi-plantigrade, and has a dentition very like that of the weasels and otters, but adapted for a less carnivorous regimen. But it has the tardy gait and nocturnal habits of the other plantigrades; it does not, however, become torpid in winter. All these animals, like the weasel tribe, have the power of emitting a fetid odour at will.

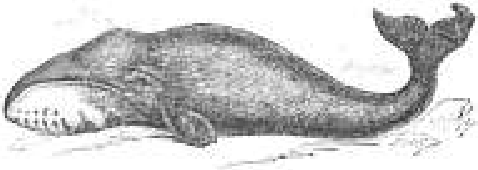
5. The last family, that of PHOCIDÆ, is sufficiently distinguished from all the rest by the peculiar adaptation of the animals composing it to a marine residence. Their feet are so short, and so enveloped in the skin, that they are of little use in progression on land. In fact, the seal employs them only when clambering, wriggling itself forwards along a plane surface by the action of the abdominal muscles. The intervals between the toes are occupied by membranes, so as to convert the feet into oars. The body is lengthened, and the spine very flexible, as in the Cetacea and Fishes; and the animals are covered with a short close fur, sitting flat upon the skin. All these adaptations combine to render them able swimmers; and they pass the greatest part of their time in the water, which they only quit to bask in the sunshine and to suckle their young.

Of the two genera, the *Seal* and the *Morse*, which this family contains, the former presents the least departure from the general type of the order, being adapted, as to its teeth and digestive organs, for animal diet; the latter group is chiefly herbivorous.

VI.—CETACEA.

In the order Cetacea, or *Whale* tribe, the adaptation of the mammiferous structure to the life of a fish is remarkably displayed. The whole body is formed for an exclusive residence in the water. The posterior extremities are no longer present, as in the seal, to assist in progression on land; nor are the toes of the anterior furnished with claws. The trunk is prolonged into a thick tail, which terminates in a horizontal cartilaginous fin, by the vertical movement of which the propulsion of the body is effected. The head is very large, and is connected with the body (as in fishes) by so short and thick a neck, that no diminution of its circumference is perceptible; and the cervical vertebræ, which are still (as in all Mammalia) seven in number, are very thin, and partly united together. The bones of the arm and fore-arm are very short; and those of the hand are flattened, and enveloped in a tendinous membrane, which reduces them to the condition of fins. Hence their whole aspect is that of fishes, except that they are not covered with scales, and that they have the tail-fin expanded in the contrary direction. The object of this last provision is to enable them more readily to come to the surface to breathe, which they are obliged frequently to do. The largest species can remain, however, for an hour under water. Their blood, like that of other Mammalia, is warm; and to prevent the animal temperature from being rapidly lowered by the conducting power of the water, they are furnished with a thick coating of fat over the whole body. There are never any external ears, nor hairs upon the body. In these general characters, some other whale-like animals, now separated from the true Cetacea, agree; but they differ in being adapted for vegetable food, whilst the true whales are all animal-feeders, and are therefore properly associated with the Carnivora, to which they make a near approach through the seal. It is evident that the want of claws should not exclude them from this division of the Mammalia, since these are rendered useless by the adaptation of the animal to an exclusively aquatic residence. Some of them, which feed upon large marine animals, seize their prey with their jaws; whilst others, which derive their support from the smaller kinds, engulf them, with a large quantity of water, in their capacious mouths.

The true Cetacea are further distinguished from those herbivorous forms which are now associated with the Pachydermata, by the remarkable conformation from which they receive the name of *Blowers*. As with their prey they necessarily take in a great volume of water, a means of getting rid of this is required, and it is accordingly transmitted through the nostrils, and expelled, by a strong muscular action, through a narrow aperture pierced at the summit of the head. It is thus that these animals produce the jets by which they are observed at a great distance. Their nostrils, being continually



Whale.

bathed in water, are not adapted to a delicate perception of odours; and their organs of hearing, being deficient in the external ear, and otherwise formed on a lower type, are also probably incapable of very acute perception of sound. But what is deficient in these respects seems to be compensated by a very high degree of sensibility of the general surface; and there is reason to believe that, by this diffused sense, whales are enabled to take cognisance of what passes in the water at a considerable distance, through the medium of the vibrations excited in the fluid.

In subdividing this order, the *dentition* does not afford much assistance, for the teeth are frequently absent altogether; and among the species which possess them, they often exhibit great differences, when the animals are closely allied. Where they exist, they are mostly small, numerous, and of a conical form, similar to each other. These animals do not chew their food, but swallow it whole. The stomach is usually of a rather complex form. The order may be divided into two families, according to the relative size of the head and body. In the first, DELPHINIDÆ, or the *Dolphin* tribe, the head is not out of the usual proportion; in the second, the BALÆNIDÆ, or *Whale* tribe, it is immoderately large.

1. The DELPHINIDÆ have teeth throughout both jaws, all simple, and nearly always conical. They are the most carnivorous, and, in proportion to their size, the most cruel of their order. The common *dolphin* has its snout prolonged into a kind of beak. It is extremely agile in its movements; and a number are often seen sporting together on the surface of the water. Nearly allied to the dolphin is the *porpoise*, which has a short muzzle. This is one of the smallest of the Cetacea, not exceeding four or five feet in length, and is very common in various parts of the Atlantic, assembling in vast herds. Allied to the porpoise is the *grampus*, which has large conical teeth, and is the most powerful of this family, attaining the length of from twenty to twenty-five feet. It is a cruel enemy to the whale, which it attacks in troops. Other species of this family are known on our coasts by the names of *white whale*, *bottle-nose*, *narwhal*, or *sea-unicorn*, &c. This last animal is remarkable for the enormous development of a single tooth or tusk, commonly reputed to be a horn, whence the name commonly given to the species. In the general form of the head and body it agrees closely with the porpoises; but it possesses no other teeth than this tusk, which projects forwards apparently from the centre of the upper jaw, to the length of ten feet. The animal really possesses, however, the germs of two tusks, of which only one is generally developed. That, on the left side usually attains its full growth, whilst the other remains permanently concealed within its socket.

2. The remaining Cetacea, constituting the family BALÆNIDÆ, have the head so very large, as to constitute one-third, or even one-half, of the entire length; but neither the cranium nor the brain participate in this disproportion, which is entirely due to an enormous development of the bones of the face. This family contains several remarkable and important animals, amongst which the following may be noticed:—The *catodon*, or spermaceti whale, receives its technical name from possessing teeth in the lower jaw only;

these are of considerable size, and lock into cavities in the upper jaw when the mouth is closed. The superior portion of the enormous head consists almost entirely of large cavities, separated and covered by cartilages, and filled with an oil that concretes in cooling, and is known by the name of spermaceti. This is commonly, but erroneously, reputed to be the brain of the animal; the cavities which contain it, however, are very distinct from the true cranial cavity, which is rather small, and lies at the posterior portion of the head. Cavities containing spermaceti are found in various parts of the body, even ramifying through the external fat or blubber, and these communicate with those in the head. This whale is extensively distributed through various seas, but chiefly abounds towards the antarctic region. It sometimes attains the length of seventy feet.

The *balæna*, or Greenland whale, equals the catodon in size and in the proportional length of the head, which is not, however, so much enlarged in front. Instead of teeth, the mouth is provided with a number of vertical plates, terminating in fringes, which are composed of a sort of fibrous horn, and may be regarded as a kind of prolongation of the gum. These fringed plates, commonly known as whalebone, serve to retain, by straining from the water, the minute animals on which these enormous beings subsist. Their food consists partly of fishes, but chiefly of soft mollusca, acalephæ, &c. The blubber is of immense thickness, and furnishes a large quantity of oil—a hundred and twenty tons being sometimes obtained from a single individual. The whalebone also is an important object of pursuit. This animal was formerly not very uncommon in our seas, but has now retired to the far north, where its number, in consequence of the attacks of man, is constantly diminishing. The *rorqual*, an allied species, attains to still greater size, having been seen of the length of a hundred feet.

VII.—Rodentia.

The order Rodentia bears a striking contrast to the last in the size as well as habits of the animals composing it, which are for the most part very diminutive; but they are very widely diffused, and are often extremely numerous. One species or another is found in every part of the world except New Holland, and sometimes their numbers are so great, as to render them very destructive to vegetation. Some of the order are the most gentle of the Mammalia, whilst others are so ferocious, that, if their size and strength were proportional, they would be extremely formidable. This order contains also some of the species most remarkable for their instincts, as the beaver. Generally speaking, the Rodentia are the most prolific of the Mammalia, the period during which they go with young being shorter, and their litters more numerous.

But though the animals differ much from one another in size and external appearance, the order is a very natural one; all the species contained in it being remarkable for the peculiar adaptation of their teeth to gnawing hard vegetable substances, and of the stomach and intestinal canal to the digestion of them. The mouth of a rodent animal is at once recognised by the two long teeth which project forwards from each jaw, working against one another, and separated from the molars by a wide interval. These are usually regarded as incisors; but they are really the canines, the direction of which has changed in consequence of the absence of the incisors. In the hare, the small true incisor teeth may be seen behind them. These gnawing teeth have enamel in front only; so that, their posterior edges being worn away faster than the anterior, they constantly retain a sloping or chisel-like edge. They continue to grow at the root as fast as they wear away at their points; so that, if either be lost or broken, its antagonist in the other jaw, having nothing to wear it down, becomes developed to an enormous extent. The mode in which the lower jaw is articulated to the skull, allows of no horizontal motion except backwards and forwards; and the flat-crowned molar teeth have enamelled ridges arranged transversely, so as to be in opposition to the horizontal movement of the jaw, and the better to assist in trituration. In a few of the genera the structure of the molars more approaches that of the Carnivora.

The form of the body of the Rodentia is generally such, that the hinder parts exceed those of the front, so that they leap rather than run. In some of them this disproportion is as excessive as in the kangaroos. The inferiority of these animals to those of the orders already considered is perceptible in many details of their organisation; the brain is less complex in structure; the fore-arm loses the power of rotation, its two bones being often united; and the eyes are directed sideways, showing their tendency to retreat from their enemies rather than to pursue them. In some, the clavicles (collar-bones) are nearly or entirely absent; the anterior extremity being then usually deficient in strength.

The Rodentia may be divided into seven families, the technical distinctions between which are founded upon minute particulars in the structure of the cranium and of the lower jaw. 1. SCIURIDÆ, or *Squirrel* tribe, comprehending a large number of light and agile animals, chiefly distinguished by their long bushy tails, and by their adaptation to a residence in trees, and to live upon their produce. 2. MURIDÆ, or *Rat* tribe. 3. CASTORIDÆ, or *Beaver* tribe, including the voles, lemmings, &c. 4. HYSTRICIDÆ, or *Porcupine* tribe. 5. CAVIDÆ, or *Guinea-pig* tribe. 6. CHINCHILLIDÆ, the *Chinchilla* tribe. 7. LEPORIDÆ, the *Hare* tribe. The rodents of the fourth, fifth, and seventh families are destitute of the clavicle, which those of the three first and the sixth possess.

1. Of the family SCIURIDÆ, the common *squirrel* of this country may be taken as a characteristic illustration; and its form and habits are sufficiently well known to render particular description unnecessary. It lives entirely upon vegetable food, in search of which it leaps with great agility from branch to branch. In taking these leaps, when it is once thrown off by an effort of its long and powerful hind-legs, it is in a measure sustained by the horizontal spreading of its limbs and bushy tail, the hairs of which are directed laterally, so as to resemble a feather. In the *pteromys*, or flying squirrel, this sustaining power is much increased by an extension of the skin of the flank between the fore and hind legs, which serves as a parachute. The *marmots* are allied to the squirrels in the number and structure of their teeth, which are partly adapted, however, to insect food. In other respects they are almost the reverse of squirrels, being heavy, with short limbs and a moderate-sized tail, and living on the ground, or even in burrows beneath it. More allied to the squirrels in the size of their tail and active habits, but differing in their dentition, are the *dormice*, the structure of whose teeth shows them to approximate with the next family. They chiefly subsist on vegetable food; but some species of them attack small birds. All the members of this family pass the winter in cold climates in a state of lethargy, which is most profound in the marmots and dormice.

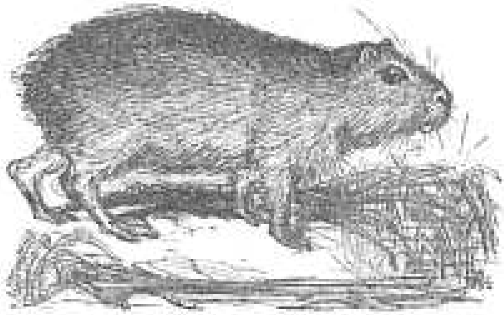
2. The family of MURIDÆ contains the smallest, and at the same time the most numerous, of the Mammalia. No undomesticated animals are better known than mice and rats. Of the common mouse, Cuvier thus concisely speaks—'known in all times and in all places.' The house *rats*, abundant in this country, are almost as universally diffused; but the time of their introduction into many parts of the globe can be distinctly traced. The *brown* (commonly, but erroneously, called the Norway) *rat* made its first appearance in Paris about the middle of the eighteenth century, and in England not many years earlier; it is believed to have originally come from Persia. The brown rat is now speedily replacing the *black* or *old English rat*, which is becoming rather a rare animal in this country, and which, from its smaller size, is an unequal match for the usurper. There is reason to believe, however, that even this is

not a native of England, and that it was introduced from France about the middle of the sixteenth century. From Europe these two rats (which infest vessels equally with houses) have been sent to America, the islands of the Pacific, and many other places, in some of which they have now become a serious inconvenience. The only strictly indigenous British species of Muridæ are the *harvest-mouse* and *long-tailed field-mouse*, both of them very beautiful little animals, and very interesting to the naturalist, although highly injurious to the agriculturist. A great number of species exist in various parts of the world, which do not differ widely from each other.

3. Of the CASTORIDÆ, the *beaver* is probably the type; but this family contains many genera having a close resemblance to the rats. The beaver is distinguished from all other rodents by its horizontally-flattened tail, which is of a nearly oval form, and covered with scales. The hind feet are webbed, by means of which and the tail these animals obtain considerable swimming powers. They chiefly subsist on bark and other hard substances, and can fell trees of considerable size, of which they use the bark and twigs as food, employing the stems in the construction of their remarkable habitations. The flattened tail is employed by them as a kind of trowel, with which they plaster the walls of their houses. The beavers are connected with the previous family by the *Arvicolæ*, or *Voles*, many of which bear a strong general resemblance to rats, but differ in their dentition. Most of them are in some degree aquatic in their habits; such is the common *water-rat* of this country, the food of which, like that of the beaver, is (contrary to the general opinion) almost exclusively herbivorous. To this group also belong the *lemmings*, or Scandinavian rats, which are remarkable for their occasional migrations in immense bodies. They are stated to advance in a straight line, regardless of rivers and mountains; and while no insurmountable obstacle impedes their progress, they devastate the country through which they pass. Most of this family lay up a winter store of food, upon which they subsist in the intervals of sleep, and do not go abroad during that season.

4. The animals which are characteristic forms of the family HYSTRICIDÆ are recognised at the first glance by the stiff and pointed quills with which they are armed, somewhat similar to those of the hedgehogs, but usually much larger. Besides the *Porcupines* and their allies, however, to which this description more particularly applies, this family contains several forms which connect it with the two preceding. The name porcupine is corrupted from the French *porc-epic*, a term expressive of the pig-like aspect and grunting voice of these animals, as well as of their spiny covering. They live in burrows, and have very much the habits of rabbits. The best-known species inhabits the south of Italy, Sicily, and Spain. It is nearly the largest of the Rodentia, measuring almost three feet in length. There is an American genus nearly allied to the true porcupine, which has a long prehensile tail, like that of the opossums, and lives in trees.

5. The next family, that of CAVIDÆ, contains the largest-sized animals of this order, although, when compared with ordinary quadrupeds, they would be termed small. They are naturally restricted to tropical America, where they replace the hares and rabbits of cold climates. But the *guinea-pig* is now extremely common in Europe, and is quite domesticated. The *capybara* is an inhabitant of the sides of nearly all the great rivers of South America, and is the largest known animal of the order, being about three feet in length, and of the size of the Siamese pig. It has a large, thick, and blunt muzzle, is destitute even of the rudiments of a tail, and is scantily covered with bristly hairs. Its semi-aquatic habits are shown by the webbing of the feet. By this structure it can both swim and dive with much activity. Upon land it makes but little progress, running badly, and generally diving in the water to avoid danger. It lives in small societies, and seems to be a nocturnal feeder. Another of the Cavidæ is the *aguti*, which is an inhabitant of the Antilles and tropical America. It is about the same size as the European hare; but in regard to its food, and its manner of feeding, it rather resembles the



Capybara.

squirrel, preferring nuts to herbage, and sitting upon its haunches whilst eating.

6. The animals of the small family CHINCHILLIDÆ were, until recently, known only by their skins, which constitute an important article of commerce. In their general organisation they seem intermediate between the cavies and rabbits, but differ from both of them in possessing clavicles. They are all natives of South America, chiefly inhabiting the range of the Andes, and they live socially, in extensive burrows.

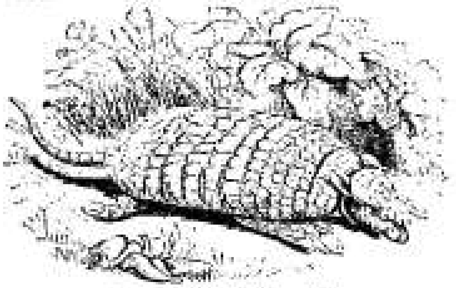
7. The LEPORIDÆ constitute the last family of the Rodentia, and are distinguished from the rest by the presence of two small incisors behind the rodent teeth. The form and habits of the typical genus, *Lepus*, are sufficiently well known in the *hare* and *rabbit* of this country. A large number of species exist in the different parts of the northern hemisphere, and some are inhabitants of the arctic regions. There is one species of this country, in which the brown fur, that forms its summer coat, changes to white at the approach of winter. The hare is a ruminating animal, though without the peculiarly complex stomach of the true Ruminantia.

VIII.—Edentata.

The animals composing the order Edentata cannot be described by any general positive characters which separate them from other groups; for there is a considerable dissimilarity in the entire structure and habits of the different species. The chief point of agreement amongst them is a negative one—the absence of incisor teeth, and the termination of the extremities in long claws. These claws are usually four in number, and partially embrace the extremities of the bones from which they are prolonged, so that each forms a kind of pointed hoof; and we have thus an approximation towards the unguiculated division of the Mammalia. The order may be separated into two distinct groups: one consisting of the EDENTATA-PROPER, and containing the Ant-eaters, Armadillos, &c. all of which are insectivorous; the other, denominated TARDIGRADA, from the slow movement of the animals composing it, and containing the Sloths.

1. The true EDENTATA are distinguished, like other insectivorous Mammalia, by their pointed muzzle. This is particularly remarkable in the *Ant-eaters*, which are peculiar to the warm and temperate regions of South America. They are destitute of any teeth; but possess a very long slender tongue, which they insinuate into ant-hills and the nests of the termites (or white ants), whence these insects are withdrawn by being entangled in the viscid saliva that covers it. Their fore-nails, strong and trenchant, enable them to tear open these nests, and also furnish them with an effective means of defence.

Most of the other true Edentata are burrowing animals, and are covered with a dense armour, composed of hard scales arranged in a *tesselated* manner, or fitted together like stones in a pavement. Between the different bands of these there are narrow rings of membrane, which allow the body to bend. They have claws adapted for digging, seven or eight cylindrical molars on each side, and a tongue but little extensible. Of these animals, the *Armadillos* are the chief, and are the forms best known. They subsist partly on vegetables, and partly on insects and carcasses. Some of them appear to prefer putrefying animal matter; and many are nocturnal feeders.



Peyou, or Six-banded Armadillo.

2. The animals belonging to the family TARDIGRADA are at once known from the EDENTATA-PROPER by the peculiar shortness of the muzzle. The name of the family is derived from that commonly applied to the animals composing it. In the *Sloths*, according to Cuvier, 'nature seems to have amused herself with producing something imperfect and grotesque.' And if we consider the peculiarities of their organisation in reference to the ordinary habits of mammiferous animals, this appears to be true. Both the fore and hind legs, by their form and proportions, and the manner in which they are joined to the body, are quite incapacitated from acting in a perpendicular direction, and of supporting the body from below; so that when the animal is placed on the floor, his belly touches the ground. Moreover, he has no soles to his feet, and his claws are very sharp, long, and curved backwards; so that he has no firm support, and can only move forwards by laying hold of some fixed object, and dragging himself on by his hooked claws. But when placed on a branch, his aspect is altogether different. In the wild state, the sloth passes his whole life on trees, and never leaves them but through force or accident, or to pass from one to the other, which, in the densely-tangled forests of South America, where alone it exists, is not frequently necessary. But though appointed to spend its whole life in trees, it is not adapted to live on the branches, like the squirrel or monkey, but *under* them. It moves suspended from them; it eats suspended from them; it sleeps suspended from them. And when its structure is considered in its adaptation to this extraordinary position, it is seen to be most admirably devised to meet the wants of the animal. The muscular system seems capable of prolonged action without effort; and this may perhaps be aided by a peculiar disposition of the arteries, such as is possessed by the lori. The sloth usually remains upon a tree until it has stripped it of every leaf, and then it proceeds to another. It has been observed that, in the more open places, where the trees are less contiguous, the sloths take advantage of windy weather to effect their transits, when the boughs are blown together and commingled. The peculiar conformation of these animals ought, therefore, no more to excite our pity and compassion, than the circumstance of fishes being destitute of legs. The perennial foliage of the tropical forest supplies them with food, and their elevated habitation removes them out of the reach of the carnivorous animals.

There have been found in South America—the country to which the existing Edentata are almost confined—remains of some enormous recently-extinct animals, belonging evidently to the same group. Of one of these, the *megatherium*, nearly the whole skeleton has now been studied, by comparing different imperfect specimens; and there can be little doubt that it belonged to a gigantic animal intermediate between the sloths and ant-eaters. Its haunches must have been more than five feet wide; and its body fourteen feet long and eight high. Its feet were a yard long, and terminated by gigantic claws. Its whole structure seems to have been adapted to digging the earth in search of the succulent roots which probably constituted great part of its food. Another extinct animal of the same description is known by little else than its claws, and fragments of bones and teeth. From the form of the claw, the *megalonyx* (as it has been named) was at first supposed to be a carnivorous animal; but Cuvier satisfactorily proved it to belong to the Edentata. It seems nearly allied to the megatherium. Remains of tesselated bony armour have also been found, which indicate the former existence of a large animal allied to the Armadillos, to which the name *glyptodon* has been given; and other remains of gigantic ant-eaters have since been discovered in the same locality.

The Edentata terminate the series of the *unguiculated* or *clawed* true Mammalia; and, as has been just seen, there are some among them with the claws so large, and so enveloping the ends of the toes, and these reduced to so small a number, as to approximate to the nature of hoofs. Nevertheless, they have still the faculty of bending their toes round various objects, and of grasping with greater or less force. The entire absence of this faculty characterises the *hoofed* animals. They use their feet only as supports, and the fore-arm has not the power of rotation, its two bones being frequently consolidated into one, or one of them greatly enlarged at the expense of the other, like those of the leg of man and of most Vertebrata. The hoofed animals in no instance possess clavicles, and they are entirely vegetable feeders. Their forms and mode of life present, therefore, much less variety than is found in the unguiculated animals, and they can hardly be divided into more than two orders—those which ruminate, and those which do not. The former constitute a very natural and easily-circumscribed group, the animals which compose it bearing a strong general resemblance to each other, and being easily distinguished from other groups; the latter contains a number of different forms, the connection of which with one another, by any very important peculiarities common to all, is not very obvious. On account of the general thickness of their skins, they are called PACHYDERMATA.

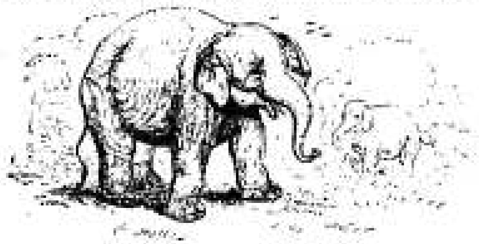
IX.—Pachydermata.

This order, consisting of hoofed animals which do not ruminate, may be divided into three groups, each of which shows a certain degree of resemblance to some other order.

1. The first group, PROBOSCIDEA, contains only one living genus, the *elephant*, to which the *mammoth*, which has become extinct within a comparatively recent period, is allied. [See GEOLOGY.] Another extinct animal of this group is the *mastodon*, which, in the conformation of its teeth, appears to have some affinity with the hippopotamus. All these animals agreed in possessing a pair of enormous tusks or front teeth, and a very elongated nose or proboscis; and it is probable that this last organ was formed, as in the elephant, to answer the purposes of a hand, laying hold of large objects by coiling itself round them, and of small by means of the finger-like organ at its extremity. The magnitude of the sockets necessary to hold the tusks, renders the upper jaw so high, that the nostrils, which are prolonged through the trunk, are placed in the skeleton near the top of the face. By means of its trunk, the elephant not only lays hold of its food, but sucks up its drink, which it makes to fill its capacious nostrils, and then discharges,

by bending its trunk, into its mouth. By this admirable organ, the shortness of the neck, rendered necessary by the weight of the head, is fully compensated. The cavity for the brain by no means corresponds with the external form of the skull; for in order, as it would seem, to give a larger surface for the attachment of the muscles of the trunk, the outer layer of bone is widely separated from the inner, and between the two are a number of large bony cells.

In none of the Proboscidea has the lower jaw of the adult any front teeth. The arrangement of the grinders differs in the various species; but in all they are composed of alternating plates of hard *enamel* and softer *bony* matter, cemented together by a third substance, which is termed the *cortical*. These grinders are in constant progress of renewal; but they succeed each other, not by rising from below upwards, as in man, but by being pushed forwards from behind, in proportion as the tooth before each is worn away. There is never more than one *perfect* molar on each side; but in proportion to the age of the animal, there may be two, three, four, or more, the front ones being the worn-down remains of those at first formed. It is stated that the molars are thus renewed eight times. The tusks, however, are only changed once; but, like the cutting teeth of the Rodents, they are constantly being renewed at the roots. Two species of elephants exist at the pre-



Elephant.

sent day, both of which inhabit tropical climates, one in Asia, the other in Africa. Their food is entirely vegetable; and in their undomesticated state, it consists chiefly of the leaves and young branches of trees, and of the long herbage of the ground, both of which it gathers with its trunk. The tusks serve not only as weapons of offence and defence, but to root up small trees, and tear down cross branches, either to obtain their leaves, or to make a passage for the bulky body of the animal through the tangled forest.

2. Of the true Pachydermata, the first family is that of SUIDÆ, the *Pig* kind. It is characterised by the peculiar thickness of the skin, and by the presence of four toes on each foot. They have three sorts of teeth in each jaw; the canines are usually long, and project forwards as tusks; the anterior molars are more or less narrow and conical; whilst the posterior are tuberculated. The food is principally vegetable, but admits of considerable variation. The domesticated pig is well known to be quite an omnivorous animal. In the true pigs, the foot has two toes furnished with large hoofs, and two much shorter ones that scarcely touch the ground. The *wild boar*, which abounds in some parts of the continent of Europe, is well known to be a very ferocious animal; and the domesticated race which is derived from it often exhibits indications of the same character. One of the most curious animals of this tribe is the *babyroussa*, a native of the Indian Archipelago; the upper canines of which are very long, and grow spirally upwards and backwards. These serve as defensive weapons of a very powerful description, inflicting, it is said, severe lacerations by an upward stroke of the head.

With the family of Suidæ is probably to be placed the *hippopotamus*, or river-horse, of which only one species is known, confined to the rivers of middle and south Africa. But for its short, thick, and very blunt muzzle, it might be compared to a gigantic pig. The body is extremely massive, and the legs so short, that the belly almost touches the ground; and it is destitute of any covering but a few weak and scattered bristles. The canine teeth are long; the upper ones straight, and the lower curved backwards, so that they rub against each other. Although ferocious, or rather courageous, when attacked, these unwieldy inhabitants of the waters are in their nature shy and retiring, and feed entirely on roots and other vegetables, seeming to prefer those which are partially decomposed by the action of the water.

3. The second family of true Pachydermata, to which the name of TAPIRIDÆ, or the *Tapir* tribe, may be given, resembles the first in the thickness of its skin, but differs in the arrangement of the toes, of which there are only three on each hind foot, and sometimes also in front, without any central cleft. There is considerable variation in regard to the teeth; but the whole family is exclusively herbivorous. No members of it exist in Europe at the present time; but fossil remains of very large species are abundant in some places. The *tapir* of America is about the size of a small ass, with a brown and almost naked skin, a short tail, and fleshy neck that forms a crest at the nape. It is common in humid places and along the rivers, and its flesh is eaten. The nose assumes the form of a short fleshy trunk—the rudiment, as it were, of that of the elephant. Other species have been recently discovered of a larger size; one of which has the bones of the nose still more elongated, approaching a very remarkable fossil genus, the *palæotherium*. This seems to have been an animal nearly allied to the tapirs. Remains of several species, varying in size from a rhinoceros to a small sheep, have been found in the gypsum quarries of Paris, and other places. [SEE GEOLOGY.]

To this family belongs the *rhinoceros*, which is remarkable for its large size, and for the kind of horn, composed of a solid fibrous substance, resembling agglutinated hairs, which is supported on an arch formed by the nasal bones. Several species exist in different parts of the tropical portion of the old world. They are naturally stupid and ferocious, frequenting marshy places, and subsisting on herbage and the branches of trees. In some species a second horn exists behind the first. The upper lip is generally elongated, and has some power of prehension. Rhinoceros' bones have been disinterred in many parts of Europe.

4. The third group of Pachydermata, the SOLIDUNGULA, contains only one family—that of the EQUIDÆ, or *Horse* tribe. Though there is only one apparent toe and single hoof to each foot, there are appendages beneath the skin which represent two lateral toes. The well-known animals of this tribe—the *horse*, *ass*, *zebra*, *quagga*, *onager*, and *dziggetai*—are commonly regarded as forming one genus. There are six incisors to each jaw, which, during youth, have their crowns furrowed by a groove, and six molars on each side, above and below, with square crowns, marked, by plates of enamel which penetrate them, with four crescents. The males have, in addition, two small canines in their upper jaw, and sometimes in both; these are always wanting in the females. Between the canines and the first molar there is a wide space, which corresponds with the angle of the lips, where the *bit* is placed, by which alone man has been enabled to subdue these powerful quadrupeds.

5. The animals associated in the family *Manatidæ*, may be considered as Pachydermata still more adapted than the hippopotamus to an aquatic residence. In their teeth and general organisation, they bear a close correspondence to this order; and the fish-like form which they exhibit, is scarcely a greater variation than is seen in the order Carnivora. The posterior extremities of those animals are entirely wanting, as in the true Cetacea. The type of this family is the *manati*, which grows to the length of fifteen feet, and frequents the mouths of the African and American rivers. It is called sea-cow, and its flesh is eaten.

This group is connected with the true Pachydermata by several fossil genera, but particularly by a very remarkable one recently discovered—the *dinotherium*, for a figure and description of which, see GEOLOGY. This must have been the largest of the Mammalia not strictly aquatic, its total length being probably eighteen feet. It blends the characters of the tapir and elephant with that of the Cetacea, having probably possessed a trunk and an enormous pair of tusks, directed downwards, though fixed in the lower jaw, and having been deficient in posterior extremities. The tusks, like those of the morse, were probably employed in raking up vegetable matter from the bottoms of the rivers and lakes it seems to have inhabited.

X.—Ruminantia.

The order Ruminantia is perhaps the most natural and best determined of the whole class, for all the species which compose it seem constructed, as it were, upon the same model, the camels alone presenting any considerable exceptions to the general characters of the group. The first of these characters is the entire absence of incisor teeth from the upper jaw; whilst the lower appears to possess eight; of these, however, the two outer ones are really canines which have taken the form of incisors, so that the number of the true incisors is six, as in the other viviparous Mammalia. The molars are almost always six in number, both above and below, and have their crowns marked with two double crescentic ridges of enamel, which aid in triturating the food. The feet are each terminated by two toes and two hoofs, which present a flat surface to each other, appearing as though a single hoof had been cleft; hence the names that have been applied to these animals, of cloven-footed, &c. Behind the hoof there are always two small spurs, which are the vestiges of lateral toes.

The name of the order intimates the singular faculty possessed by these animals of masticating their food a second time, or 'chewing the cud.' This faculty depends on the structure of their stomachs, which are four in number. The food which is cropped by the incisor teeth, is swallowed almost without mastication, and is moistened in the stomach; and after being compressed into little pellets or *cuds*, is returned to the mouth to be rechewed while the animal is at rest. When this operation has been performed, the food is transmitted to the true digestive stomach, as already explained under ANIMAL PHYSIOLOGY.

The Ruminantia are exclusively herbivorous animals. As a group, they are timid and innocent, and destitute of powerful means of defence. With this character their structure corresponds. Their legs are long in proportion to their body, and the spinal column is very flexible; both which conditions are favourable to great activity of motion. They are endowed with a very acute sense of smell, which seems to be their guide in the selection of their food. Their ears are placed far back, and are very movable; and these are well adapted to catch sounds from behind, so as to warn the animals of danger whilst feeding. The eyes are placed at the sides of the head, and the pupil is in the form of a horizontal oblong; so that the range of vision along the surface of the earth is very great, and the animals can easily look behind them when pursued. Their means of defence consist in the use of their horns to gore the enemy, and of their hind feet to kick it; but it is only when peculiarly courageous that single animals of this species will act on the offensive, or stand on the defensive, against others of proportional size and strength.

The Ruminants, of all animals, are those which are most useful to man. They supply him with a large proportion of his animal food. Some serve him as beasts of burden; others furnish him with their milk, their tallow, leather, horns, and other useful products.

The great resemblance which exists among the very numerous members of this order, renders the distribution of them into families, each characterised by some important peculiarity, a matter of some difficulty. These subdivisions are, probably, best erected upon the character of the horns, which are possessed by the males of all the species in their natural state, excepting such as (like the camel) connect this order with other groups. The horns are essentially bony prominences from the fore part of the skull. In some Ruminants, commonly termed *cattle*, such as oxen, sheep, goats, and antelopes, these prominences are covered with an elastic sheath, formed as it were of agglutinated hair, which continues to increase by layers during life. It is to the substance of this sheath that the name of *horn* is commonly applied, whilst the bony support is termed the *core*; this grows during life, and never falls. In the *giraffe*, again, the bony prominences are covered with a hairy skin, which is continuous with that of the head; and here, too, the bony part of the horn is permanent. But in the *deer*, these prominences, which are covered for a while with a hairy skin (commonly termed the *velvet*), like the other parts of the head, have at their base a ring of bony tubercles, which periodically enlarge, and compress the nutritive vessels of the horns. These accordingly die, and fall from the skull; and the animal remains defenceless. Others, however, are reproduced, generally larger than before, which are destined to undergo the same fate. These horns, periodically renewed, are usually styled *antlers*.

The Ruminants with horny sheaths to the bony prominences may be divided into three families. ANTELOPIDÆ, or *Antelope* tribe, characterised by the light-

Spring-bok Antelope.

ness of their forms and the activity of their movements, and by the solidity of the bony core. CAPRIDÆ, or *Goat* tribe: in these the bony core is partly occupied with cells, and the general form approaches that of the Ox tribe; but the horns are directed upwards and backwards. BOVIDÆ, or *Ox* tribe: these have the horns directed upwards and forwards; the form is robust, and the movements heavy. The division of the Ruminants in which the horns are periodically cast off, constitutes only one family, that of CERVIDÆ, the *Stag* tribe. Another family, including only the giraffes, and named CAMELOPARDÆ, is characterised by the shortness and permanence of the horns, which are covered with a skin. Of the Ruminants without horns there are two distinct families—the MOSCHIDÆ, or *Musk-deer*, which are remarkable for their elegance and lightness, and differ but little from the rest of the order save in the absence of horns; and the CAMELIDÆ, or *Camel* tribe, which in their dentition, and in the structure of the extremities, exhibit a transition to the Pachydermata.

1. The family ANTELOPIDÆ, remarkable for the slenderness of form and swiftness of foot of the animals composing it, contains above seventy well-ascertained species, bearing a strong general resemblance to each other. Most of these are natives of Africa; a few species, however, inhabit Asia; a still smaller number exist in America; and one only, the *chamois*, now remains in Europe. Among these numerous species we meet with forms that remind us of the other families of the Ruminantia—the ox, goat, stag, &c. They generally associate in large herds, which migrate together in search of pastures. A species well known to the colonists of South Africa is the *spring-bok*, which occasionally visits their cultivated lands, during seasons

of drought, in innumerable herds, causing devastation wherever they pass. The antelopes may probably be regarded as the types of the Ruminantia, exhibiting the peculiar characters of the order in the most remarkable degree. They are extremely vigilant and timid; and the speed of the swiftest species surpasses that of every other mammiferous animal. Those which are adapted to live on rocks and mountains exhibit the most remarkable agility, and fearlessness of those dangers which their habits would seem to involve; they walk with perfect composure along the giddy brinks of the most awful precipices, climb and descend with wonderful care and precision, and leap up or down to the smallest surface that will contain their collected feet, with perfect firmness; and yet they are so fearful of any supposed enemy, that it is difficult to get within gunshot of them.

2. The family of Capridæ is connected with the last by many antelopes which, like the chamois, approach the goats in form. It includes only the *goats* and *sheep*. The original stock of the domestic breeds of the former appears to be indigenous to Persia, where it inhabits the mountains in large troops. The goats of Angora, Thibet, &c. celebrated for the fine quality of their hair, are no more than varieties of the common species. The *ibex*, which inhabits the mountains of the old world, and especially the Caucasian chain, is distinguished by the size and strength of its horns. It is said that this animal fearlessly precipitates itself down precipices, always falling on its horns, the elasticity of which secures it from injury. The *sheep* appear to have extremely little real difference from the goats: a large number of races exist, the relation of which to each other is uncertain; and there is doubt as to the original stock of the whole. Of the domestication of this animal we have an earlier record than of any other.

3. The species of the Bovidæ, or *Ox* tribe, are comparatively few. They are all rather large animals, with a broad muzzle, heavy and massive body, and stout limbs. Of the original stock of the domestic ox we have no certainty, since, as in the case of horses, the existing races of wild cattle are probably all descended from those which have been at some period subservient to man. Of all the animals which have been reduced to his service, the ox is, without exception, that to which he is most indebted, for the extent and variety of its means of usefulness. The universal utility of the animal appears to have been very soon detected; and we find, consequently, that its domestication soon followed that of sheep, and that it is mentioned in the most ancient records as a servant of man, long before either the horse or dog are noticed.

Cape Buffalo.

Amongst the undomesticated species of this family, which have all a strong general resemblance to each other, and are the most powerful and savage animals of the whole order, may be noticed the European *bison*, which was formerly spread over Europe, but is now restricted to Lithuania and the Caucasian region; the American bison, commonly called *buffalo*, which inhabits all the temperate parts of North America; the *Indian buffalo*, of which there are several different races (in one, the horns include a space of ten feet from tip to tip), of which some have been domesticated; the *Cape buffalo*, an extremely ferocious animal, with large horns, first directed downwards, so as nearly to cover the forehead, inhabiting the woods of Caffraria; and the *musk-ox*, a species inhabiting the coldest regions of North America, with short legs, and long hair reaching the ground, which diffuses more strongly than the rest the musky odour common to the whole genus, and which is particularly noticeable in the European bison.

4. The Cervidæ, or *Stag* tribe, includes, like that of antelopes, a considerable number of species, differing but little from each other, very widely diffused over the earth's surface, and easily separated from others by the character of the horns. With the exception of the reindeer, however, the female is destitute of horns, save in a few rare individual cases, analogous to those in which the hen assumes the plumage of the cock bird. The substance of the horns, when completely developed, is that of a dense bone, without pores or internal cavity; their figure varies greatly according to the species, and even in the same individual at different ages. These animals are extremely fleet, and live mostly in forests, where they feed on grass, the leaves and buds of trees, &c. They may be subdivided into sections, according to the form of the antlers. In some, these are wholly or partially flattened, as in the *elk*, one of the largest existing species, which lives in troops in the marshy forests of the north of both continents. It is as large as a horse, and sometimes larger. The antlers of the male, at first dagger-shaped, and then divided into narrow slips, assume, at the age of five years, the form of a triangular blade, with tooth-like projections on its outer edge. These increase with age; so that the horns have at last fourteen branches proceeding from each expanded portion, and weigh fifty or sixty pounds. To this group also belongs the *reindeer*, so serviceable to the Laplanders, which is the only species properly domesticated, though others are doubtless susceptible of being so. The *fallow-deer*, now naturalised in this country, but probably introduced from the south of Europe, is another species of this group. The remains of a gigantic species of deer, belonging to the same section, are frequently found in peat bogs, and other recent deposits in this country, and more especially in Ireland, whence the name *Irish elk* has been given to it.

The species with round antlers are more numerous; those of temperate climates change colour, more or less, with the seasons. The common stag, or *red deer*, is the best known of these, being indigenous to the forests of all Europe and of the temperate parts of Asia. The Canadian stag, or *wapiti*, the elk of the Anglo-Americans, is a fourth larger. A great number of species are indigenous in Central and Southern Asia.

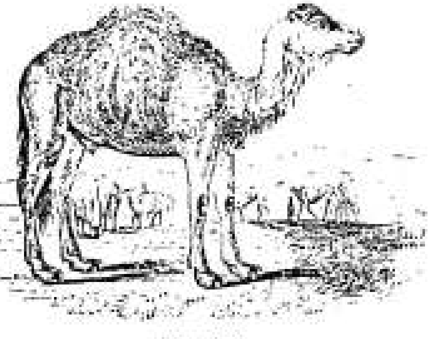
5. Of the family Camelopardidæ, only one species was for a long time known to exist; but there are probably two, or even three, kinds of giraffe, all of which are natives of Africa, frequenting chiefly the borders of the deserts. Its remarkable form, depending chiefly on the great length of its neck and fore legs, is familiar to every one. In its general structure, however, it closely resembles the deer; differing from them in the permanence of the horns. It has also some points of affinity to the camels; especially in the length of its neck, the existence of callosities, or hard surfaces, on the breast and knees, and the absence of the small spurious hoofs. It is the tallest of all animals; its head being frequently raised eighteen feet from the ground. Its disposition is gentle, and it feeds on leaves; browsing upon the young branches at a height much above that which any other animal can reach, and drawing them towards its mouth by its prehensile tongue. It lives in small troops of five or six individuals, and is

very timid, although capable of powerfully defending itself by kicking. Notwithstanding the length of its neck, the number of vertebræ which this part contains is no greater than in other Mammalia.

6. The MOSCHIDÆ, or *Musk-deer*, are completely intermediate between the true *Deer* and the *Camel* tribe, which last connects the Ruminantia with the Pachydermata. They resemble the ordinary Ruminants in the lightness and elegance of their forms, and in the nimbleness of their movements; and differ chiefly in the absence of horns, and in the projection of the canine tooth on each side of the upper jaw, as in the camels. The name of this group has been derived from the common Musk, the males of which secrete the odoriferous substance so called. This species is almost without tail; and the hairs, which completely cover it, are so coarse and brittle, that they might almost be called spines. It is confined to the mountainous region between Siberia, China, and Thibet, from which most of the Asiatic rivers descend. Its habits are nocturnal and solitary, and its timidity extreme. The other musk-deer inhabit the warmer parts of Asia and the eastern Archipelago; they have no musk pouch. They are the smallest and most elegant of the Ruminantia, and are active and gentle in their habits.

7. The CAMELIDÆ, or *Camel* tribe, approximate to the preceding order, and especially to the whole-hoofed division of it constituting the Horse tribe, more than do any other Ruminants—to such a degree, indeed, that some naturalists prefer associating them with that group. They have always canines in both jaws, and two of the incisors have also the same pointed shape. The animals of this family are much less elegant in form and graceful in action than the other Ruminants; but their organisation is, equally with theirs, most perfectly adapted to the circumstances in which they exist. The family contains two groups—the *Camels* and *Llamas*; the former are restricted to the old world, and the latter correspond to them in the new.

In the true *Camels*, the two toes are united below by a kind of horny sole, almost to their points, which terminate in small hoofs; and there is a soft cushion beneath the foot, by which it bears upon the sandy surface over which it is formed to move. Two species are known, one called the *Bactrian*, or *two-humped camel*, and the other the *Arabian*, or *one-humped*. Both are completely domesticated. The first is employed chiefly in Central Asia, the latter in Arabia, North Africa, Syria, Persia, &c. The two-humped camel is the larger and stronger, being capable of sustaining above one thousand pounds' weight, and is best adapted for rugged ground; the other is the most abstemious, and the best



Dromedary.

fitted for the sandy desert. The *dromedary* is merely a lighter variety of it, possessed of greater fleetness and power of endurance. The flesh and milk of the camel serve as food, and the hair for the manufacture of cloth, to the people who possess it. Their humps, principally composed of fat, are provisions of superabundant nutriment, which are gradually absorbed and disappear on the occasion of a scarcity of other food, as is observed at the end of a long journey. By resting on their callosities, they are enabled to repose on a scorching surface, and their stomachs are adapted to contain a supply of water sufficient for several days.

The *Llamas* of South America are much smaller than the preceding; they have the two toes quite separate, and are without humps. They were the only beasts of burden possessed by the Peruvians at the time of the conquest. They can only make short journeys, and the largest of the four species known cannot sustain more than one hundred and fifty pounds. Remains of a fossil species have been lately found, which must have equalled the camel in stature.

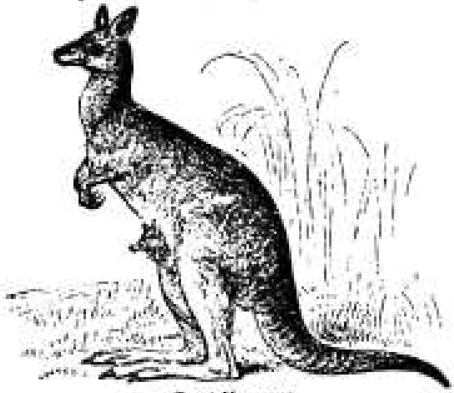
XI.—Marsupialia.

The two remaining orders of Mammalia, the Marsupialia and Monotremata, are now usually regarded as constituting a distinct sub-class, termed *Ovo-vivipara*, intermediate between the truly viviparous Mammalia and the oviparous Birds and Reptiles. Their most obvious peculiarity is the production of their young at a very early period of development, resembling the half-formed chick in an egg which has been but a few days incubated. In accordance with the lower grade of this important function, we find a general inferiority of the whole organisation to that of the truly viviparous Mammalia. The skeleton, the nervous system, the arrangement of the large blood-vessels, and the larger number of the incisor teeth (which in the higher subclass never exceed six), all show indications of this approximation; and this is also indicated in the deficiency of intelligence, which is manifest in their physiognomy as well as in their actions.

Of these two orders, that of Marsupialia is the one which exhibits the least departure from the general type of the Mammalia; and it is that, too, in which the provision for the continued nourishment of the young by its parent is the most remarkable. The new-born imperfect offspring attaches itself to the teats of the parent, and remains fixed there until it has acquired a degree of development comparable to that with which other animals are born. The skin of the abdomen of the parent is so disposed as to form a pouch, in which these imperfect young are protected, and into which, long after they can walk, they retire for shelter on the apprehension of danger. It is from the pouch (*marsupium*) that the order takes its name, this being its distinguishing peculiarity. It is remarkable that, notwithstanding the general and usually very striking resemblance of the species to each other, they differ so much in the teeth, the digestive organs, and the feet, that, if we rigidly adhere to these characters, we should find it necessary to separate them into distinct orders.

The geographic range of this order is extremely peculiar. With the exception of the Opossum group, which inhabits America, its species are at present almost confined to Australia and the neighbouring countries, where they constitute, with the Monotremata, almost the only mammaliferous animals.

The Marsupials may be divided into families according to the nature of their food. Some of those inhabiting Australia (*dasyurus*) are carnivorous, and display considerable ferocity. The *Opossums* have a mixed diet; and are remarkable for possessing an opposable thumb, like that of Quadrumana. Another group is more formed to live in trees, where they feed upon insects and fruit; to this belongs the *petaurus*, or flying opossum, which is formed upon the same plan with the flying lemur. The *Kangaroos*, of which several species exist, resemble the Ruminantia in food and habits. They are remarkable for the enormous length of their hinder feet, whence their generic name, *Macropus* (long-footed), is derived. The hind legs and tail are also very largely developed; whilst the fore legs and feet are very small. From this great inequality in the size of the limbs, they advance on all-fours very slowly; but they can make immense leaps with the hind legs, the tail probably assisting them. These are furnished with one large nail, almost like a hoof, which is a powerful weapon of offence and defence; for, supporting itself upon one leg and its tail, the animal can inflict a very severe blow with the leg which is at liberty. It will sometimes grasp its enemy with its fore paws, whilst it kicks it with its hind foot; but this it will only do when attacked, for it



Great Kangaroo.

is naturally a very gentle animal. The largest species is sometimes six feet in height, having the bulk of a sheep, and weighing 140 lbs. Its flesh is used as food by the New Hollanders, and is described as being like venison. The members of the last family, which includes the *Wombats*, are root-eaters, and in the structure of the teeth and alimentary canal are true Rodents.

XII.—Monotremata.

The order Monotremata contains but two species—the *echidna*, or spiny ant-eater, and the *ornithorhyncus*, or duck-billed platypus; and these are found nowhere else than in New Holland and Van Diemen's Land. These were included by Cuvier (who regarded the absence of teeth as the chief character) amongst his Edentata; but zoologists have now generally agreed that the peculiarities of their structure and physiology fully entitle them to rank as a distinct order, even more dissimilar to the other Mammalia than are the marsupial quadrupeds just considered. Until recently, indeed, it was much doubted by many, whether they could be included among the class Mammalia at all, since their organisation did not appear at all adapted for the nourishment of the young by suckling, which is the essential character of the group. The lips of both animals, in adult age, are of horny consistence, resembling the bills of birds; in the echidna they are prolonged into a narrow beak, and in the ornithorhyncus they form a wide flat bill like that of a duck. Moreover, the presence of glands for the secretion of milk appeared doubtful. But the late researches of Mr Owen have shown that the lips, in the young state of these animals, are much softer and more flexible, and that mammary glands certainly exist; so that the question may now be regarded as decided.

The name and character of the order are derived from the fact of the excretory openings at the posterior part of the body being united into one, as in birds; and this is a point of very remarkable affinity with that class, which is borne out by their *general* organisation. There is a sort of clavicle (collar-bone) common to both shoulders, placed before the ordinary clavicle, and analogous to the *furcula* (merry-thought) of birds. Each foot possesses five claws; and, besides these, the males have a peculiar spur on the hinder ones, like that of a cock. The young ornithorhynci are produced in an extremely imperfect state; the fur being totally wanting, and the place of the eyes scarcely discernible. The tongue, which in the adult is lodged far back in the mouth, advances in the young close to the lower mandible; and this disproportionate development, viewed in connection with the flexibility of the bill, is evidently designed to enable it to derive its nourishment by suction. The young echidna has not yet been discovered.

The *Echidna* is characterised by the slenderness of the prolonged muzzle or bill, which contains an extensible tongue, like that of the ant-eater. The feet are short, very robust, and adapted for digging. The whole upper part of the body is covered with spines, bearing some resemblance to those of the hedgehog; and when apprehensive of danger, and unable to escape from it by burrowing, the animal can erect its spines, and roll itself into a ball. The habits of the *Echidna* are but little known; for they do not exist in any large number; and they burrow so rapidly in the ground, that even when one is discovered, it is not easily got hold of. To lift it from the ground requires more force than would be supposed; for it firmly fixes itself to the earth in an instant, and but a few moments elapse before it is so far down, that its back is level with the surface. It feeds upon insects, principally ants, which it captures by its long extensile tongue; and this appears to be furnished with a glutinous secretion which causes them to adhere to it.

The muzzle of the *Ornithorhyncus*, as already stated, bears a close resemblance in form to the bill of a duck. The jaws contain no true teeth; but there are two pairs of horny ridges on each side, which may be considered as representing them. The fore feet are furnished with a membranous web, which not only connects the toes, but extends beyond the claws. The under surface or palm of this is concave, so that it can strike the water with great effect; but when the animal burrows, it falls back behind the claws. The hind feet are directed backwards when the animal is swimming, and somewhat resemble a fin; the membranous web does not extend on them, however, beyond the roots of the claws. The tail is broad and flat. The body is covered with two kinds of hair, like those found in the seal and the otter; the one fine, long, and thick; the other a still finer, short, and very soft fur. The whole organisation of the animal adapts it for seeking its food in the water, and for chiefly inhabiting that element. It burrows in the banks of rivers, and seeks its food in precisely the same manner as the duck. River insects, small shell-fish, and water-plants, appear to constitute its nourishment. The animal is very timorous; and if alarmed whilst at the surface of the water, dives down head foremost, and does not ascend at the same spot. In captivity, it is said to be harmless and playful; but it moves with great difficulty over the surface of the ground.

Such is the class Mammalia; a class the members of which are of the highest importance to man, not only from their occupying the chief grade in vital development, and therefore in some measure partaking of the characteristics of his own being, but from their supplying him directly or indirectly with much that is necessary to the comfort of his existence. The horse, ass, ox, reindeer, elephant, camel, llama, and dog, in their respective countries, assist materially in lessening the amount of his drudgery and toil; these and others, with their skins, hair, fur, and wool, furnish him with his finest, warmest, and most durable clothing; the flesh and milk of many are principal elements in the food of most nations; while the horns, teeth, bones, bristles, &c. of others, are fashioned into numerous articles of utility or ornament. Viewing them, therefore, as fellow-creatures exhibiting structural adaptations, instincts, and propensities somewhat akin to our own, as contributing economically to our well-being and comfort, and as partakers of the same common bounty, we should ever treat them, and all other animated forms, however humble, with considerate kindness. Even the most bloodthirsty and destructive are indispensable parts of the great scheme of creation; and while reason may dictate their suppression for our own safety and advantage, it as sternly forbids every approach to wanton massacre and cruelty.

CLASS II.—BIRDS.

Birds take their place as a class immediately after Mammalia, in consideration of their possessing, like them, a complete double circulation and warm blood; while, on the other hand, they approach the Reptiles in being oviparous. There is a more striking conformity in the entire class of Birds to one general type than is seen in any other group of equal extent in the Animal Kingdom. All are remarkable for the arrangements made in their organisation for lightness in proportion to bulk, a provision necessary for the aërial life which they generally lead. They are divided into orders, with the usual regard chiefly to external peculiarities and obvious habits—namely, INSESSORES, Perching-Birds; RAPTORES, Birds of Prey; SCANSORES, Climbing-Birds; RASORES, Scrapers; CURSORES, Runners; GRALLATORES, Waders; NATATORES, Swimmers.

I.—INSESSORES.

This is an extensive group of birds, presenting no very marked differences among its members. The principal character in which all agree, is the slenderness and shortness of the legs, with a form of foot (three toes in front and one behind, furnished with long and slightly-curved claws) adapting them to *rest* on the branches of trees; hence the name of the order. Their food is various, but in general mixed, consisting of insects, fruit, and grain; a few are almost as predacious as the regular birds of prey. In general, the females are smaller and less brilliant in their plumage than the male: they always live in pairs, build in trees, and display the greatest art in the construction of their nests. The young come forth from the egg in a blind and naked state, and are wholly dependent for subsistence, during a considerable period, upon parental care. The *larynx*, or organ of voice, is always of complex structure in the members of this order, which contains all that are commonly known as singing-birds. There are few that do not either sing, or utter some peculiar note or chatter analogous to song, during the season of courtship; and even of those which in general utter only monotonous cries, or of which the notes are harsh, some are frequently capable of being taught to speak, to whistle airs, or to imitate other sounds.

The families composing the order may be distributed under four large groups or assemblages, characterised by the respective forms of their bills. The CONIROSTRES have a stout beak, more or less conical, and with regular edges. The DENTIROSTRES have the upper mandible notched, as in the Raptores, towards the point; but this notch only exists in the horny covering, and not in the bone. The FISSIROSTRES have a short, broad, horizontally-depressed beak, so formed, that the gape of the mouth is extremely wide; it is slightly hooked, but without any tooth at the edge. The TENUIROSTRES have the bill very slender and elongated; sometimes straight, and sometimes curved.

1. The CONIROSTRES are to be regarded as containing the types of the order, the species belonging to it having the most varied faculties. They feed indiscriminately upon insects and vegetables, and are therefore termed omnivorous. Their feet are so constructed, that they can walk upon the ground with nearly the same facility as they perch upon branches. The families included in this tribe are the CORVIDÆ, or Crows; STURNIDÆ, Starlings; FRINGILLIDÆ, Finches; BUCERIDÆ, Hornbills; and LOXIADÆ, Crossbills:—

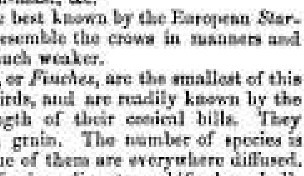
Of the family CORVIDÆ, the common *Crows* are the most characteristic examples, and may be regarded as combining the general features of the class in a greater degree than any other birds. In every climate habitable by man these birds are found: they are constructed for powerful and continued flight, as well as for walking firmly upon the earth; they feed indiscriminately on animals or vegetables, and, when pressed by hunger, do not refuse carrion: their smell is remarkably acute. They are bold, but wary, live in common societies, and possess great courage: when domesticated, they possess a power of imitating the human voice nearly equal to that of the parrot; and, like it, show signs of greater intelligence than is found in the rest of the class. Under the general term *Crow* are included the raven, which is the largest of European perching-birds, and which is bold enough occasionally to carry off poultry; the corby crow, which is very destructive to eggs and young game; the rook, which chiefly feeds on insects, and especially devours the grubs of the Coleoptera, though it occasionally eats grain, if its proper food be scarce; the hooded crow; and the jackdaw. The *magpies* are nearly allied to the crows; as are also the *jays*, which live principally, however, in woods, and feed on acorns, beech-mast, &c.

The STURNIDÆ are best known by the European *Starling;* they greatly resemble the crows in manners and structure, but are much weaker.

The FRINGILLIDÆ, or *Finches*, are the smallest of this group of perching-birds, and are readily known by the shortness and strength of their conical bills. They subsist generally on grain. The number of species is very great; and some of them are everywhere diffused. The sparrows, chaffinches, linnets, goldfinches, bullfinches, and larks, are those best known in Britain.

The BUCERIDÆ, or *Hornbills*, are readily distinguished at first sight by the enormous size of their bills, which are swollen or enlarged at the base into protuberances resembling horns or knobs, which are sometimes as large as the beak itself. The form of this excrescence varies much with age; and in very young individuals there is no trace of it perceptible. It is not solid, except in one species, but composed of a fragile network of bony fibres. The use of this curious appendage is unknown. The Hornbills are gregarious noisy birds, of large size, and are peculiar to the old world. They subsist on all sorts of food—devouring fruits, chasing mice, small birds, and reptiles, without disdaining carrion. They breed in the clefts of lofty trees.

The LOXIADÆ, or *Crossbill* tribe, contains a large number of genera, of which the common crossbill can scarcely be regarded as a characteristic illustration, the peculiarity from which it takes its name not being possessed by more than a few other species. This peculiarity consists in the strong curvature of the mandibles, so that their tips pass each other, and not always on the same side. By this extraordinary bill, the bird is enabled to extract the seeds from pine-cones with astonishing facility, and it is confined to localities in which these are to be obtained. The species common in Western Europe has of late years become more abundant in the British Isles, where it was previously known as an occasional straggler.

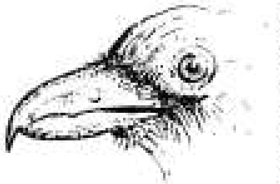


Beak of Crossbill: *a* and *b*, muscles which move it.

2. The DENTIROSTRES are the most allied of all the Insessores to the Birds of Prey. As the name imports, the species it includes are distinguished by a distinctly notched bill; and they are the greatest destroyers of insects among the Perchers. With very few exceptions, they either live entirely on insects, or resort to fruit only when insufficiently supplied with their favourite nourishment. The mouth is protected on each side by bristles, which defend the soft parts during the struggles of the prey; and the feet are generally adapted more for perching than for walking. The form of the beak varies in different species; in the shrikes, for example, it is stout and compressed, whilst it is flattened or depressed in the fly-catchers, which lead towards the Swallow tribe. The group includes the following families:—LANIADÆ, or Shrikes, which most prominently manifest the peculiarities of

the section; MERULIDÆ, Thrushes, in which there is less restriction to peculiar kinds of food; SYLVIADÆ, or Warblers, chiefly peculiar for the small size, delicate structure, and vocal powers of the species it contains; AMPELIDÆ, or Chatterers, distinguished by the enormous width of their gape; MUSCICAPIDÆ, Fly-catchers, which are more exclusively insectivorous than the rest of the tribe, and have small and weak legs.

The analogy between the LANIADÆ, or *Shrike* tribe, and the rapacious birds, is extremely evident. In the most characteristic specimens of the family, the bill, which is in all short and strong, is abruptly hooked at the point, and the notch so deep, as to form a small tooth, more or less prominent on each side: by this conformation, the bird is enabled to take a firm grasp of its food, and to tear it in pieces. The claws, also, are usually strong and sharp. Like many of the falcons, the shrikes will sit for hours watching for their prey, which consists of small birds, and, in the less powerful species, of insects; and will suddenly dart down upon such as come within their reach, seize it with their feet, and carry it home to be devoured at leisure. They not only pursue small birds, but successfully defend themselves against larger ones, even attacking them when they intrude in the vicinity of their nests. Many species feed also upon frogs, and other small terrestrial animals. The family contains a large number of species, distributed through all quarters of the globe.



Bill of Shrike.

The MERULIDÆ, or *Thrushes*, have an arched and narrow beak, but the point is not hooked, and the lateral tooth is not so marked as in the shrikes. Nevertheless, the transition from one form to the other is very gradual. This family is inferior to the shrikes, therefore, in the peculiar organisation adapted to rapacious habits, but they possess a greater variety of powers. It is in this family that we find the birds most distinguished for the sweetness, compass, and versatility of their song. They are not confined to animal food, but live much on fruits and berries. The common *thrush*, the *blackbird*, and *fieldfare*, are well known and also characteristic examples. These, as well as the *missel-thrush*, *redwing*, *ring-thrush*, &c. are closely allied species of the same genus, of which the other members are distributed over the whole globe. The *mocking-birds*, on the other hand, which probably stand unrivalled for their powers of voice, are restricted to America: some of them approximate to the shrikes in their habits. A few species of the family have somewhat aquatic habits.

The chief peculiarity which runs through the numerous family of SYLVIADÆ, or *Warblers*, is the very small size and delicate structure of the species which compose it. Excepting the Humming-Birds, we find among these elegant little creatures the smallest birds in creation. The diminutive golden crests, the nightingale, the white-throat, and the wood-wren, are examples of this family well known to the British naturalist; as are also the robins, stone-chats, wagtails, tit-larks, and tit-mice. Its different groups are spread over all the habitable regions of the globe, and appear to have a peculiar function in the economy of nature, being specially designed to keep down the multiplication of the innumerable minute insects which lurk within the buds, the foliage, or the flowers of plants. The Sylviadæ are for the most part migratory birds; appearing in spring, when the insect world is called into life and activity by the renewal of vegetation, and disappearing in the autumn, when their supply of food diminishes.

Of the AMPELIDÆ, or *Chatterers*, the most characteristic examples belong to tropical America, and only one is found in Europe—the *Bohemian wax-wing*. The Chatterers are distinguished from all the other Dentirostres by the enormous width of their gape, which in many extends beyond the eye, and in some is nearly as wide as in the goatsucker. They subsist almost entirely on soft berries and small fruits, which they swallow whole.

The MUSCICAPIDÆ, or *Fly-catchers*, are a family hardly less numerous than that of the Warblers; and are composed, like that group, entirely of small birds. They are more purely insectivorous than any other of the order, few of them ever partaking of fruits. They are distributed through the temperate and tropical portions of the old world, and the temperate latitudes of the new.

3. The FISSIROSTRES form a comparatively small group; but it is very distinct from all others in the beak, which is short, broad, horizontally depressed, slightly hooked, and deeply cleft, so that the gape is extremely wide. The birds possessing this kind of bill are adapted for capturing insects on the wing, receiving their prey in full flight into their mouths, which remain open for that purpose; and the victim is secured by a gluey exudation within, and a strong fence of bristles on the outside, which also serves to protect the soft parts of the head from its struggles. Although such is the typical or characteristic form of the bill in the group, it is not always seen. In some species, the bill is stronger and longer; and these also are distinguished by having the external toe nearly as long as the middle one, and attached to it until nearly its end; to these the name of *Syndactyli* was given by Cuvier, who associated them into a separate group. The Fissirostres, as a whole, are peculiarly distinguished by having the powers of flight developed to the highest degree. All the energies of their nature seem concentrated in this one perfection; for their feet are always very short and weak, and serve but for little else than to rest the body after flight.

This group may be divided into the five following families:—HIRUNDINIDÆ, or Swallow tribe; CAPRIMULGIDÆ, or Goat-suckers—both these present, in a remarkable degree, the organisation which has been described as characteristic of the order; the remaining families have a longer and narrower bill, and are syndactylous—MEROPIDÆ, or Bee-eaters; HALCYONIDÆ, or Kingfishers; TODIDÆ, or Todies.

The HIRUNDINIDÆ, containing the swifts and swallows, are diurnal birds, remarkable, like the diurnal Raptores, for their close plumage, the extreme length of their wings, and the rapidity of their flight. The *swifts* possess these characters in the highest degree, and surpass all other birds in the power of sustaining a rapid flight for a long time. They are distinguished from the swallows by having the hind toe directed very much forwards; and all four toes are armed with strong crooked claws, which give to the bird such a firm grasp, that it can sustain itself by the side of perpendicular rocks or buildings with great facility. In some species, the tail feathers are very stiff, as in the woodpeckers, and serve as an additional support. They spend their time almost entirely in the air, and pursue insects in flocks, sometimes at a great height, uttering discordant screams. They nestle in the holes of walls and rocks. The *swallows* are less capable of sustaining a continued flight than the swifts. Several species exist in Europe, and many more in the warmer parts of the world. Among them may be mentioned a small species inhabiting the Indian Archipelago, which forms its nest of a species of sea-weed, which it macerates in its stomach, and then arranges in layers. These *edible birds'-nests*, as they are commonly termed, are highly prized as delicacies in China, and constitute an important article of traffic with that country.

The CAPRIMULGIDÆ, or *Goat-suckers*, are nocturnal birds, and have the same light soft plumage which characterises the owls. Their eyes are large, and their gape still wider than that of the swallows, so as to be capable of engulfing the largest insects. They come forth in the twilight, and return to rest before morning; but in their other habits they much resemble the swifts, with which, indeed, they are closely connected by intervening species; for whilst there are some which fly by day, skimming over the surface of ponds in small flocks, precisely in the manner of swallows, there is also a swift which only flies at night.

The family of MEROPIDÆ, or *Bee-eaters*, is confined to the warm regions of the old world; only one species being known as having occasionally strayed to Britain. They have long and pointed wings and short feet, and fly in the manner of swallows. The European Bee-eater annually visits Italy, in flocks of twenty or thirty, and may be seen skimming over the vineyards and olive plantations, especially pursuing bees and wasps. It is remarkable that they are never stung by these insects, which they seize and at once crush by a snap of their powerfully-compressive beaks.

The HALCYONIDÆ, or *King-fishers*, are remarkable for the great length of the bill, and the extreme shortness of the feet. Their habits are sedentary, much resembling those of the fly-catchers; but their food is more various. The common British species partly lives on small fish, which it takes by precipitating itself into the water, either from the branch on which it had perched, or by suddenly arresting itself during rapid flight, poising for an instant, and then plunging. It returns to its perch to gulp its prey, first killing it by repeatedly beating it against a bough.

The TODIDÆ, or *Todies*, are small American birds, resembling the king-fishers in their general form, and may be regarded as representing them in the new world.

4. The TENUIROSTRES, it has been well remarked, 'are among the most interesting of the animal world. Deriving their subsistence, for the most part, from the nectar of flowers, we never fail to associate them in our idea with that more beautiful and perfect part of the vegetable creation with which, in their delicacy and fragility of form, their variety and brilliancy of hues, not less than by their extracting their nourishment from vegetable juices, they appear to have so many relations.' This tribe is confined exclusively to the torrid zone and southern hemisphere. The length and slenderness of the bill are its distinguishing characteristics. It is not by this, however, but by the long filamentous tongue, that the juices of flowers are sucked up; and to protect this important organ, the peculiar conformation of the bill seems chiefly intended. The tongue is often simply forked; but is sometimes divided into so many slender filaments, as to resemble a painter's brush. The feet are very short and delicate.

The TROCHILIDÆ, or *Humming-Bird* tribe, so celebrated for the metallic lustre of their plumage, and particularly for the gem-like brilliancy of some of their feathers, have, within their long slender beak, a tongue capable of protrusion like that of the woodpeckers, and divided almost to the base into two filaments. These filaments are *not* tubular, as they are sometimes described, but are flattened. It is not improbable that the tongue may serve for catching insects, as well as for sucking the juices of flowers; since it is unquestionable that, like others of the order, the humming-birds are partly insectivorous. When hovering over flowers, these birds balance themselves in the air by a rapid motion of the wings, like many flies; and it is by this movement that the *humming* sound is produced from which they take their name. The family is exclusively confined to America; and, with few exceptions, to the southern part of that continent and the adjacent West Indian islands. About two hundred species are at present known; and others are constantly being discovered. The smallest of them, when plucked, is less than a large humble-bee; and one only, which is much larger than any others as yet known, nearly equals the common swift in size.

The CINNYRIDÆ, or *Sun-Birds*, represent the humming birds in the eastern continent. They are closely allied to the Trochilidæ in general structure, and in the mode of obtaining their food, but their tongue is not so deeply divided. They are small birds, and the males have the most brilliant colours, rivalling those of the humming-birds during the breeding season; but the garb of the female, and of the male at other times of the year, is much more dull. The PROMEROPIDÆ, or *Hoopoes*, are also restricted to the old world; one species, the common hoopoe, annually visits Europe, in company with the bee-eaters and other swallow-like families.

The PARADISIDÆ, or *Birds-of-paradise*, are among the largest of the order, and live, like the rest, chiefly upon soft vegetable substances. They are confined to New Guinea and the neighbouring islands. The extraordinary development of their feathery appendages is well known; but of the purpose these serve in their economy, no plausible account has been given.

The MELIPHAGIDÆ, or *Honey-suckers*, are distinguished from all the preceding families by their notched bill; their tongue is terminated by a bunch of delicate filaments, and the hind toe is so strong and robust, that it serves as a support to the bird during the process of feeding. This group is chiefly confined to Australia, where its members abound in great variety of form, and where they find a never-failing support in the luxuriant vegetation of that country.

The members of the family CERTHIADÆ, which consists of the Tree-creepers, Nuthatches, &c. strongly resemble the scansorial birds in their habits; but they more closely approximate to the Tenuirostres, and especially the Meliphagidæ, in general structure. Like these, they are of small size; the foot has three of the toes directed forwards, and the bill is more slender and delicate than that of the woodpeckers. The *Tree-creepers* bore into trees, however, and rest upon their tail in climbing, much as do the woodpeckers; but they rather seek for their food in the natural chinks of the trees, or among the mosses and lichens which cover the branches. The *Nuthatches* have a stronger bill, which is straight and pointed, like that of the woodpeckers. They use it, however, rather to scale off the bark than to perforate it, and they do not support themselves upon the tail. They feed not only upon insects, but upon various seeds, and are celebrated for the instinct of fixing a nut in a chink while they pierce it with the bill, swinging the whole body as upon a pivot, to give effect to each stroke.

II.—Raptores.

The rapacious birds constitute a well-marked group, which may be compared with that of the Carnivora among Mammalia. In comparison with the Insessores, their number is but few; had it been otherwise, they would soon have extirpated the whole race. They usually breed but slowly, leading solitary lives, and never appearing in numerous flocks. Most of them are large and powerful birds; and, what is an exception to the general rule, the female is larger than the male, but her plumage is usually of a duller aspect. There are few of this family which do not show great strength of wing; but the power and swiftness of flight which are possessed by the different species, vary with their habits. They are all remarkable for their strong hooked bill and large acute talons. The force of these is indicated by the size of the muscles of the legs and thighs; and the foot is usually but of moderate length, that its power may not be lost by being diffused over too large a space. It is by the talons that the prey is usually struck first; and, when secured by the feet, it is torn open by the bill.

The FALCONIDÆ, or *Falcon*, exhibit the perfection of the order, and correspond very closely in their general habits, and the adaptations of structure to them, with the Feline tribe among the Carnivora. Their bodies are of moderate size; their forms light, but powerful; their flight graceful; and their courage very great. They are technically distinguished from the vultures, to which (being both diurnal birds of prey) they are most nearly allied, by the bill being toothed or notched, as well as shorter and sharper; and by the acuteness and strong curve of their talons, which, like those of the Cat tribe, are retractile. The members of this family are almost universally diffused over the earth's surface, some species of them existing wherever there is a sufficient expanse of land. They are less abundant in islands, for a considerable extent of country is necessary to supply them with food. Their plumage is destitute of a bright assemblage of colours, but is nevertheless in several instances peculiarly elegant. The Falconidæ have been commonly divided into the *noble* and *ignoble;* the latter not being susceptible of being trained to the (so-called) noble sport of falconry. The noble division comprehends the *Falcons-proper*, which are distinguished from the rest by the size of the tooth on the mandible, and by the power of their wings, which are long and pointed. They are the most courageous of all the family, in proportion to their size, and are specially adapted to pursue and bring down their prey whilst it is on the wing. The *Eagles* may be considered as ranking next to the falcons. They are the largest and most powerful of the whole group, and pursue and destroy quadrupeds as well as birds. They are distinguished from all other Raptores by having the legs and feet feathered quite down to the toes. They usually build their nests in lofty and secluded situations, and resist with great courage any attack upon their young. The *Hawks*, *Kites*, and *Ospreys*, are well-known forms of this family.

The birds of the VULTURIDÆ, or *Vulture* tribe, are, on the whole, much larger than those of the previous family, but they are much less courageous. The beak is lengthened, and curved only at the end, and it is not in the least toothed. The power of their talons by no means corresponds with the stature of these birds, and they make more use of their beak than of their claws. Hence they are not adapted for a contest with a courageous victim, and rather seek carrion already decomposing, to which they are attracted—whether by the sight or by the smell, is still a disputed question. The vultures are most abundant in hot climates, where they perform important services, by removing decomposing carcasses, which would otherwise be a source of offensive and noxious exhalations. They are sparingly scattered over the south of Europe; in Egypt they are more numerous; and in tropical America, although the species are fewer, the individuals are much more plentiful.

The STRIGIDÆ, or *Owl* tribe, including all the nocturnal birds of prey, is characterised by the large proportion of the head to the body, and by the

Barn Owl.

size of the eyes, which are surrounded by a fringe of feathers. Their soft downy plumage, too, may at once be distinguished from the firm and sharply-cut feathers of the diurnal Raptores. All these peculiarities have reference to their habits. The size of the eyes has an evident relation to the small amount of light in which they are usually to be employed; the pupils are so large, that the birds are dazzled in full day; hence in part arises the stupid appearance which they exhibit. The fringe which surrounds them probably has for its object to prevent the interference of light from the sides above or below, and to enable them to concentrate their whole power of sight upon the object directly before them—as when we look through the hand contracted into a tube at some object which we desire to see more distinctly. This fringe is most remarkable in the *Barn Owl* and its *allies*. In the owls which are partly diurnal in their habits, this circular fringe is hardly perceptible. The owls seek their prey, not by power of flight, but by stealing upon it unawares; hence the movement of their wings should be as noiseless as possible; and this object is peculiarly answered by the downy character of the whole plumage, and by a particular arrangement of the barbs of the feathers at the edge of the wings. Their food is wholly animal; consisting of mice, frogs, small birds, fish in some instances, and insects.

III.—Scansores.

The peculiar disposition of the toes in the birds of this order—two being placed behind, and all four arising nearly on the same level—gives them great facility in climbing the branches of trees, but proportionally impedes their progression on level ground. By this character they may be readily distinguished from all other birds, notwithstanding many and striking variations in the form of the bill and wings. Their nests are generally less skilfully constructed than those of the Insessores; and they often employ for this purpose the clefts and hollows in decayed trees: one family is remarkable for depositing its eggs in the nests of other birds. Their flight is ordinarily but moderate. Their nourishment consists of insects and fruits; and the species feeding upon each may be distinguished by the greater or less robustness of the beak. They may be divided into the four following families:—

1. PICIDÆ, or *Woodpeckers*, chiefly characterised by their long, straight, angular bill, the end of which is compressed into a wedge, adapted to perforate the bark of trees. The tongue is also of peculiar conformation, being worm-like in its shape, barbed at its point, and capable of being suddenly thrust out to a great length. By this mechanism the bird can introduce it into holes and crevices, or even under the loose bark of trees infested by those peculiar insects which it is its province to destroy; and these they obtain, not only by transfixing them with the barbed point, but by causing them to adhere to it by means of a viscid glue with which it is covered. The feet of these birds are short, but very strong; the nails are broad and crooked. As an additional and powerful support in their rapid and perpendicular ascent up the trunks of trees, their tail-feathers are very firm, and terminate in points; so that this member, being pressed against the bark, is of assistance to the bird in maintaining its perpendicular attitude.

2. CUCULIDÆ, or *Cuckoos*, a numerous and diversified race, spread over all the temperate regions of the globe. They are principally distinguished by the short and slender make of the feet, of which one of the back toes can be occasionally brought forwards. The beak is of mean length, slightly arched, and compressed at its sides. Most of this family are migratory, and scarcely any build nests of their own. They fly rapidly, and subsist upon insects and fruits. The common cuckoo has long been celebrated for its habit of depositing its eggs in the nests of other birds, generally insectivorous species; and, what is more extraordinary, the foster parents, often of species inferior in size, bestow as much care upon the young cuckoo as upon their own proper nestlings, even though the rearing of this involves the destruction of their own young; for, if other eggs are hatched with that of the young cuckoo, the latter speedily ejects the rightful tenants from the nest, and receives all the attention of their parents. If it were not for this, it must speedily perish for want, from the frequency and urgency of its demands for food, and its long incapability of assisting itself.

3. RAMPHASTIDÆ, or *Toucans*, easily recognised by

the enormous size of the bill, which is nearly as large and long as the body itself, but internally very light and cellular; its edges are toothed, and both mandibles are arched towards the tip. The tongue is narrow and elongated, and laterally barbed like a feather. Their feet are formed more for grasping than climbing; accordingly, they always live among trees, and proceed by hopping from branch to branch. So light and elegant are their movements, that in the living bird, in its natural situation, the disproportionateness of the bill does not attract observation. Its large size is to give a more extensive distribution to the nerves of smell, for the purpose of enabling the birds to discover their food, which consists chiefly of the eggs and young of other birds, and also to enable them to obtain it, by dipping it into the deep hanging nests which abound in their natural abodes, for which purpose its surface is endowed with considerable sensibility, enabling it to feel the contents of these nests. Toucans are mostly large-sized birds, and clothed with brilliant plumage. They are peculiar to the warm regions of America, where they live in small flocks, different species often associating together.

4. Psittacidæ, or *Parrots*, a family which is very widely diffused through the torrid zone in both new and old continents, and is scarcely found beyond it. It contains a large number of species, each of which has its peculiar locality, the short wings of these birds not enabling them to traverse large tracts of sea. They correspond with the other Scansores in little else than the structure of the foot, and this is formed rather for grasping than for climbing. It is also used for conveying food to the mouth, a peculiarity nowhere else seen but in the goat-suckers. Their beak is stout, hard, and solid, curved and pointed, and serves to assist them in climbing. They subsist upon vegetable food, and have a peculiar provision for supplying their young, analogous to that which will be described as possessed by the pigeons. Their jaws are set in motion by a greater variety of muscles than are found in other birds. Their tongue is thick, fleshy, and rounded; and their larynx, or organ of voice, is more complicated than in other birds—by which peculiarities they gain their facility of imitating the human voice as well as other sounds. Their voice, in a state of nature, however, is loud and harsh. They use their crooked bills in clambering upon trees, where they feed, nestle, and spend almost the whole of their time.

IV.—Rasores.

This order, corresponding with the *Gallinaceæ*, or poultry tribes, consists of birds with bulky bodies, and essentially formed to live upon dry ground. They are the most easily domesticated of the whole class; they furnish man with a considerable amount of savoury and wholesome food, and their fecundity is very great. The majority of them are at once known by their strong thick legs, long necks, short wings, and large ample tails; and the heads of many, especially of the males, are ornamented with elegant crests. The form of the bill is well seen in the common cock; the upper mandible is vaulted, and at the same time destitute of any notch; the whole is short and strong, having a peculiarly horny appearance. The wings are muscular, but their feathers have rounded ends; and the breast-bone presents a much smaller surface for the attachment of the muscles than in the previous orders, so that the power of flight is comparatively small. Their food, with few exceptions, is entirely vegetable, and their chief support is derived from the seeds and grains of various plants. Many of them eat also the green portions, and are in this respect nearly peculiar among birds. Almost all of them have a large crop and an extremely muscular gizzard.

The Rasores are mostly social birds, and are readily domesticable. In general, they deposit and hatch their eggs on the ground, in a rudely-constructed nest of straw; but some of them, which reside in forests, build in trees. Each male usually associates with many females; he takes no part in the construction of the nest or in rearing the young, and these are generally numerous, and able to run about and provide for themselves the moment they quit the shell. When this is the case, the male is larger and more gaily-coloured than the female. But in the few species which associate in pairs, as the ptarmigan and partridge, the sexes nearly resemble each other both in size and colour.

From the strong resemblance which subsists among all the members of this order, the division of them into families is difficult. The following may be regarded as the most natural distribution:—1. Phasianidæ, *Pheasant* and *Fowl* tribe, distinguished by the shortness of the hind toe, the presence of spurs on the legs, and the beautiful development of the tail. 2. Cracidæ, *Curassows*, the legs of which are destitute of spurs, and the hind toe so much developed, as to give considerable power of perching. 3. Tetraonidæ, *Partridge* tribe, having a short hind toe, and also very short tails. 4. Columbidæ, the *Pigeon* tribe, which are much isolated from the rest, and may be regarded as in some respects allied to the Insessores. From the well-known character of most of these birds, a detailed description of the families is unnecessary.

1. The whole of the Phasianidæ, with the exception of the turkey, are restricted to the old world. The characters by which they are known from the other families, are those which peculiarly distinguish the order; hence there can be no hesitation in regarding this family as its type. It is in the hotter parts of Asia that the most brilliantly-coloured birds of this family present themselves in the greatest numbers. The *peacock*, for example, abounds in the forests of India; and the wild specimens even surpass the domestic ones in brilliancy. The *turkeys* are the only representatives of this group in the new world, whence they were brought by the early discoverers, and are now quite naturalised in Europe. The *guinea-fowl* is originally a native of Africa, where it lives in large flocks, in the neighbourhood of marshes. Of our common fowls, the original stock, like that of most domesticated races, is obscure; but it was probably a species of *gallus*, inhabiting Java or Sumatra. The *pheasants* were originally brought from the banks of the Phasis in Asia Minor: several very handsome species abound in different parts of Asia.

2. The Cracidæ, or *Curassows*, which are restricted to America, offer a remarkable contrast, in their plain colours, to the brilliant plumage of the Asiatic races which occur in nearly the same parallels of latitude. They are equally capable of domestication with the fowls; and their flesh is of excellent quality.

3. The Tetraonidæ, or *Grouse* tribe, also differ strongly from the Phasianidæ, in the comparative dulness of their plumage, as well as in the extreme shortness of the tail. The *grouse* are formed to inhabit cold climates, and are found in Europe, Asia, and North America. The largest species, commonly known as the capercailzie, is the largest of the true poultry, surpassing the turkey in size. It particularly feeds on pine shoots. These birds strut with outspread tail, in the manner of the turkeys; and are polygamous. The *ptarmigan* live in pairs, and do not strut in this manner; the more generally-diffused species become white in winter; there is one species peculiar to Britain, however—the moorfowl or red grouse—which does not change. Nearly all the grouse have the toes and legs more or less covered with soft feathers; a character which disappears in the *Partridges*, an extensive group, scattered in nearly all parts of the old world, but unknown in the new. In the *Quails*, we have the miniature resemblance of partridges, but the tail is so short, as to be nearly imperceptible.

4. The family of Columbidæ, containing a large number of elegant and lovely birds, appears as much isolated from the rest as the Parrots are from the Scansores. Although it is particularly numerous, and spread over every part of the world, there is no difficulty in distinguishing its members from all other birds.

One of their chief peculiarities is the *double* dilatation of the crop, which expands on each side of the gullet; and the young are fed with grain disgorged from this receptacle by the parent, and impregnated with a secretion which it forms. These birds live invariably in pairs; they nestle in trees, or in the holes of rocks, and lay but few eggs, though they breed often. This family includes the whole of the well-known tribe of *Pigeons and Doves*. Some of the tropical species are of considerable size, and of very rich plumage.

V.—Cursores.

This order contains a small number of species, differing so considerably from one another, that almost every one may be regarded as belonging to a different family, and yet all agreeing in one characteristic—the non-development of the wings, and the enormous size and power of their legs—by which they seem justly separated from all other orders of birds. They may be regarded as in many respects intermediate between the Rasores and Grallatores; but they also present many remarkable points of approximation to the Mammalia. The most obvious of these are the loss of the powers of flight, and the dependence on the legs alone for locomotion; and the deficiency (most conspicuous in the cassowary) of barbs upon the feathers, so that they much resemble hair. In their internal structure, moreover, similar approximations exist: thus the ostrich has the rudiment both of a diaphragm and urinary bladder, organs which are wanting in all other birds. Although destitute of the powers of flight, wings exist in an undeveloped or rudimentary state; and it has been observed that, when the ostrich is running, its small anterior members execute analogous motions, which seem to assist it. Their muscles, however, requiring but little strength, the sternum has no prominent keel, but is flat as in man; whilst, on the other hand, the muscles of the posterior extremities are of enormous size and power. Only five genera are at present known to exist in this order:—

The *struthio*, or ostrich, is a well-known bird in the tropical parts of the eastern hemisphere; its feathers do not differ so widely from those of other birds as do those of the cassowary, being furnished with barbs; but these do not adhere to one another, so that no continuous resisting surface is formed. Still, the wings present sufficient expanse to assist the bird in running; which movement it executes so swiftly, that scarcely any animal can overtake it. The *rhea*, or South American ostrich, is about half the size of the African ostrich, and more thinly covered with feathers. Two species, or rather varieties, exist, one inhabiting the central parts of South America, where it is as abundant in some localities as the ostrich in Africa; and the other in Patagonia, where it is rare.

The *casuarius*, or cassowary, has wings shorter than those of the ostrich, and quite useless in aiding progression. Besides the peculiarity of the feather, which has been already mentioned as giving it the appearance of hair, there is another, consisting in the great development of the *accessory plume*, so that two or even three equal stems appear to grow from the same quill. In its general aspect and size it much resembles the ostrich, but differs in the structure of its digestive organs. The head is surmounted by a bony prominence, covered with horn. The skin of the head and neck is bare of feathers, and of a bright-blue and flame colour; it is furnished with wattles, like those of the turkey-cock, which change colour under the same circumstances. It lives on fruit and eggs, but not on grain; and is an inhabitant of the Indian Archipelago.

The *dromaius*, or emu, is a native of New Holland, and is closely allied to the cassowary; but its plumage is more dense, from its feathers being more barbed.

The *apteryx* of New Zealand appears, of all birds, to have the wings reduced to the most simple rudiments; and it presents, at the same time, many points of approximation to the Mammalia. It has a complete diaphragm, and no air-cells exist in its abdomen; nor are any of its bones hollow. The bill is long and slender; the rudiments of wings are terminated by a sharp hook, which seems to be an important organ of defence; the feet have three toes in front; and the rudiment of a fourth behind, the claw of which is alone externally visible. The size of this bird is about that of a domestic fowl, and its colour a deep brown. It runs with rapidity, and defends itself vigorously with its feet. It is nocturnal in its habits, and subsists on insects.

With this group is probably to be associated the *dodo*, now known to us only by some very imperfect remains, and by the paintings and descriptions of naturalists nearly two centuries since, when it seems to have existed in the islands on the eastern coast of Africa, especially Madagascar; though no traces of it can now be found there. Another recently-extinct bird of the same group is the *Dinornis* (from *deinos*, terrible; and *ornis*, a bird), bones of which have been found in the river-mud of New Zealand, indicating a size nearly twice that of the ostrich.

VI.—Grallatores.

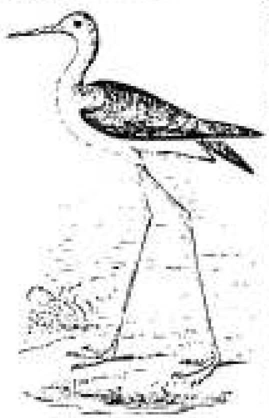
The Grallatores, Waders or Stilt-birds, derive their name from their habits and conformation. Their long legs raise up their bodies, as it were, upon stilts; and thus elevated, they frequent the banks of rivers and lakes, marshes, the shores of estuaries; and, whilst resting with their feet upon the land, derive their nourishment chiefly from the water—some feeding exclusively upon small fishes, aquatic mollusca, worms, small reptiles, and water insects—whilst others are of more terrestrial habits and food. Such as are more especially aquatic have a short web to their toes. Their wings are long, affording them the power of changing their habitation with the seasons, which most of them enjoy. During flight, they stretch out their long legs behind, to counterbalance their long necks; and the tail is always extremely short, its function as a rudder being transferred to the legs. They mostly construct or choose their nests upon the ground; and the young are enabled to run about as soon as hatched, except in those species which live in pairs. They are remarkable for their power of preserving a motionless position upon one leg for a considerable time.

The Waders may be grouped together under four families, principally characterised by the form of the beak:—1. Ardeidæ, the *Heron* tribe, in which the beak is long, thick, and stout, and has usually cutting edges, as well as a point. 2. Scolopacidæ, the *Snipe* and *Woodcock* tribe, in which the bill is long, slender, and feeble. 3. Rallidæ, the *Rail* and *Coot* tribe, in which the bill is less slender; but the chief character is derived from the extreme length of the toes. 4. The Charadriadæ, or *Plover* tribe, in which the bill is of moderate size, and the back toe either entirely absent, or not long enough to reach the ground.

1. The family of Ardeidæ includes the Cranes and Storks besides the true Herons. Nearly all the *Cranes* are large birds, with short powerless wings; their necks long, and frequently naked, and their habits more terrestrial than those of any of their congeners. They feed almost exclusively upon vegetables; and have a muscular gizzard. Most of them live in warm latitudes; and those which frequent Europe, migrate southwards in the autumn, and return in the spring. The *Herons* differ from the Cranes in being decidedly carnivorous; they are known by a larger and more pointed bill, and by the greater length of their legs. Their stomach is a large undivided sac, but slightly muscular. As a whole, they are the most beautiful of all the Waders; not so much, however, on account of the colours of their plumage, as from the elegant crests and prolonged feathers which ornament nearly all the species. They build in societies, usually in trees in the neighbourhood of banks of rivers; but generally feed and live solitarily. They are chiefly supported by fish, for which they watch in some concealed situation, transfixing them as they pass with their long and sharp bills. The *Storks* are less aquatic in their habits than the rest

of the family, nestling, by preference, on towers and chimney-stacks; each pair returning, for many successive seasons, to the same place in the spring, after having passed the winter in Africa.

2. The SCOLOPACIDÆ, or *Snipe* tribe, characterised by their long, slender, and feeble bill, which only enables them to bore in the mud in search of worms and small insects, have all nearly the same conformation, the same habits, and the same distribution of colours; so that it is difficult to distinguish amongst them. They are also remarkable for the delicacy of their legs, and the smallness of the hinder toe. They run with vast celerity, and have considerable powers of flight; and they have also the faculty, in part, both of swimming and diving. The females are usually larger than the males, and lay their eggs on the ground, in little or no nest. Their geographic dispersion is as wide as their locomotive powers are great. The shores of every part of the world abound with *sandpipers* and *curlews*; whilst snipes, woodcocks, &c. frequent the inland waters and marshy grounds. The *stilts* surpass all the rest of this family, and probably therefore all other birds, in the length and slenderness of their legs.



Stilt.

3. The RALLIDÆ, or *Rail* tribe, are furnished with very long toes, for traversing aquatic herbage; and they are even useful in swimming, especially in some species in which their surface is extended by a border of membrane. They are also distinguished by the form of the body, which is very thin and narrow—a structure adapted to their habits and mode of life, since they live for the most part in the thick and tangled recesses of the reeds and aquatic vegetables which clothe the sides of rivers and morasses. Their wings are short, or of moderate length, and their flight feeble; but they run with considerable swiftness. They are for the most part solitary and timid birds, hiding themselves at the least approach of danger, but quitting their semi-aquatic retreats morning and evening, to feed in more open spots. The flesh of these birds is delicate; and, as they live chiefly upon aquatic seeds and vegetable aliment, they may be regarded as aquatic Gallinaceæ. The *rails*, *coots*, and *crakes*, are the chief British species of this family, and are sufficiently characteristic.

Under the *Rail* tribe are placed two remarkable birds, the place of which is rather doubtful. One is the *jacana*, which is distinguished from all other stilt-birds by the length of its toes and claws, which enable it to walk with facility on the floating leaves of aquatic plants. The other is the *flamingo*, which is perhaps rather to be considered as one of the duck tribe, with an inordinately long neck and legs. The front toes are webbed to their ends, and the hind toe is extremely short. The mandibles are suddenly bent downwards, about the middle of their length; and they are roughened at the edges, like those of the ducks, to which the fleshiness of the tongue also shows an alliance. It feeds on mollusca, insects, the spawn of fishes, &c. The flamingoes construct their nests in marshy situations, placing themselves astride of them during the act of incubation, being incapacitated by the length of their legs from sitting on them in the usual manner.

4. The CHARADRIADÆ, or *Plover* tribe, are less aquatic than most of the other families. The legs are long, and the back toe is either quite absent, or so short as not to reach the ground. They live only on sandy and unsheltered shores, or on exposed commons, congregating in flocks, and running with great swiftness. The bill is usually of moderate strength, enabling these birds to penetrate the ground in search of worms, to obtain which they have the habit of patting with their feet, which causes the worms to rise. The species in which the bill is more feeble, frequent meadows and newly-ploughed land, where this food can be obtained with greater ease; those which have stronger bills, subsist additionally on grain, herbage, &c. Of the plovers, several species exist in Britain; and others are distributed through most other countries. Some chiefly frequent the sea-coast, and others the upland moors. The *Lapwings* are nearly allied to the plovers, and, like them, are migratory, passing the winter in warm latitudes: they are peculiar to the eastern hemisphere. They are very noisy birds, screaming at every sound they hear, and defending themselves with courage against birds of prey.

Three other genera of this family are worthy of notice. The *Bustards* connect the Grallatores with the Rasores, in the heaviness of their bodies, the small membrane at the base of their toes, and some other characters. They have, however, the long naked legs of this order, and the flavour of their flesh resembles that of the wading-birds. They fly little, scarcely ever using their wings, except (like the ostriches) to assist them in running. They feed equally on grain, herbage, worms, and insects. The great bustard is the largest of the European birds, and is one of the finest kinds of game: it has been nearly extirpated in Great Britain. The *Turnstone* is at once recognised by a short stout bill, turned slightly upwards: the name is derived from the habit it possesses of turning up stones on the sea-shore, to feed upon the marine animals concealed beneath. The *Oyster-catcher* has a long, straight, wedge-shaped beak, strong enough to force open the bivalve shells of the mollusca upon which it feeds.

VII.—Natatores.

The Swimmers are, of all the orders of birds, the most easily recognisable by the structure and position of their oar-like feet. This peculiarity, which occasions that awkwardness of gait on land which every one may observe in ducks and geese, is extremely favourable to those birds whose 'business is in the great waters.' The body is boat-shaped, and the neck very long in proportion, for the purpose of reaching prey beneath the water when the bird is floating on the surface. The thick downy covering is rendered impervious to water by the abundant application of an oily secretion. The bones of these birds are not hollow, like those of the rest of the class, but are filled with an oily marrow. In this, and in other points, their structure approximates to that of reptiles. Their circulation is less energetic than that of the other orders, and is capable of being considerably retarded, by the obstruction of the respiration, without injury. As the water is the element on which these birds are formed to move, so does it also supply them with food. Some of them live on aquatic plants and submarine insects; but the greater proportion prey upon fish, and those innumerable swimming and creeping things which subsist in the sea, and cover its shores. In general, several females associate with one male, and the young are hatched in a condition which renders the co-operation of both parents for their support unnecessary, being able to take to the water, and swim about in search of food, the instant they are liberated from the egg-coverings.

This order may be divided into five families—1. The ANATIDÆ, or *Duck* tribe; 2. The LARIDÆ, or *Gulls*; 3. The PELICANIDÆ, or *Pelicans*; 4. The COLYMBIDÆ, or *Divers*; 5. The ALCIDÆ, or *Penguins*. The three first are distinguished by the length of their wings, which enables them to fly well; while in the two latter, these members are so short, that they seem perfectly useless for any other purpose than that of fins.

1. The ANATIDÆ are distinguished by a thick bill,

which is horny only at its extremity; the remainder of the mandibles being invested with a soft skin, which in other birds is found only at their hinder part. This skin, in the ducks, is extremely sensitive, and by it the animals take cognisance of the food contained in the mud into which they plunge their bills. The edges of the bill are roughened, either by plates or small teeth arising from it; and the tongue is large and fleshy. These birds live more in fresh waters than in the sea; and many of them (such as geese and swans) are exclusively vegetable-feeders. The ducks, on the other hand, subsist in part upon animal diet; and one tribe of them, the mergansers, feed almost exclusively upon fish. Under the general designation of *ducks*, *geese*, and *swans*, all the birds of this family may be arranged; and as those typical forms are so well known, it is unnecessary to dwell longer on it, although the habits of many species are extremely interesting.

2. The LARIDÆ, or *Gull* tribe, resemble the higher orders of birds in their general structure. The wings are very long, and their powers of flight considerable. The feet, although webbed, are so constructed as to enable them to walk with ease along the shore in search of food; the legs are slender, and sometimes so long, as to resemble those of the waders; the hind toe is very small, and sometimes wanting. Many of the birds of this tribe have a tendency to associate in flocks. In consequence of their capability of protracted flight, they are met with at a greater distance from land than most others: many species are almost constantly on the wing, and brave the most violent storms. They seem to devour almost every description of animal and vegetable food. This family includes, with the *Gulls*, the *Skuas*, *Terns*, *Petrels*, and also the *Albatross* of the Southern Seas, which is the largest of all aquatic birds, and in its general habits may be described as a sort of marine vulture. It is extremely voracious, and devours almost anything that falls in its way.

3. The PELICANIDÆ, or *Pelican* tribe, are characterised by having the hind toe united to the rest by one continuous membrane: notwithstanding this conformation, which renders their feet perfect oars, they are almost the only Natatores which perch upon trees. All of them fly well, and have short legs. They are a large, voracious, and wandering tribe, living for the most part on the ocean, and seldom approaching land but at the season of incubation. The *Pelicans* themselves are remarkable for the length of the bill, which is armed with an abrupt hook at the end; the width of the gape is excessive; and the skin hanging from the lower jaw, and forming the throat, is so extensible, as to dilate into a pouch capable of holding a large quantity of fish. The *Cormorants* are remarkable for being not only voracious, but docile, so that they have been trained for fishing, as hawks for fowling.

4. The COLYMBIDÆ, or *Divers*, may perhaps be regarded as intermediate in structure between the Duck tribe and the next family. They are all marine birds, with a lengthened, strong, straight bill. The wings are in general remarkably short; and the feet placed so far behind the point of equilibrium of the body, that they will not allow the birds to walk upon land even so well as ducks; but they can pursue the fishes upon which they feed, even beneath the water, with great swiftness. They are few in number, and are chiefly confined to the seas of northern regions.

5. The ALCIDÆ, or *Auk* tribe, exhibit the most remarkable adaptation of the structure of the bird to an aquatic life with which the entire order presents us. This is best seen in the *Penguins*, whose wings are very small, and covered with mere vestiges of feathers, which resemble scales; so that they serve as admirable fins or paddles, but are totally useless for flight. The feet are placed very far back, so that, when upon land, the bird stands nearly erect. Having no power of flight, and not being able to run, the penguin may be overtaken with ease upon land; but once in the water, it distances its pursuers, swimming with the ease and rapidity of a fish.

CLASS III.—REPTILES.

The Reptiles, which constitute the class next to be considered, presents us with more diversity of form amongst its separate orders than any other division of the vertebrated sub-kingdom. Scarcely any animals are more unlike in external aspect than tortoises and serpents; yet we find that these extreme forms are connected with each other by a gradual series; and the internal differences are not so great as to prevent their association into one class, distinguished by characters which are common to all. These characters are—their low power of maintaining heat, or cold-bloodedness, arising from the imperfect aëration of their blood, of which only a portion is sent to the lungs at each impulse of the heart (see ANIMAL PHYSIOLOGY); their oviparous reproduction, and the protection of the skin by hard scales or plates.

The deficiency in the oxygenation of the blood, combined with the slowness and feebleness of the circulation, is connected with general inactivity of the nutritive functions, as well as with obtuseness of sensation and sluggishness of locomotion. It is a curious result of the feeble exercise of these functions, that they may be suspended for a considerable time without apparent injury to the animal; and that parts separated from the body, retain for a long period much of that low degree of vitality which they usually exhibit in connection with it. Although, at present, Reptiles appear to perform a comparatively insignificant part in the economy of nature, especially in temperate climates, where their numbers are few, and their powers feeble, we learn from the records of geology that there was a period, long antecedent to the creation of Birds and Mammalia, when gigantic animals of this class constituted the chief tenants of the earth.

I.—Chelonia.

The order Chelonia differs the most of any from the general form of the class. The shell in which the body is enclosed, and into which, in some species, the head, legs, and tail can be completely withdrawn, would seem a perfectly new organ, to which nothing correspondent exists among vertebrated animals. And the fin-like extremities of the aquatic species remind us more of fish than of other reptiles. The shell, however, is composed of the usual bones of the skeleton, modified only in their form. The upper piece, termed the *carapace*, is usually more or less arched, and is composed of a bony expansion of the ribs, which are consolidated into a firm structure, adhering to each other along their edges, and covered with horny plates, secreted from the skin like hair or nails. The lower plate, or *plastron*, is formed by a peculiar development of the sternum or breast-bone, which, instead of being prolonged forwards into a keel, to give attachment to large muscles, as in birds, is extended laterally for the protection of the subjacent parts.

Most of the Chelonia possess no weapons of offence, being destitute of teeth, claws, or other sharp instruments. The jaws are covered with a horny substance, resembling that of the bills of birds; but their surfaces are usually rounded, so as to be more adapted to bruise than to bite. The shell, however, serves as a most effectual means of passive resistance. In the land species it is usually high-arched, and firmly united, so as to bear a very great weight without injury; and the feebleness of the power of motion in these animals is thus compensated. But in the aquatic species it is generally more flattened, so as to oppose less resistance to the water. Some of these have the power of swimming with considerable rapidity, and are altogether more active in their habits than the rest of the order. In these, the shell affords a much less complete protection to the body, and its parts are more loosely united, so that it possesses some degree of flexibility.

Among the families into which the Chelonia are subdivided, it will be convenient to notice first the CHELONIDÆ, or *Turtles*. These are distinguished by the incompleteness of their shelly covering, and by the peculiar modification of the feet for swimming. The ribs, by the union of which the carapace is formed, are separate from one another around its margin, and the pieces which compose the plastron do not form a continuous plate, but leave great intervals, which are occupied only by cartilage. All the feet are much elongated, particularly the anterior pair, and are flattened, so as to serve for oars or paddles. The toes are seldom at all separated, the whole foot being enveloped in the same skin, closely set with hard plates. They live almost entirely at sea, feeding chiefly upon marine plants, and they only come to the shore to deposit their eggs.

The EMYDÆ, *Fresh-water Turtles*, or *Mud Tortoises*, are intermediate in form between the family just described and the Land Tortoises. The character by which they may be most constantly separated from the marine Turtles, is the distinctness of their toes, which are terminated by claws; but a web still exists between the toes, which assists them in swimming, and also prevents the feet from sinking into mud. Rivers, ponds, and running streams are the haunts of these animals, of which one species is common in the south and east of Europe, and is fattened for food in Germany and Russia, where it is considered a delicacy. The food of the Emydæ consists of mollusca, aquatic insects, small fish, carrion, and vegetables.

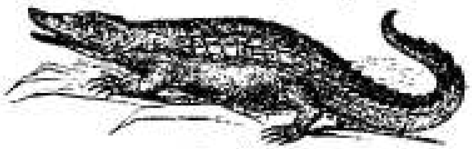
The family of TESTUDINIDÆ, or *Land Tortoises*, is distinguished by the highly-arched carapace, and still more by the short clubby feet, of the animals composing it. Their armour is harder and thicker in proportion to their size, and also more firmly united together, than that of the aquatic species. The neck and legs are short, and capable of being drawn entirely within the shell; so that the whole structure of the animal is adapted for passive resistance. The feet, shaped very much like those of the elephant, are adapted for walking on firm ground only, as the surface they present is very small. They are subdivided into toes, of which there are five on the fore feet and four on the hind; and these are furnished with short conical claws, well adapted for digging. These creatures are of the most inoffensive character possible. They feed only upon roots and vegetables, and upon the worms and slugs that infest these: during the summer they live in woods, or among herbage; and they pass the winter, in cold climates, beneath the earth, where they burrow and sleep. They are generally dispersed in all the warm and temperate latitudes; but they do not naturally extend to Great Britain, although individuals that have been introduced have lived to a great age.

II.—Enaliosauria.

The order Enaliosauria has been founded upon two extraordinary fossil genera—the *Ichthyosaurus* and the *Plesiosaurus*, for an account of which, see GEOLOGY.

III.—Loricata.

The order Loricata includes the Crocodiles, Alligators, and Gavials. The body is enclosed in a sort of plate-armour, of which the separate portions are closely fitted together, and are capable of great resistance. This order includes the most bulky reptiles at present known to exist. Some of them attain the length of thirty feet, and a circumference of seven or eight. Although capable of moving on land, the greater number of them prefer the water, and show their chief activity in it. Besides the expansion of the foot, they are adapted for swimming by the lateral compression of the tail, which thus acts as a large and powerful fin. The crocodiles and their allies are all inhabitants of the rivers and fresh waters of warm climates; and they are all purely carnivorous. They destroy their prey by holding it beneath the surface of the water until it is drowned; the position of their nostrils, and the arrangement of the air-passages, being such that they are themselves enabled to breathe during the process. They cannot swallow under water, however, and their habit is to hide their prey in holes on the bank, until it has become putrid, and then to devour it at leisure. The group may be divided into—the *Crocodiles*, chiefly inhabiting the Nile and other African rivers; the *Gavials*, found in the Ganges and other Asiatic rivers; and the *Caymans* or *Alligators*, confined to the new world. The characteristic differences of these three divisions are best marked in the form of the head. The *Gavials* have the muzzle exceedingly prolonged and narrow, somewhat resembling in form the beak of the spoonbill. In the true *Crocodiles* it gradually widens from



Crocodile.

the point towards the eyes; and in the *Caymans* the snout is much more rounded, and the head is broader in proportion to its length. These last appear less adapted to aquatic habits than the Crocodiles and Gavials, for the feet are not webbed to nearly the same extent as in the latter, and the ridge which increases the surface of their hind legs is wanting in the Alligators. With these exceptions, the general conformation of all, as well as their mode of life, is very similar.

IV.—Sauria.

The order Sauria comprehends all the animals commonly known as Lizards. They are intermediate between the Loricata and Serpents, for they have a lengthened body, terminating in a tail, like the former; but this, instead of being enclosed in large shields or plates, is covered with small scales, as in the latter. Moreover, they have usually four legs; but in some species one pair disappears, and in others they are all concealed beneath the skin, so that the body presents a snake-like aspect. In this group are found some of the most active, and certainly the most beautiful, of the Reptile class. Many of them are tinctured with the most brilliant colours, and as they are called into the greatest activity in the bright sunshine, nothing can surpass the splendour of their ever-changing hues. These colours bear an interesting relation to the habits of the animal, having a general resemblance to that of the places they frequent; thus tree-lizards are almost always of bright colours, in which green predominates; ground-lizards, brown, more or less speckled; and those which live in stony places are of a grayish hue.

The majority of the Sauria are carnivorous, feeding upon other animals of inferior size and strength to themselves, and almost always preferring living prey. Many of them pursue nothing but insects; others lie in wait for small birds. The Iguanas, however, feed almost wholly upon vegetables. Many of them are possessed of very great agility upon land; some of them can ascend perpendicular walls, and even run along the ceiling with their backs downwards; none of them are inhabitants of the water, though a few occasionally resort to it. The activity of the smaller insectivorous lizards, when in pursuit of their food, is exceedingly curious and interesting. They watch with all the caution of a cat, and dart upon their prey with the quickness of lightning. Their movements are effected chiefly by means of their feet, and in the higher tribes exclusively so; but in those species in which the legs are short, and the feet very small, in proportion to the length of the body, progression is greatly assisted by the lateral motion of the trunk, which works its way along somewhat in the manner of that of the serpents.

The order is usually subdivided into five families—1. The LACERTINIDÆ, characterised by the small head and thick neck, but particularly by the very long slender forked tongues of the animals composing it. This group includes the common lizards of this country, and most of the Saurians whose habits are peculiarly active. 2. The IGUANIDÆ, having the same general form, but short thick tongues, and including some of the largest of the Sauroid type, both recent and fossil. Among these may be noticed the genus *Draco*, the animals included in which are distinguished at the first glance from all other Saurians, by the possession of a pair of wing-like appendages to the sides of the body. These are formed by extensions of the skin, supported by the false ribs, which are much prolonged, and serve as a kind of parachute, on which this little dragon, not many inches long, flutters from branch to branch in search of its insect prey; and also as a support to it when shooting, like the flying-squirrel, from tree to tree. These animals, the only living representatives of the fabulous dragons of the olden time, are found in the woods of tropical Africa and Asia, especially in the Indian Archipelago. 3. The GECKOTIDÆ, which are nocturnal in their habits. These have not the attenuated form of the previous families, but are flattened, especially on the head. Their legs are short, and their movements comparatively tardy. Their colour is usually very sombre; and they are reputed, but without foundation, to be venomous. 4. The CHAMÆLEONIDÆ, whose tongue is of immense length, but obtuse at its point. The feet and tail are both peculiarly adapted for climbing; the former having two of the toes opposable to the rest, and the latter being round and prehensile. Their movements are very slow, except when the tongue is darted out to secure its insect prey. 5. The SCINCOIDÆ, or Serpent-lizards, which are recognised by the shortness of the feet, the non-extensibility of the tongue, and the equality of the tile-like scales which cover the whole body and tail.

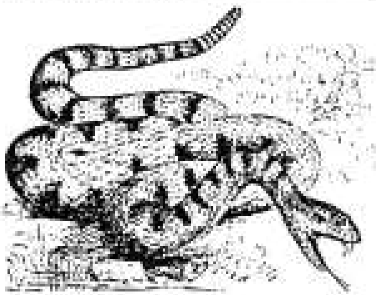
V.—Ophidia.

The animals composing this order are at once distinguished not only from all other Reptiles, but from all other Vertebrata (except certain fishes of the *eel* kind), by the entire absence of members or appendages for locomotion. Although no trace of these is ever perceptible externally, there are some species bordering upon the Saurians in which rudimentary legs can be detected; and these approximate, therefore, towards the lizards in their own tribe, just as the two-legged long-tailed lizards approach the serpent in theirs. Although apparently so different from other reptiles, Serpents are to be distinguished from lizards by little but the absence of extremities; since, in the possession of teeth, and in the scaly covering of their bodies, as well as in their general interior organisation, they closely correspond with them. They pass the coldest part of the year in a state of torpidity; on emerging from which, they slough or cast their skin. Their progression is accomplished in two ways: sometimes the whole body creeps along the ground, the scales on its under side serving (like the minute bristles of the earthworm) as so many points of resistance to a backward movement, when the trunk is elongated, after being contracted; and sometimes it is bent upwards into a series of arches, by which the tail is brought near the head; and when these are straightened, the head is thereby projected forwards. In crawling along the ground, they are much assisted by the points of the ribs, which do not meet again in a sternum, but bear upon the ground, and serve as so many short feet, having a certain power of movement in themselves by means of the intercostal muscles. Most serpents can swim when placed in the water; and there is one group which is pre-eminently aquatic, and is distinguished by its vertically-flattened tail. So closely do the members of this group resemble certain species of the eel tribe, that it is not always easy to determine to which a specimen belongs, until its respiratory organs have been examined. The great flexibility of the body is partly due to the very large number of vertebræ (from 200 to 300) composing the spinal column, each of which is united to those before and behind it by a very beautiful ball-and-socket joint. A large group of serpents is distinguished by the possession of venomous teeth, or *poison fangs*, in addition to the ordinary teeth. (See fig. of rattlesnake.) These are sharp, long, and tubular, and are connected at their roots with a gland by which the poison is secreted; and this is instilled into the wound through the tube in the tooth.

As in the case of other reptiles, we find that serpents only attain their full development in warm climates, having very little proper heat of their own. The species inhabiting the temperate zone are not nearly so remarkable either for size, brilliancy of colour, or poisonous properties, as those which exist between the tropics. The order may be divided into five families—1. The COLUBRIDÆ, consisting of the *Boas*, *Pythons*, *Colubers*, and other non-venomous snakes not belonging to the subsequent orders; 2. The CROTALIDÆ, containing the *Rattlesnake*, *Viper*, and all the venomous species; 3. The HYDROPHIDÆ, or *Water-snakes*; 4. The AMPHISBÆNIDÆ, or *Double-walkers*; 5. The ANGUINIDÆ, or *Slow-worms*.

The COLUBRIDÆ are particularly distinguished by the power of dilating the opening of the jaws to an enormous extent, so as to permit of animals being swallowed which are much larger than the diameter of the serpent itself. This is accomplished by the separation of the jaw-bones into various pieces, which are very movable on one another and on the skull. The most remarkable species of this family, which is the most numerous of the order, are the *Boa Constrictors* of the new world and the *Pythons* of the old; these, when full grown, attain the length of from thirty to forty feet, and in thickness nearly equal a man's body. They do not fear to attack any animal; and if they can once coil themselves round it, crush it by the enormous combined power of their muscles, in spite of all its means of resistance and defence. Their power is much increased by coiling the tail round a tree, so as to give a point of support from which the muscles may act more efficiently; and it is in this manner that they commonly wait for their prey. When they have seized and entirely destroyed it by crushing, in which process all the principal bones are broken, they begin to swallow it. The process of digestion takes some days, or even weeks, for its performance, according to the size of the prey; and during that time the monster lies in a very inactive state, only issuing forth to seek a new victim when the digestion of the last has been for some time finished. The hair, horns, and other least digestible parts are usually disgorged during the process. The Boas are distinguished from other serpents by the presence of two projecting bones near the vent, which are called *claspers*, and which may be regarded as the rudiments of posterior extremities. The *Colubers*, strictly so called, are of comparatively small size; but their habits are the same in proportion.

The CROTALIDÆ, or *Venomous Serpents*, do not differ much in external characters from the preceding family; but the character of their teeth is quite sufficient to distinguish them. The poisonous properties of the different species vary considerably; in general, they are more severe in the serpents of warm climates than in those of temperate regions. Cases of death from the bite of the British viper are very rare, and are generally to be attributed in part to some previously-existing derangement of the system. There are many serpents in the torrid zone, however, whose bite is fatal to man and to other large animals in a few hours. This family contains two principal sections—the *Rattlesnakes* and the *Vipers*. The former are generally regarded, but probably incorrectly, as the most venomous of all serpents. The rattle at the end of the tail, which is their distinguishing characteristic, is formed of several separate pieces of a dry horny substance, one of which is received within another. They are quite loose, and receive no nourishment after they are once formed. A new piece is said to be added every time the skin is cast, which usually takes place twice a-year. The sound made by the rattle is not great in the ordinary motion of the serpent, and cannot be heard at more than two or three yards' distance. Several species of *Crotalus* are described, varying in length from four to eight feet. They are all natives of America. Their ordinary food consists of birds, squirrels, and other small animals. It was once supposed that they possessed the power of charming or fascinating these animals: this is certainly an error; but it is equally certain that most animals are so terrified at the sight of the rattlesnake, as to lose the power of escape, and so become an easy prey.



Rattlesnake.

The *Vipers*, being destitute of the peculiar characteristic of the Rattlesnakes, are more like the Colubers; their forms, however, are less elegant, their colours less splendid, and their movements less active. In general, they are remarkable for the dark lurid tints of their covering. The most deadly species of this group is the *cobra di capello*, or *spectacle-snake* of the East Indies. Its first name, given to it by the Portuguese, signifies hooded snake, and is derived from the power of dilating the skin behind the head, when irritated, so as to give the appearance of a hood. The English appellation is bestowed in consequence of a mark, in the shape of a pair of spectacles, behind its head.

The Hydrophidæ, or *Water Serpents*, are comparatively few, and are limited in their geographical range. They are mostly found in the seas and rivers of the East Indies.

The Amphisbænidæ, or *Double-Walkers*, are a still smaller group, intermediate in some respects between the true serpents and the slow-worms. They derive their name from the power of moving either backwards or forwards with equal facility. The two extremities of the body are so much alike, that they would not be distinguished by a superficial observer, the eyes being so very small, as sometimes to appear wanting: the whole body is of nearly equal diameter. They are restricted to the warmest parts of South America: and notwithstanding the common idea of their venomous properties, are quite harmless.

The Anguinidæ may almost be called either lizards or serpents, so remarkably do they combine the characters of the two orders. In one species, the rudiments of hind legs form a visible projection near the vent; and in another, the anterior ribs are connected by a cartilage which is the rudiment of a sternum. The common *slow-worm* or *blind-worm* of this country has received its second name from the supposed absence of eyes; this is an absurd error, however, as the eyes, though small, are very brilliant. It is a perfectly harmless animal, feeding on insects, slugs, &c.

VI.—Amphibia.

The general peculiarities of the Amphibia may be thus stated:—Their skin is soft and naked, being destitute of scales or plates. Most of them undergo a metamorphosis which has reference to a change of condition, from the form of a water-breathing fish to an air-breathing reptile. In many species, however, little change is seen from the time that the animal emerges from the egg to its adult stage. With the exception of the frogs, they have much the form of lizards, and have generally four feet and a lengthened tail.

The order, which contains but a small number of different genera, may be best subdivided according to the degree to which the metamorphosis proceeds. Thus, in the first, Anoura, embracing the *Frogs* and *Toads*, the gills are entirely lost in the perfect state, and the tail also disappears. In the Urodela, including the *Salamanders*, *Water-Newts*, &c. the gills disappear in the perfect state, but the tail is retained. The Amphipneusta, to which the *Proteus* and *Siren* belong, retain their gills during the whole of life; the tail continues to form a large part of the body, and in some instances only two legs are developed. In the Abranchia, a group which consists only of two little-known genera, no gills have been found at any period of life, but the body and tail are evidently formed for swimming. And in the Apoda, including only one genus, the *Cœcilia*, the body is altogether destitute of feet, and has a serpent-like form.

The principal subdivisions of the first group are the Ranidæ, or *Frogs*, and the Bufonidæ, or *Toads*. The former frequent water, and are adapted for swimming in it; the latter are usually found at a distance from water, and are much less adapted for active movements of any kind. The metamorphosis of both these is attended with the same general phenomena. It is one very easily observed, for, by obtaining a little water containing young tadpoles, the whole process may be made to go on under our eyes, and the young naturalist is earnestly recommended to watch it for himself. The spawn, soon after its deposition in pools, consists of a transparent gelatinous mass, enveloping a number of little black dots, which are regularly distributed through it, and which are the eggs. These are abundantly found in stagnant pools in the month of April, being usually deposited (in this country) at the end of March, and hatched about a month afterwards. When the tadpole first emerges, it presents, in every respect, the appearance of a fish. It has a large oval head, and an elongated tail, flattened vertically, by the vibrations of which it swims actively through the water. The gills are found hanging in tufts on each side of the head; and if examined with a microscope, the motion of the blood through them may be very beautifully seen. The circulation may be observed also with great facility in the fin-like expansion on the upper and under edge of the tail. Very soon, however, the gills are withdrawn, as it were, into the head, being covered over by a fold of skin analogous to the operculum, or gill-plate of fishes. The little creature, which at first seemed to derive its subsistence from the fluid absorbed within the body, and on its surface, now seeks its food amidst softened or decomposing vegetable matter; and, to give greater power of movement, the surface of the tail is considerably increased. It now undergoes but little change in external form for a considerable time, but increases rapidly in bulk. The first appearance of limbs is seen in a tubercle or knob which projects at the back of the head; this is the rudiment of the hind leg. It soon acquires somewhat the form of the perfect limb, the toes budding, as it were, at the extremity; but it still continues very short, even in proportion to the diminutive size of the animal. Meanwhile, the fore legs are also budding out in the same manner, and gradually assume their distinct and ultimate form. During this process, the development of the body advances at the expense of the tail, which is gradually removed by absorption. The gills disappear by a similar process. The little animal has now undergone its complete development, and having, at the same time, become capable of respiring air by true lungs, and of moving freely on land by means of its hinder legs, it comes to the shore to feed on small insects and worms, which are henceforward to constitute its nutriment. Such multitudes of these little beings are often found in damp weather enjoying their new scene of existence, as to have given rise to stories of showers of frogs, which are still believed in some parts of the country. They now grow with great rapidity during the rest of the year; but on the approach of winter, retire to the mud at the bottom of the water, where they congregate in large masses, remaining torpid until the return of spring.

The BUFONIDÆ, or *Toads*, are a perfectly harmless and inoffensive race, although certainly not inviting in their general aspect. The idea of their venomous character is altogether unfounded. The body is of a dull hue, its shape awkward, and its movements appear difficult; but it is by no means deserving of that disgust which it has inspired in some naturalists, as well as in the popular mind. It issues forth from its concealment at twilight in search of food, which consists of insects, worms, slugs, &c. When about to feed, it remains motionless, with its eyes turned directly forwards upon the object, and the head inclined towards it; and in this attitude it remains until the animal moves, when, by a stroke like lightning, the tongue is thrown forward upon the victim, which is instantly drawn into the mouth. So rapid is this movement, that it requires some little practice, as well as close observation, to distinguish the different motions of the tongue. This organ is folded back upon itself, as in the frog; and the under surface of the tip is imbued with a viscid secretion, which adheres to the prey. The toad, like the other Amphibia, becomes torpid in winter; but instead of returning to the water, like the frog, it chooses for its retreat some sheltered hole, or a space amongst loose stones.

The members of the section URODELA bear so strong a general resemblance to lizards, that they were united with that group by *Linnæus*, and are still popularly regarded as such. The *Salamanders* and their allies, however, are easily distinguished by the smoothness and softness of their skin, which is entirely destitute of those scales which all lizards possess. Moreover, they undergo a metamorphosis similar to that of the frogs, except that the change of form does not proceed to the same extent. Like the Anoura, this group may be subdivided into two families, of which one—the TRITONS—is of aquatic habits even in the adult state; whilst the other—the true SALAMANDERS—bears more analogy with the toads in its aspect and habits.

Of the TRITONS, several species exist in this country, and are known under the names of *Evat, Eft, Newt, &c.* The largest is about six inches in length: it is not at all uncommon in ponds and large ditches, where it lives upon aquatic insects and other small living animals: it even devours the smaller species of newt. The *Salamander* is a land animal, of the same general character with the water-newt, but possessing a rounded instead of a flattened tail, and a surface somewhat warty, like that of the toad. It discharges, when alarmed, an acrid secretion from the tubercles in the skin, which is said to be poisonous to small animals. In other respects it is quite harmless, and is not possessed of any remarkable properties.

The members of the section AMPHIPNEUSTA exactly resemble salamanders, the development of which has been checked just at the period of their transformation from aquatic to air-breathing animals. They retain their gills during their whole life, and acquire lungs in addition by the partial metamorphosis they undergo. The legs bear but a very small proportion, in their degree of development, to the tail; and in some instances only one pair is formed. The first-discovered animal of this order was the *proteus*, an inhabitant of the underground lakes of Carniola and Styria, and of the passages between them. So strongly does this resemble the larva of a salamander, that it was at first believed by naturalists to be such; and it was only after the discovery of others of the same character, that its true nature was understood. Unlike most other animals, it appears to suffer injuriously from light; for not only does it prefer dark places, but even dies if it be exposed to open day for any length of time without the power of hiding itself. The *siren* is an animal of similar character, inhabiting the North American rivers, where it feeds upon earthworms, aquatic insects, &c. in search of which it burrows in the mud. Only the anterior pair of feet is developed, and there is no rudiment of the others.

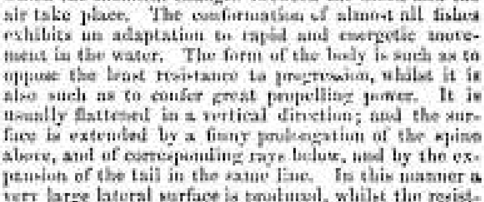
The group ABRANCHIA contains only two genera, and these both peculiar to North America—the *menopoma* and the *amphiuma*. They are not known to undergo any metamorphosis, but breathe by lungs during the whole period of life, and have never been seen destitute of legs. These are, however, very short, and seem almost useless appendages to the body, which is shaped like that of an eel.

The APODA present but one genus, the *Cæcilia*, blindnewt, or naked serpent. Its name was conferred by Linnæus, on account of its supposed blindness. The eyes are exceedingly small, and are nearly hidden under the skin, and it is believed that, in some species, these organs are altogether wanting. These animals frequent the rivers and marshy grounds of many tropical countries: further information in regard to them is much needed. They are said to burrow in the ground, and to live very much in the manner of earthworms.

CLASS IV.—FISHES.

The animals of this class are the only Vertebrata which, in their adult state, are formed for respiring beneath the surface of the water they inhabit. In them, as in the Mollusca, the blood receives its necessary purification by being exposed to the air contained in the surrounding fluid. This is done by its transmission to a series of delicate filaments, constituting the *gills*, each of which consists of two minute blood-vessels (one to convey the blood from the heart, and the other to return it), enclosed in a delicate membrane, through which the chemical changes between the blood and the air take place. The conformation of almost all fishes exhibits an adaptation to rapid and energetic movement in the water. The form of the body is such as to oppose the least resistance to progression, whilst it is also such as to confer great propelling power. It is usually flattened in a vertical direction; and the surface is extended by a finny prolongation of the spine above, and of corresponding rays below, and by the expansion of the tail in the same line. In this manner a very large lateral surface is produced, whilst the resistance to forward movement is very small. The propulsion of the fish is chiefly effected by the movement of the whole body and tail from side to side, which operates in precisely the same manner as the oar of the sculler; and this is facilitated by the great flexibility of the spine, the bones of which are so united together as to move with the slightest possible effort.

The propulsion is usually aided by lateral fins, which answer to the legs and arms or wings of higher Vertebrata. Besides the fins on the central line of the body, above and below (of which the one running along the back is called the *dorsal* fin, and the one under the body the *anal*), there are generally found two *pairs*, of which one, corresponding to the anterior extremities of other Vertebrata, is always situated near the head, and is called the *pectoral*; whilst the position of the other,



a, dorsal fin; *b*, pectoral fin of one side; *c*, ventral fins; *d*, anal fin; *e*, caudal fin or tail.

corresponding with the posterior extremities of land animals, and called the *ventral*, is extremely variable. Sometimes the ventral fins are placed far back, in the usual position of hind legs; and sometimes they are fixed far forwards, even anteriorly to the pectoral. It is chiefly by the vibrations of the pectoral fins that the animal is raised or depressed in the water; and they also assist in changing its direction from side to side. The forward position of the ventral fins is chiefly noticed in those species whose habits involve a considerable variation of their depth in water. Sometimes one, and sometimes both pairs of these fins are absent; in the latter case the fish is said to be *apodal*, or footless. In other instances, the pectoral fins are enormously developed, like the wings of birds, and even enable the animal to rise out of the water, and to skim for a short time along its surface.

The surface of the body is generally covered with numerous scales, which vary considerably in form and size in different species. Each scale is attached to the skin of the fish by its anterior edge, which is covered by those in front of it, whilst its posterior edge overlaps the scales behind it. This arrangement is not universal, however; for the scaly covering is sometimes formed by a series of bony or even enamel plates, united to each other by their entire edges. Such an arrangement was very common in the fishes existing at the time of the coal formation (see GEOLOGY), but is now much more rare.

When we consider that more than two-thirds of the earth's surface is covered with water, often to a very great depth, and that, as far as is known, the whole of this element is habitable by fishes, little doubt can be entertained that they form the most numerous class of vertebrated animals. Their numbers are kept up by their extreme fertility. The cod-fish has been ascertained to lay not much fewer than four millions of eggs at a single deposit; and in other species the number may even be greater. Their voracity is also extreme. Almost all of them are adapted to devour and digest animal food, some of them living chiefly on crustacea, mollusca, and other invertebrate inhabitants of the ocean; and others having it for their especial function to keep down the inordinate multiplication of their own kind. Some attain a considerable size. The pike has been found nineteen feet long. The sun-fish has reached the length of twenty-five feet; and some rays and sharks have exceeded forty feet.

The primary division of the class is into the *Osseous* and *Cartilaginous* Fishes, the former having a hard bony skeleton, and the latter having one of less firm consistence, possessing but little calcareous matter. The former group is divided into six orders, which are principally characterised by the structure and arrangement of the fin rays. These are distinguished as either consisting of a single piece—in which case, whether stiff or flexible, they are said to be *spinous*—or as consisting of a number of jointed pieces, divided at their extremities, when they are called *soft* or *articulated*.

DIVISION I.—OSSEOUS FISHES.

I.—Acanthopterygii.

The Acanthopterygii, or Spiny-finned Fishes, are divided by Cuvier into fifteen families, the most important of which will be noticed:—

PERCIDÆ, the *Perch* tribe. These are very numerous in the waters of all warm climates, some species inhabiting the rivers, and others the open sea. Their bodies are oblong, and covered with hard or rough scales; and the gill-covers are toothed at the margin. They are mostly *thoracic*, or have the ventral fins under the pectoral. Their teeth are very minute, and set close together in numerous rows. Their flesh is in general agreeable and wholesome. This family includes all the fish known as Perches, of which some species are found in almost all the rivers in the world, and a large number of marine fishes used as food on different shores.

TRIGLIDÆ, the *Gurnard* tribe. These bear a general resemblance to the Perches, but have the head peculiarly armed with spines or hard scaly plates. In several species the pectoral fins are very much extended; but in none, except the flying-fish, are they sufficiently powerful to raise the animal out of the water. Many species of this tribe are found in the temperate seas. The most interesting of all is the *dactylopterus* or *flying-fish*, which has a kind of supplementary pectoral fin on each side, formed of a membrane stretched over finger-like processes, which in the gurnards are unconnected. By the impulse of these on the surface of the water, the flying-fish can raise themselves to the height of several feet into the air, and can suspend themselves above the surface for a few seconds, often skimming lightly over it for a considerable distance; but they cannot sustain themselves in the atmosphere for any length of time. They are gregarious; and it is when a shoal of them is chased by the *coryphæna* (commonly, but erroneously, termed *dolphin*), or some similar enemy, that the most remarkable leaps are taken. They not unfrequently fall upon the deck of a large vessel that may be passing amongst them.

The family SQUAMIPENNES is so named because the soft, and even the spinous parts of their dorsal fins are so covered with scales, as not to be distinguished from the rest of their bodies. The most interesting genus is the *Chætodon*, of which several species, remarkable for the beauty of their colours, abound in tropical seas. One of these, the *C. rostratus*, which has a very prolonged snout, has the faculty of shooting insects with drops of water projected from the mouth, and it then seizes them as they fall. This power is the more extraordinary, as, according to the laws of the refraction of light, the place of the insect will appear to the fish different from the reality, the rays passing from a rarer to a denser medium; and the drop must not, therefore, be projected in the line in which the insect *appears* to be, but somewhat below it. This little fish, which is a native of India, is often kept in glass vases by the residents there, as gold-fish are in this country, for the purpose of affording amusement by its dexterity.

The next family, SCOMBERIDÆ, or the *Mackerel* tribe, is one of very great importance to man. It comprises a large number of genera, a vast collection of species, and numberless individuals. The aspect of the common *mackerel*, with its spindle-shaped, beautifully-coloured, smooth, and small-scaled body, is well known. It very rapidly dies out of water, and soon becomes tainted. Mackerel has been supposed to be migratory, on account of its appearing on our shores, in immense shoals, at particular epochs. The fact is, that it passes most of the year in the open sea, and its object in approaching the shore is to deposit its spawn; after which, those that have escaped being entrapped by the ingenuity of man, return to their former quarters. The extent and importance of the mackerel fishery of Britain, especially in the south and east, are well known. The *tunny* is an allied species, attaining a much greater size, and also valuable as an article of food. This frequents the Mediterranean, and is occasionally seen on our own shores. It sometimes attains the length of fifteen or even eighteen feet. To this order belongs also the *xiphias*, or *sword-fish*, distinguished by its long pointed beak. This is a most powerful offensive weapon, and with it this fish attacks the largest inhabitants of the ocean. By its high dorsal fin and expanded tail, it is able to impel itself forwards with great force; and when attacking a large animal, it makes a violent dart against it, quite transfixing it with its sword. It has been known in this manner to drive its beak into the timbers of a ship, and not being able to withdraw it, to break it off and leave it. The sword-fish abounds in the Mediterranean, but is less frequent in the Atlantic. It is very palatable as food; and often attains the length of fifteen feet. The *dory*, of which one species is highly prized by epicures, is another fish of the same family. It is remarkable for the filamentary prolongations from its dorsal fins. And lastly may be mentioned the *coryphæna*, commonly known as the *dolphin*. This is a large and splendidly-coloured fish, which darts through the water like a radiant meteor, exhibiting an extraordinary play of colours when brilliantly illuminated. It has long been celebrated for its change of colour when dying. It swims with great rapidity, and is very voracious, committing great havoc among the flying-fish and others of like size.

The fishes of the family PHARYNGINÆ LABYRINTHIFORMÆ, are characterised by a very peculiar structure, from which they derive their designation. The membranes of the pharynx (or back of the mouth) are divided into small irregular leaves, containing cells among them, which the fish can at pleasure fill with water; and, by ejecting a portion of this water, it moistens its gills, and may thus continue its respiration out of its proper element. By means of this apparatus, which resembles that possessed by the land crabs, these fishes are enabled to quit the pool or rivulet which constitutes their usual element, and move to a considerable distance over land. Such a provision is especially desirable in tropical climates, where shallow lakes are often dried up by a continued drought, and their inhabitants must perish if not enabled to migrate. The people of India, who often witness the appearance of these fishes where they were known not to exist, believe that they fall from heaven. Some of them are able not only to traverse plane grounds, but can climb steep banks, or even trees, in the course of their journeys. Of these, the most curious is the *anabas*, commonly known as the *climbing perch* of Tranquebar, which climbs bushes and trees in search of its prey, a species of land crab, by means of the spines on its back and gill-covers.

The members of the family GOBIIDÆ, or *Goby* tribe, are known by the thinness and flexibility of their dorsal spines. Many of them are remarkable for producing their young alive, the eggs being hatched within the body of the parent. This is the case with the *blenny*, of which several species frequent the British shores, living in small troops among the rocks. They are remarkably tenacious of life, being capable of being kept a good many days in moist grass or moss, but they are of little value as articles of food. The true *gobies* are chiefly remarkable for the *nest* which they construct among the sea-weed for the protection of their young, which was observed by the ancients. They prefer a clayey bottom, in which they excavate canals, and in these they pass the winter.

The next family, PECTORALES PEDUNCULATI, derives its name from the peculiar structure of the pectoral fins, which have a kind of wrist formed by the elongation of the bones to which they are attached. This conformation gives these fishes a very strange appearance, and enables them to leap suddenly up in the water in pursuit of their prey, and even to leap over the mud. In many of them the skeleton is demi-cartilaginous. One of the most curious is the *lophius*, or *fishing-frog*, of the British seas, which is met with chiefly on muddy shores. It derives its name in part from its wide gaping mouth, and in part from the peculiar manner in which it angles for its prey. It has some curious appendages to its head, which terminate in long, round, and rather brilliant filaments, having a resemblance to worms. The animal lurks in the mud, and puts these appendages in vibration; they are mistaken for worms by small fishes, which they attract, and these are gulped down the capacious swallow of the lophius. To such an extent is this voracity carried, that the *angler* (as it is sometimes called) is often an article of value for the live fish which it has in its stomach, although its own flesh is worth but little. There is an allied genus, the *chironectes*, of which a species abounds on the north coast of Australia. When the tide ebbs far back in the dry season, these frog-fishes are so abundant, and capable of taking such vigorous leaps, that those who have visited these places have taken them at first sight for birds. The fishes of this genus can inflate their large stomachs with air, in the manner of the Tetrodons.

II.—Malacopterygii Abdominales.

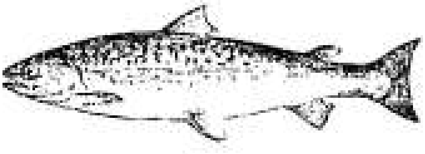
This order, consisting of Soft-spined Fishes which have the ventral fins under the abdomen, contains five families, all of which are highly interesting to the naturalist.

1. The CYPRINIDÆ, or *Carp* tribe, are all fresh-water fishes. They have the mouth shallow, the jaws feeble, and very often without teeth, but the pharynx is strongly toothed. They are among the least carnivorous of fishes, feeding chiefly on seeds, the roots of plants, and decomposing vegetable matter. The common *carp* is imported into England from the warmer parts of Europe; it thrives better in ponds or lakes than in rivers, it feeds on insects and worms, as well as on vegetables, and it is very tenacious of life, so that it is easily transported from place to place.

2. The ESOCIDÆ, or *Pike* tribe, contains the most voracious fresh-water fishes, as well as several important marine species. The *pike* is very destructive of the smaller fishes in the ponds and rivers in which it exists, and sometimes attains a considerable size, weighing between thirty and forty pounds. The *gar-fish*, or *sea-pike*, is an allied species, frequenting the British shores, and stretching into the arctic regions. Some of this kind have been known to attain the length of eight feet, and to bite very severely; hence they may be considered as the sharks of northern seas.

3. The SILURIDÆ are distinguished from all the rest of the order by the want of true scales; having only a naked skin, or large bony plates. The fishes of the genus *Silurus* inhabit the rivers of warm countries: they have a strong spine in front of the dorsal fin, which can be laid flat on the shoulder, or perpendicularly erected, so as to become a formidable weapon; and the ragged wounds inflicted by it are reputed (but probably erroneously) to be poisonous. One species, belonging to the sub-genus *Malapterurus*, an inhabitant of the Nile, and of the rivers of Central Africa, has electric properties, similar to those of the gymnotus.

4. The fishes of the order SALMONIDÆ, known as *salmons* and *trouts*, are very extensively, indeed almost universally, diffused over the globe, some of them being confined to fresh water, and others passing a part of their lives in the sea, but resorting to rivers to deposit their eggs. They are distinguished by the fatty deposition in the dorsal fin, from part of which the spines often disappear. All of this family are clouded with dusky patches when young, and many remain permanently spotted. The flesh of most of them is esteemed as food. The *salmon* inhabits the seas of comparatively



Salmon.

cold regions, ascending the rivers for the purpose of spawning at seasons varying with the climate. The efforts which they make to overcome difficulties in the ascent are very great: they will not only swim against powerful streams, but will leap up cascades of considerable elevation, and find their way to the brooks and small lakes of lofty mountains. They return to the sea after this operation is accomplished, and are followed by the young produced from the eggs they have deposited. These, in their turn, ascend the rivers for the same purpose, and are understood to resort to those in which they were produced. The *trout* appears to vary much in size and colour, according to the conditions of its residence, so that it is difficult to distinguish species from mere varieties.

5. The CLUPEIDÆ, or *Herrings*, form one of the most important families in the whole class, for the amount of food it supplies to man. The fishes belonging to it resemble the Salmonidæ in many characters, but differ in having no fatty matter in the dorsal fin. They chiefly inhabit the seas of the temperate zone.

The *herring*, which periodically visits our shores in such immense shoals, was formerly supposed to migrate from arctic seas; but this is now ascertained to be a mistake, the fish being almost unknown there, and often appearing on the southern coast of Britain before the northern. The fact is rather that the herring, like the mackerel and many other fish, usually lives in the open ocean, and resorts periodically to the nearest coast to deposit its spawn.

III.—Malacopterygii Sub-Brachiati.

The Soft-rayed Fishes, which have the ventral fins brought forwards beneath, or even in advance of, the pectoral, are divided into three families:—

1. Gadidæ, the *Cod* tribe. The fishes of this genus are easily known by the softness of all their fins, and by having the ventrals inserted under the throat, and pointed. The greater number live in cold or temperate seas, and furnish a most important article of food, their flesh being wholesome, easy of digestion, and agreeable to the palate, and their numbers (owing to their extraordinary reproductive power) extremely abundant. The *cod* is nearly the largest of the family, but is usually surpassed by the *ling*, which is commonly from three to four feet long: both these are especially valuable for their excellence when salted. The *haddock* is a smaller species, nearly allied to the cod; for, eating in the fresh state, it is perhaps the most delicate of the whole family. Many other species are useful to man, occurring in large numbers in particular localities. Such are the *whiting*, the *coal-fish*, the *pollock*, the *hake* (of which some species frequent high southern latitudes), the *burbot* (which ascends rivers), the *rockling*, and many others. Besides their use as food, these fish are valuable on account of the oil obtained from their large livers, which is very serviceable in the arts.

2. The second family is that of Pleuronectidæ, the *Flat-fish* or *Flounder* tribe. The form of these fish is peculiar, not only for the extreme flattening of the body, but for its deficiency in symmetry. The two flat surfaces—one of which (in the ordinary position of the fish during life) is above, and the other below—are in reality the two *sides* of the fish, differing in several important respects. Both the eyes are placed on the upper side; and its colour is usually much deeper than the other. The body, from the head backwards, partakes a little of the same peculiarity. The two sides of the mouth are not equal, and the pectoral fins rarely so. On the other hand, the dorsal fin, which runs along one of the lateral edges, corresponds with the anal, which occupies the other, and with which the ventrals are sometimes united; so that, when we look at the fish in its usual position, its body appears more symmetrical than it really is. These fishes are destitute of air-bladder, and they frequent the bottom of the sea, from which they seldom rise far. The colour of their upper surface usually corresponds closely with that of the ground on which they lie; and thus they escape the observation of their enemies, and are unnoticed by the small fishes on which they prey. Individuals are occasionally found, however, in which both sides are alike; these are called 'doubles:' it is usually the dark side which is doubled. The fishes of this family are found along the shores of almost all countries, and are, generally speaking, wholesome and agreeable as food. The form and aspect of the different species exhibit little variation. The *flounder*, *turbot*, *brill*, *plaice*, *dab*, and *sole*, are the chief species of our own coasts: the *halibut* is a very large species, attaining the length of six or seven feet, and weighing 500 lbs., occasionally taken in the British seas; and other species inhabit the Mediterranean.

3. The Discoboli, so named from having their ventral fins formed into a sucker or disk, are the last family of this order. By this curious provision, these fishes have the power of attaching themselves to rocks and other hard substances, and thus remain and find their food in situations where every other species would be swept away by the current of water.

IV.—Malacopterygii Apoda.

The fishes in which the ventral fins are wanting form but one natural family—the Murænidæ, or *Eel* tribe. They are all lengthened in form, have the spine extremely flexible, the skin thick and soft, and the scales almost invisible. In most of them, the external gill-apertures are very small, and open very far back; by which arrangement they are enabled to keep the gills moist for a long time when out of water, whilst the roundness and flexibility of their bodies facilitate their motion upon land. Many of them inhabit rivers, whilst others are exclusively marine. The *eel* is the kind most abundant in Britain. The *conger* is a marine eel, frequenting the European seas; it is one of the largest of the family, being from four to six feet long, and as thick as a man's leg. The *gymnotus*, or *electric eel*, is a native of the South American rivers. It attains the length of five or six feet, and communicates shocks so powerful, that men and horses have been stunned by them. This power seems voluntary, and can be sent in a particular direction, or even through the water, the fish in which are killed or stunned by its shocks. By giving these, it is greatly exhausted, and requires rest and nourishment before it can renew them.

V.—Lophobranchii.

This order is a very small one, containing but one family, of which the genera are few. Their appearance is very peculiar. The tufted gills are covered by a large operculum; but this is bound down by membranes on all sides, so that there is only one small hole for the water to escape. The body is covered, not with small scales, but with shields or plates, which often give it an angular form. In general, they are of small size, and almost without flesh. The *syngnathus* possesses a long tubular snout; it is peculiar for the protection which it affords to its young, which resembles that provided in the marsupial Mammalia. The eggs are conveyed into a sort of pouch under the body of the male, and are hatched there, the young fry afterwards finding their way out. Some of these are found in the British seas, as are also the *hippocampi*, commonly called sea-horses, from the resemblance of the upper part of the body (especially when the dead specimen bends in drying) to the head and neck of a horse in miniature. Their tail is prehensile, and they climb or hold on to the stalks of marine plants by its means. Some of this family are almost destitute of fins, having none but the dorsal.

VI.—Plectognathi.

This order, the last of the Osseous Fishes, approaches the cartilaginous in many points of its organisation; principally, however, in the slow ossification of the skeleton, and the imperfect structure of the mouth. They derive their name, as already stated, from the union of the upper jaw to the skull; so that its motion is obtained, not from a distinct joint, but by the mere flexibility of the half-ossified cartilages. The gill-lid is concealed under the thick skin, with only a small opening; the ribs are scarcely developed; and there are no true ventral fins. The order contains two families.

1. The Gymnodontes, or Naked-toothed Fishes, are distinguished by having the jaws covered with a substance resembling ivory, arranged in small plates (which are reproduced as soon as destroyed by use), and really representing united teeth. The most remarkable species are the spinous globe-fishes, *diodon* and *tetraodon*, which have the power of blowing themselves up like balloons, by filling with air a large sac which nearly surrounds the abdomen. When thus inflated, they roll over with the belly upwards, and lose all power of directing their course; but they are remarkably defended by spines over their whole surface, which are erected as they are inflated. They are mostly inhabitants of warm seas, but a specimen is occasionally drifted to our coasts. The *sun-fish* has a body of somewhat similar form, but incapable of inflation: the tail

is so short, that it looks like the anterior half of a fish cut in two in the middle. Some species attain an immense size; one which is occasionally taken on the British coast has been known to weigh 300 lbs.

2. The second family, SCLERODERMI, contains fishes which are remarkable for their very hard and granulated skins. They have a prolonged muzzle, with distinct teeth. Their skin is covered with scales in some species, and in others very rough, like a file; whence they are commonly termed *file-fishes*. They are principally inhabitants of warm seas, living near rocks, or on the surface of the water, their brilliant colours sparkling in the sunshine like those of the Chætodons.

DIVISION II.—CARTILAGINOUS FISHES.

The skeleton of these fishes is not entirely devoid of calcareous matter, but this is disposed in separate grains, and does not form fibres or plates; hence the hardest portions of the framework remain quite flexible. This division contains two subordinate groups: in the first, the gills are attached by one edge only, hanging in fringes, as in the osseous fishes; in the second, they are so attached to the skin by the second edges, that the water cannot escape from their intervals except by holes in the surface. Accordingly, instead of having a single pair of large apertures, with a valve-like cover, or *operculum*, behind the head, they have as many apertures on each side as there are arches of gills. The first group contains but one order, the second two.

VII.—Chondropterygii Branchiis Liberis.

This order contains only one family, the STURIONES, or *Sturgeons*. In many of its characters, as well as in the disposition of the gills, it is intermediate between the Osseous Fishes and the Sharks, which may be regarded as the types of the Cartilaginous division. Sturgeons are chiefly river fish, and from their large size, vast numbers, and the quantity of food and other important products they afford, are extremely valuable to man. The common *sturgeon* of the British shores is about six feet long, and its flesh is somewhat like veal. The rivers falling into the Black and Caspian Seas, however, produce several other species, of which the largest not unfrequently attains the length of fifteen feet, one individual being recorded as having weighed 3000 lbs. The roe of the sturgeon furnishes the caviar so much esteemed in Russia; and from its air-bladder is manufactured the isinglass of commerce.

The section of CHONDROPTERYGII BRANCHIIS FIXIS is divided into two orders—the first having teeth, and the second having the mouth formed into a sucker:—

VIII.—Selachii.

This order only comprises one family, that of *Sharks* and *Rays*. A great metamorphosis here takes place in the condition of the bones of the mouth, those which are commonly termed the jaws, in which the teeth are fixed, being very different in position and character in osseous fishes, and the true jaw-bones not being here developed. This tribe is distinguished from other fishes by many peculiarities: in several members of it, the young are produced alive, the eggs being hatched within the body of the parent; and in others the eggs are enclosed in a peculiar horny casing, which has often long tendril-like appendages, that coil round and attach them to other bodies. This is the case with the eggs of the common *dog-fish* of our coasts, vulgarly known as *sea-purses*. The sharks much resemble ordinary fishes in their form, having the gill-openings on the sides of the neck, and the eyes on the sides of the head, in both of which respects they differ from the rays. The dog-fish differs but slightly from the true sharks, and is, in its way, equally voracious.

The *white shark* is the most celebrated species of the tribe, being, from its size and voracity, the terror of mariners in the seas it inhabits. It frequents warm latitudes, but has occasionally visited the British shores. It has been known to attain a length of thirty feet; and the opening of the jaws in the largest individuals is sufficient to admit with ease the body of a man. The mouth is placed on the under surface of the head, from which circumstance the fish cannot bite whilst in the act of swimming forwards; so that a dexterous person has been known to defend himself from its attack. The *blue shark*, which frequents the Mediterranean, the *fox shark*, or thresher, so called from the use which it makes of its powerful tail, and the *porbeagle*, are other species of this tribe which occasionally visit our shores. A remarkable genus, allied to the Sharks, is the *zygæna*, or *hammer-headed shark*, so named from the projection of the head at each side in the form of a double-headed hammer, with an eye in the middle of each extremity. The *pristis*, or saw-fish, is another interesting genus. Its general form and character are like that of the sharks, but the snout is extended like the blade of a sword, with strong and cutting tooth-like spines on both edges. With this formidable weapon, the fish, which sometimes attains the length of fifteen feet, will attack the largest whales, and inflict dreadful wounds.

The *Rays* are less numerous than the Sharks, and abound rather in temperate than in tropical seas. They are characterised by the extreme horizontal flattening of the body, in which, however, there is not (as in the Pleuronectidæ) any want of lateral symmetry. The two sides are expanded horizontally, and unite with the expanded and fleshy pectoral fins to form one continuous surface. The eyes are placed on the back or upper surface; whilst the mouth, nostrils, and gill-openings are below. To this group belong the *rays* and *skates*, *thornbacks*, and other species; but the most interesting of all is the *torpedo*, or electric ray, sometimes found on the Channel coast of England, but more abundant in the Mediterranean. The electric apparatus is of very similar structure with that of the *gymnotus*; and it is disposed in the space between the pectorals and the head and gills. The shocks given by this fish, though smart, are not so benumbing as those of the gymnotus; their use in its economy are not apparent, as the animal can obtain its prey without them. The flesh of the rays is wholesome, and that of most species agreeable as food. The skin of some is employed for polishing, and from that of others shagreen is prepared.

IX.—Cyclostomata.

The third order of the Cartilaginous Fishes, and the last of the class, is one which contains comparatively few species, and these exhibiting but a very low degree of organisation. They take their name from the adaptation of the mouth to the purposes of suction, by its transformation into a round fleshy disk, having the oral opening in the centre, and the margin supported by a ring composed of the cartilaginous jaws united together. The spinal column loses its distinct division into vertebræ, the space elsewhere occupied by these bones being traversed from end to end by a cylindrical membranous tube filled with a mucilaginous fluid; and this, in the higher species, presents cartilaginous rings at intervals, which are the rudiments of vertebræ; whilst in the lower, there is no vestige of these bodies, and the whole structure is reduced to the level of that of the Annelida. The pectoral as well as the ventral fins are absent; and the skin is soft and mucous, with scarcely a vestige of scales. This order contains but a single family. The *lampreys* are the most allied to other fishes in their general organisation; they possess teeth within the ring, and with these they tear the bodies of the animals to which they attach themselves. There is a marine species two or three feet long, and other smaller ones which inhabit rivers. The *myxine*, or *hag*, is destitute of eyes, and is altogether of lower organisation than the lamprey; but the species that differs most in its general characters from the rest of the class, is the *amphioxus*, or *lancelet*. This is a very small animal, about an inch long, sometimes found lurking under stones in pools left by the ebbing tide. It is destitute of almost every one of the characters which have been mentioned as peculiar to vertebrated animals; and, nevertheless, can scarcely be classed anywhere else than with this family.

ARTICULATA.

From the Vertebrata we might pass, in the descending scale, either to the Mollusca or the Articulata, both of which exhibit some points of approximation to that series. In both we meet, as in the Vertebrata, with very highly-organised, as well as very simply-constructed beings; in both we find animals much superior to the lowest Vertebrata; and in both, also, we find species which are in many respects below the highest Radiata. It is the necessary consequence of a *natural* classification, which aims at grouping together the different forms of living beings according to the type or plan on which they are constructed, that such should be the case. Neither of these two sub-kingdoms can be regarded as in all respects superior to the other. The high development of the locomotive power in the Articulata, strikingly contrasts with its usually slight possession by the Mollusca. On the other hand, the digestive and nutritive systems in the Mollusca are much more complex, and attain a higher organisation; so that the heart, for example, of a tunicated mollusc, is as powerful in its action on the circulating fluid as that of the highest Articulata. On the whole, however, the Articulata should be regarded as ranking above Mollusca in the animal scale, since it is in the *animal* powers that the former have the superiority.

The leading character of the series is the jointed or *articulated* form of the skeleton or hard portion of the structure, and the enclosure of the body within this. Nothing can be found in the Molluscs at all approaching in character to the shell of a lobster or the horny case of the beetle. It is the peculiarity of the skeleton in the Articulata, that it not merely encloses the body, but is prolonged over the appendages for locomotion, where they exist; and the portions of it which cover these are also jointed, for the sake of conferring upon them the requisite flexibility. This structure is more apparent, however, in some cases than in others. In the lowest members of the series, where there are no appendages for locomotion, and where all movements are effected by the body itself, this is endowed with great flexibility, and the whole envelope is so soft, that the division into segments can scarcely be recognised. This is the case, for example, in the leech and earthworm. The articulated character is most apparent in the Centipede tribe, where the segments are all of nearly equal size, and where each possesses a pair of short legs, which are themselves also articulated. But in the highest classes of the sub-kingdom we again lose the appearance of the division into segments, from an opposite cause—the consolidation of several rings into one piece. In proportion as the locomotive power is more intrusted to the extremities, so does it become unnecessary that the trunk should possess much flexibility; and in the same proportion does it become necessary that the portion of it from which arise the muscles of those extremities should be very firmly framed. Accordingly, the part of the body behind the head, which is called the *thorax*, and from which the legs and wings of Insects, and the principal walking legs of Crustacea, have their origin, very commonly appears as if composed of one piece, although it is really made up of three or more segments, each of which gives rise to a pair of external members.

The Articulata are almost invariably of small size; and the bulk of their bodies is made up, not by their digestive and nutritive apparatus, but by the muscles which move it. It is only in those which approach the Molluscs in the vegetative nature of their existence, that we find any considerable dimensions attained. As the Mollusca are an essentially aquatic group, so are the Articulata principally adapted to atmospheric respiration; and the most active among them can even quit the surface of the ground, and mount up into the air. We find their respiratory apparatus constructed, therefore, upon an opposite plan. Instead of the blood being sent into external prolongations of the surface—gills—to meet the air contained in the surrounding fluid, the air is introduced into the body to meet the blood, this being distributed on the sides of cavities or tubes into which it enters. In Insects, these tubes have a very complex and beautiful distribution through the body. The series also exhibits a peculiarity in the nervous system, which often enables us to detect the real character of doubtful animals. A double cord runs along the centre of the *lower* surface of the body, studded with knots or *ganglia* at regular intervals, which are so many centres from which the nerves pass off to the different segments. The head, also, has its ganglia, in which the double cord terminates anteriorly. Where the members, however, are not uniformly distributed along the whole body, but are concentrated to one part, as in Insects, Arachnida, and the higher Crustacea, we observe a corresponding concentration of the ganglia in that region. The degree of concentration indicates the elevation of the animal in the series.

The following classes may be arranged, in the *ascending* order, under the articulated sub-kingdom, though in some of them the characteristic structure is very indistinct:—

Annelida, or *Worm* tribe. In these the body is prolonged, without any distinct appendages for locomotion. The habitation is usually aquatic, though sometimes terrestrial. The division into segments is not very distinct, the entire skin being soft.

Myriapoda, or *Centipede* tribe. These have also a prolonged body, but are provided with legs; and the articulation of the covering, both of the body and legs, is very distinct.

Insecta, which are distinguished in their perfect state by the possession of one or two pairs of wings; by the restriction of the legs, which are never more than six in number, to the thorax; and by the division of the trunk into three portions—the head, thorax, and abdomen—which are usually very distinct from one another. They are also distinguished by their remarkable metamorphosis, commencing from a form which resembles that of the Annelida.

Arachnida, the *Spider* and *Scorpion* tribe, the members of which differ from insects in having the head and thorax united, in undergoing no metamorphosis, and in having eight or more legs.

Crustacea, which have a hard envelope, principally composed of earthy matter, and which are adapted for aquatic respiration. Many of them have the form of insects; but their legs are never fewer than ten.

The foregoing constitute a tolerably regular series, into which we must also introduce the Entozoa, that seem to exhibit the characters of the Worm tribe in their most degraded condition, and the animals composing which are parasitic upon or within others; the Rotifera, or *Wheel-Animalcule* tribe, of which some approach the Polypifera and Polygastrica, whilst others approximate the Crustacea; and the Cirrhopoda, or *Barnacle* tribe, that bear a strong general resemblance to the Molluscs, but unquestionably belong to this sub-kingdom, which will therefore embrace—

1. Crustacea.	3. Insecta.	5. Annelida.	7. Rotifera.
2. Arachnida.	4. Myriapoda.	6. Cirripoda.	8. Entozoa.

CLASS V.—INSECTS.

We begin with the Insects, which, though not the highest in point of general organisation, are the most typical of the series, and therefore afford the best standard for comparative description. As a class, they are perhaps the most interesting in the whole Animal Kingdom, both in regard to the number, variety, beauty, and complexity of the forms which it contains, the vast assemblages of individuals of the same species which not unfrequently make their appearance together, and their consequent importance in the economy of nature.

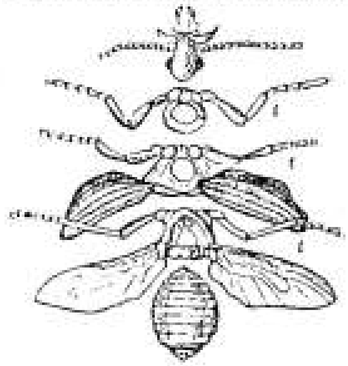
The true Insects are distinguished from the Crustacea by their peculiar apparatus for atmospheric respiration; from the Arachnida by having but six legs (eight being the number in that class), and by the division of the body into three parts; and from the Myriapoda by the limited number of legs and segments, the latter seldom exceeding thirteen. In the perfect insect, it is sometimes difficult to distinguish the division into segments; they may generally be seen, however, on the lower side of the body, especially on the abdomen. But in the larva or caterpillar state, they are never obscure, and their number is very constant, being almost always thirteen, one forming the head. Of the twelve segments of the body, three in the perfect insect form the thorax, or division succeeding the head, whilst the remaining nine constitute the abdomen. It is more common for one or two segments to be apparently deficient (being consolidated with the rest), than for any increased number to be present.

The *metamorphosis*, or complete change of form, which may be seen in the greater number of insects during their development, has attracted much attention from the earliest ages to the present time. The *larva*, which afterwards changes to a beetle, a butterfly, or a wasp, bears no resemblance whatever to the perfect or *imago* form, and is in fact allied, in almost every particular of its conformation, to a class far beneath. Moreover, it has to go through an intermediate form—if anything, still more remarkable—that of the *pupa*, or *chrysalis*, in which there is an almost complete cessation of activity, but in which preparation is being made for the exit of the perfect insect at its final change. The alteration of the entire character of the animal is no less remarkable than its change of form. In the *larva* condition, its whole energies seem to be concentrated upon the nutritive functions—the voracity being extreme, and the increase in the weight of the body very rapid; whilst, in the perfect insect, the body undergoes little increase of size, but is provided with powers of active movement, which are principally destined to enable it to seek its mate, for the purpose of propagation.

The *larva*, when it first emerges from the egg, bears but a very small proportion to its subsequent bulk. According to Lyonnet, the comparative weight of a full-grown caterpillar of the goat-moth to that of the young one just escaped from the egg, is as 72,000 to 1. During its increase, it throws off its skin several times, like the Crustacea. The larvæ in the different tribes vary extremely as to the degree of their development: in some orders they are very imperfect, not even possessing legs; whilst in others they correspond with the perfect insect in almost every particular except the presence of wings.

After attaining its full growth in the larva condition (in which the bulk of the body often much exceeds that of the imago), the insect undergoes a very remarkable change, ceasing to take food, and apparently losing all appearance of vitality. In this state it is termed the *pupa*, or chrysalis. Many larvæ enclose themselves in a silken cocoon, or in some other kind of envelope, before undergoing this change; and remain in it during the whole period of inactivity, which is sometimes many months in duration. Some bury themselves in the ground; and others, again, suspend themselves in the air. The pupæ of different orders of insects vary, like the larvæ, both in form and in degree of torpor. Some have the whole body enclosed in a horny case, without vestige of members, and are totally inactive, except when disturbed; others present the general form of the perfect insect, but appear as if the body and limbs were separately bandaged, and laid in close apposition; whilst others retain all their limbs free, and suffer no diminution in their locomotive powers or in their appetite for food. These, indeed, can scarcely be said to pass into the pupa state at all, their condition being only indicated by the gradual development of the wings—a development equally taking place beneath the envelope of the pupæ which are enclosed and inactive.

The perfect insect, or imago, when it emerges from its pupa case, exhibits in all respects the *form* which is characteristic of the species, and, in general, the size also; few growing much after they have attained this condition, and many scarcely eating at all. As already mentioned, the twelve segments forming the body of the larva may still be recognised here, but very much changed in their character. The three anterior ones are often soldered, as it were, together; forming but one strong sheath for that portion of the body from which the wings and legs proceed—and this sheath affords firm attachment for the powerful muscles which move these organs. Those which constitute the abdomen, however, retain much more of their original aspect. The head is now quite distinct from the body, and connected with it by a neck, which is often very slender. From each of the segments of the thorax a pair of legs proceeds; and the second and third usually give origin to a pair of wings each. Where, however, only one pair of these organs exists, they proceed from the second segment. The segments of the abdomen never show any vestige of legs. The accompanying diagram represents the chief parts of the perfect insect:



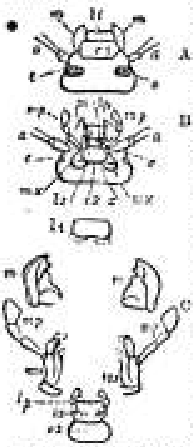
Segments of Insect.

the three segments of the thorax (*t t t*) are separated from each other to show the organs attached to them. The especial function of the perfect insect is the continuance of the species; and the wings enable it to seek its mate, and to obtain a situation fit for the deposition of its eggs, which are always laid in the neighbourhood of whatever substances will supply the larvæ with nourishment, although it most commonly happens that the image itself does not feed upon them. Many insects, such as the *silkworm* moth, and the *ephemera* or May-fly, die soon after having fulfilled this object.

However extraordinary the metamorphosis of insects, it is by no means *unique*, as was formerly supposed. The change of the tadpole into a frog is an exact parallel to it; for the tadpole is for the time a fish, resembling that class in its entire organisation, just as the maggot is for the time a worm. Moreover, we shall hereafter see, in some of the lower classes, a change which is fully as remarkable. When the larva is very imperfect, and the pupa inactive, so that its change to the form of the imago is very striking, the metamorphosis is said to be *complete*; but if the larva is more advanced, and the pupa differs little from it, and from the ultimate form of the perfect insect, the metamorphosis is termed *incomplete*.

Insects, in their perfect state, are distinguished beyond all other animals for their power of locomotion, and for the perfection of their instinctive actions. In estimating their power of locomotion, the space traversed is of course compared with the length of the body; and thus it is seen that, rapid as is the flight of many birds, that of most insects far surpasses it. The senses of insects appear likewise to be acute. They have generally large eyes, formed, in fact, by the union of a great number of small ones—often several thousand; and although these are fixed, yet, from their being directed, like the facets of a jewel, at various angles to each other, an extensive range of vision is obtained. It is believed that insects possess the power of hearing, and also of smell; though no distinct organs for receiving such impressions have been satisfactorily determined. That they have a delicate sense of touch in some part of the body, even where the general envelope is firm, cannot be questioned; and, from observations made upon the social genera, such as bees and ants, there is reason to believe that they communicate with each other chiefly by this sense.

The different organs on the head of insects furnish, by their varieties of conformation, important characters in classification. It will therefore be necessary to describe these in some detail. The most important characters, upon which, in fact, the primary subdivision of the class is founded, are drawn from the structure of the mouth: in one large group it is furnished with *mandibles*, or jaws, adapted for biting and bruising; whilst in the other, it is provided with a *haustellum*, or proboscis, adapted for suction: hence the first group is termed MANDIBULATA, and the second HAUSTELLATA. These organs are, however, but different modifications of the same primary elements.

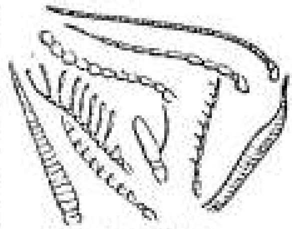


Different parts of the mouth of a beetle.*

In the mouth of the Mandibulata, six principal pieces may be readily distinguished. Of these, four are arranged in two pairs, which work against each other laterally; a fifth piece is above the upper pair, and a sixth below the lower. The two lateral pairs are the jaws; of which the upper pair is distinguished by the name of *mandibles*, and the lower by that of *maxillæ*. The mandibles are usually the largest, and are very powerful organs: sometimes they are provided with sharp or toothed edges, working against each other like those of a pair of scissors; and sometimes with hooked points, more formidable, for the size of the animal, than the teeth of the tiger. These are the principal organs by which the food, of whatever description, is usually obtained; but in the bees and wasps, of which some species are adapted to obtain their nourishment by suction, they are the instruments by which their curious edifices are built up. In a word, as has been well remarked, they supply the place of trowels, spades, pickaxes, saws, scissors, and knives, as necessity may require. The *maxillæ*, or under pair of jaws, are of similar construction, but usually smaller and less powerful. The pieces which are applied above and below to the spaces left between the jaws are termed *lips;* the upper being designated the *labrum*, and the lower the *labium*.

Various modifications of these parts are seen in the different orders of insects, but their existence may always be detected under some form or other. The most remarkable alteration in the structure of the mouth is that which we find in the Lepidoptera, or Butterfly tribe. Instead of cutting jaws, we observe a tubular appendage, or trunk, which is often of considerable length, and coiled spirally beneath the head, but capable of being unrolled when its point is required to descend into the corollæ of flowers. This tube is composed of two long narrow filaments, which are, in fact, the *maxillæ* excessively drawn out; these filaments are channelled on the sides at which they approach one another; and by the adhesion of the edges of these channels, which lock together by means of minute teeth, a complete tube is formed. In this mouth, therefore, all the parts except the maxillæ would seem at first sight to be wanting; but they may be detected by a careful examination, and the rudiments of the upper lip, of the mandibles, and of the lower lip, as well as of the *palpi* (organs to be presently described), may be distinctly demonstrated. In other instances, an entirely different modification of the same parts may be observed, which will be noticed in the proper place.

The head of the perfect insect is usually furnished with three pairs of jointed appendages, all of which are probably instruments of sensation. The first of these are termed *antennæ*; they are affixed to the sides of the head, and usually between the eyes and the mouth. The number of joints in them, and the forms they present, vary in the different tribes of insects, as also does their size, within very wide limits. Occasionally, they are three or four times as long as the whole body, and sometimes they are scarcely to be perceived: in some cases they are simple thread-like organs, gradually tapering from the base to the point; in others they swell out towards the extremity; and often they possess side branches or appendages of various forms. These different characters are extremely useful in classification. The *palpi* are organs which are not dissimilar in general character, but are usually of much smaller size, consisting of seldom more than six joints; of these, one pair is attached to the *maxillæ*, and the other to the *labium*, and are respectively called *maxillary* and *labial* palpi. The uses of these appendages are involved in some obscurity. There is good reason to believe that all of them are organs of touch; and this sense is probably sometimes most acute in the antennæ, and sometimes in the palpi. There is also reason to believe that the sense of hearing is in some way connected with the antennæ; and a curious modification of the joint at the base seems to be particularly appropriated to this function. It has been further surmised that the antennæ minister to the sense of smell.


Variously formed Antennæ.

The *wings* of insects are the organs most peculiar to them; nothing at all analogous being developed in other articulated animals. They consist of a double layer of membrane, prolonged from the skin which covers the body, and partaking of its characters. This membrane is supported by a framework of harder structure, composed of ribs, which go by the name of *veins*, or *nerves*. These terms must not be supposed to imply any analogy of structure with the organs they designate in higher animals; they are rather drawn from the analogous parts in the leaves of plants.

There is scarcely any organised substance upon which insects are not adapted to prey. In regard to the food of individual tribes, it may here be stated in general terms, that some are purely carnivorous, devouring only prey which they have themselves killed; others eat carrion, and even keep it until its decomposition is advanced. Many are herbivorous — some feeding only upon particular species of plants, whilst others are not restricted, but feed upon almost any vegetable substance. Others, again, are omnivorous, and will attack anything that falls in their way. The excessive multiplication of insects, which would result from the enormous number of their eggs, and from their rapid growth, is prevented by the influence of other tribes of animals, as well as by the wars of their own tribes against each other. The destruction of the larvæ of some species by those of others is often enormous, and far exceeds in proportion the diminution in their numbers effected by higher classes. There is no class of animals formed to exist on land, however, of which part do not derive a great proportion of their

* A, upper side; B, under side; C, parts separated: *a a*, antennæ; *e e*, eyes; *l* 1, upper lip; *m m*, mandibles; *m x*, maxillæ; *m p*, maxillary palpi; *l* 2, labium; *l p*, labial palpi; *c* 2, chin, or mentum.

food from insects; and thus, if man does not interfere with the economy of nature, a balance is maintained which is rarely disturbed. But if these higher tribes be destroyed (as, for example, if a rookery be dispersed), insects will then multiply inordinately, and will become a pest to the district.

Insects are distributed abundantly over every portion of the globe. Even in the coldest regions which man has yet explored, they present themselves to his notice during the brief summer; and no severity of the winter appears capable of destroying their vitality, although it reduces them to a state of complete torpidity. It is in tropical regions, however, that the largest and most brilliant species are found.

The subdivision of the class into orders is chiefly founded on the character of the wings; since it is found that the structure of these organs affords a good general index to that of the body. But it cannot be trusted to alone. For whilst certain orders may be included under the general designation *Aptera*, or Wingless, and another be termed *Diptera*, or Two-winged, we find wingless and two-winged insects in all the other orders.

WINGED INSECTS.

Winged insects may be distributed amongst the eight following orders, of which the first four are MANDIBULATE, whilst the rest possess a mouth formed for suction, and are termed HAUSTELLATE:—

1. COLEOPTERA (*Beetles*). In these the two anterior wings are converted into a horny or leathery substance, and enclose the posterior when folded.

2. ORTHOPTERA (*Grasshopper, Cockroach*). In these the anterior pair of wings is composed of a substance more resembling membrane.

3. NEUROPTERA (*Dragon-Fly, Termite*). Both pairs of wings are membranous, and the nerves form a close network by their interlacement.

4. HYMENOPTERA (*Bee, Wasp, Saw-Fly*). Both pairs of wings are here also membranous; but the veins have larger areas between them.

5. HOMOPTERA (*Cicada, Lantern-Fly*). In this order the four wings are of the same consistence, often somewhat like parchment; and, when folded, they incline at an angle, like the roof of a house.

6. HETEROPTERA (*Bugs*). The anterior pair of wings is horny, or leathery, but generally tipped with membrane; both pairs are horizontal, or nearly so.

7. LEPIDOPTERA (*Butterflies* and *Moths*). These have four membranous wings, covered with minute scales, which give them a downy appearance.

8. DIPTERA (*Gnat, Fly*). These have but two wings, and are in many respects parallel to the fourth order.

Besides these, there are some small orders intermediate between the principal groups. Thus a separate order, TRICHOPTERA, has been formed to include the *case-worm-flies*, which are intermediate between LEPIDOPTERA and NEUROPTERA. The order STREPSIPTERA, again, comprehends a small group termed *wasp-flies*, intermediate between the LEPIDOPTERA and DIPTERA.

I.—Coleoptera.

This order comprehends all insects which have the anterior pair of wings converted into wing-cases, or *elytra*, and which undergo a complete metamorphosis. These wing-cases are of horny consistency, and are opaque, or nearly so. When expanded, they are of little or no use in flight; and when closed, they meet along the back, in a straight line, which is called the suture. The second pair of wings constitute the true organs of flight; they are of large size, and of membranous texture; and when unemployed, they are shut up in several transverse folds, and are entirely concealed beneath the elytra. The mouth is formed for mastication, and possesses two horny mandibles. The head is provided with two antennæ, of variable form, and of which the number of joints is usually eleven; these often differ considerably in the two sexes. The eyes are large and protuberant, especially in the carnivorous species, and in these, the slowness of whose habits makes quick powers of sight necessary for the purpose of avoiding their enemies.

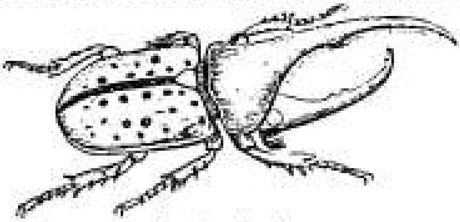
Although these characters are applicable to by far the greater number of insects included in this order, nearly all of them are subject to exceptions. Thus there are some species in which the organs of flight are altogether wanting, as in the female of the glow-worm; others which have elytra, but no wings; some, in which the elytra adhere together along the suture; others, in which they overlap; others, again, in which they do not meet; and some, in which the wings are longitudinally folded. It is well for the student to be aware that such exceptions exist in almost every large natural group, however definite its characters may generally be. In none of these instances is there an exception as to more than one or two of the characters; the remainder conform to the usual type. The most universal is that of the metamorphosis, which, being *complete*, distinguishes this order from others approaching it, either in the structure of the mouth, or in the character of the wings.

The coleopterous order comprehends an immense number of species, which have been classified, first in genera, then in tribes, and finally in sections, with a regard to the number of joints in the tarsus or divisions of the foot. Some are wholly carnivorous, others herbivorous, and some take both kinds of food. Some, again, are aquatic, while a much larger number live on land. The habits of the various families—of which we can only notice a few of the more interesting—are, upon the whole, obscure and foul.

The SERRICORNES are distinguished by the toothed or serrated structure of the antennæ. Some of this family, having the body of solid consistence, and oval in form, have the head buried, as it were, in the thorax, which advances on its two sides nearly as far as the mouth. In this way are formed the *Buprestis*, distinguished for the splendour of its colours, many of its species having spots of golden hue upon an emerald ground, whilst in others azure glitters upon the gold. These brilliant species belong to tropical climates, which these insects appear especially formed to inhabit, our native species flying with the greatest activity in warm weather. They live among trees; and if an effort be made to seize them, they counterfeit death, and fall to the ground. The beetles belonging to the allied genus *Elater*, are commonly called 'skip-jacks;' for, when laid on their backs, being unable to raise themselves on account of the shortness of their feet, they spring perpendicularly into the air, so as to alight upon their feet. This is effected by a violent backward blow of the head against the surface on which they are lying. The larva of an English species is known to the farmer as the *wire-worm*, which does much injury by devouring the roots of the corn. A species of elater inhabiting the West Indies and South America, has two brilliantly luminous spots upon the front of the thorax; and a portion of its abdomen, which is uncovered during flight, is also illuminated. Another interesting genus is the *Lampyris*, to which belong the common glow-worm, and some of the fire-flies of warmer regions. The body of these insects is very soft, especially the abdomen; and it is from the two or three last segments of this part that the phosphorescent light for which they are so remarkable is emitted. Its intensity is evidently dependent in a great degree upon the state of the animal: if the insect be irritated, it is increased; but if its powers are depressed or exhausted, it is lessened. It seems to be sometimes withdrawn simply at the will of the animal. In the glow-worm (*L. noctiluca*), it is only the female that is luminous; and she is destitute of wings and elytra, which the male possesses. They are only active by night; and as the male is known to be attracted, like moths, by lights in houses, it is probable that the phosphorescence of the female is given for the purpose of signalising her place.

The CLAVICORNES, characterised by the club-shaped form of the extremities of the antennæ, are partly terrestrial and partly aquatic; they feed for the most part on animal matter, at least in the larva state. The terrestrial ones seem to prefer substances which are in a state of decay; they creep slowly, and are mostly of a dark colour—black or bronzed. One of the most interesting genera is the *Necrophorus*, or burying-beetle, so named from its habit of excavating the ground beneath the dead bodies of small quadrupeds, such as mice or moles. Having thus interred a carcase, they deposit their eggs in it, and the larvæ, when hatched, feed upon the flesh.

The Lamellicornes is a family of very great extent, and one of the most striking of the whole Beetle tribe, in respect to the size of the body, and the variety in the form of the head and thorax in the different sexes; and often, also, in those species which in their perfect state live upon vegetable substances, in respect to the brilliancy of the metallic colours with which they are ornamented. All have wings, and they crawl but slowly along the ground. None of them are aquatic. Their food consists of dung, manure, tan, and particularly (in some species) of the roots of vegetables; whence these insects, especially in their larva state, often occasion great loss to the cultivator. This family receives its name from the peculiar conformation of the antennæ, which terminate in a mass formed of the three last joints; these are flattened into plates or lamellæ—sometimes arranged like a fan or the leaves of a book, frequently in the manner of a comb, and sometimes enclosing each other. The family is distributed into two principal sections—the *Scarabæi* and the *Lucani*. Of the Scarabæi, one subdivision, including the sacred beetle of Egypt, feed principally upon the excrements of various animals. A most remarkably formed species is the *Dynastes Hercules*, a native of



Dynastes Hercules.

Brazil, which attains the length of five inches, and of which the male possesses an enormous horn projecting from the head, which is opposed by a corresponding protuberance from the thorax. To this group also belongs the *Melolontha vulgaris*, or common cockchafer, which is most destructive to vegetation both in its larva and perfect condition, feeding on the roots in the one case, and on the leaves and young shoots in the other. The larva lives for three or four years beneath the ground, becoming lethargic in winter, but actively voracious in summer. Their excessive multiplication is usually prevented by birds; but if these be kept away, they increase very rapidly, and become a pest to the cultivator. The perfect insect sometimes makes its appearance in such swarms, as to devastate an entire forest. The *Lucani*, or Stag-Beetles, derive their common name from the peculiar form of the mandibles, which are large, curved, and toothed, like stag-horns. The *L. cervus* is one of the largest British insects, the males being two inches or more in length. This species flies about in the evening in the middle of the summer, especially round the oaks, upon the wood of which the larva feeds, remaining in that state for several years before undergoing its final transformation. Some of the exotic members of this group are very large, and splendidly coloured.

In the Melasoma, one of the herbivorous families, the body is of an ashy-brown or black colour, and for the most part the wings are absent, the elytra being united along the suture. They live for the most part in the ground, beneath stones, or in the sand—often, also, in low and dark parts of buildings, such as cellars, stables, &c. This tribe of insects is very tenacious of life; individuals have been known to remain alive for six months without food, and stuck on a pin. To this family belong the *Blaps mortisaga*, a beetle often found in dark and dirty places about houses; and the *Tenebrio molitor*, of which the larva is known under the name of the meal-worm, living among corn and flour. The perfect insect frequents bakehouses, corn-mills, &c. where it may often be found in the evening.

In the family Trachelides, one of the most remarkable species is the well-known blistering-fly (*Cantharis vesicatoria*), abundant in Spain and France, and distinguished by its fine metallic colours. To a different section belongs the Rhyncophorus, or *Weevil* tribe, so destructive in our stores of grain. One of this family is the celebrated diamond beetle (*Curculio imperialis*), a native of South America, and the most splendid of all beetles. The Trimera are a section of beetles, generally of small size, one of the most familiar being the lady-bird (*Coccinella*), which is of great benefit to plants, by feeding on the aphides which infest them.

II.—Orthoptera.

The order Orthoptera comprehends all insects that have the mouth armed with jaws fitted for mastication, and two pairs of wings; of which the anterior encase the others, the posterior being membranous, and folding longitudinally during repose. In many respects they resemble the Coleoptera; and they are closely connected with that order by the *Forficulidæ*, or Earwig tribe, which partake of the characters of both. But they differ from the Beetles in the softer covering of their bodies; in the partially membranous character of the anterior pair of wings, which seem intermediate between the horny elytra of Beetles and the membranous wings of other insects, and which do not meet along the back when closed; and in the fan-like manner in which the posterior wings are folded up beneath them, which is permitted by the straight direction of their veins. They differ also in their metamorphosis; for whilst that of the Beetles is complete, that of the Orthoptera is only partially so; for the larva and pupa closely resemble the perfect insect in form, walking and feeding in the same manner, and differing little except in the absence of the wings and wing-covers, which are gradually developed in the latter.

This order comprises numerous well-known insects, often of large size and splendid colours; such as grasshoppers, locusts, walking-leaves, as well as cockroaches and earwigs. Some of the largest of known insects belong to it; a few species attaining a length of eight or nine inches, and an equal expansion of wings. Comparatively, few are inhabitants of temperate regions; the order attaining its greatest development, both in number, size, and colour, between the tropics. All the known Orthoptera are terrestrial, both in their perfect and two previous states. Some are purely carnivorous, and others are adapted to a mixed diet—the Cockroaches, for example, being capable of feeding on almost any organised matter, whilst the great majority feed upon plants—hence, from their large size, and the quantity which each individual can devour, they are among the most destructive of all the insect tribes, when they appear in large numbers. This is particularly the case with the locusts in warm countries, the ravages of which not unfrequently cause famine and pestilence both among men and beasts.

The Orthoptera are usually divided into two sections—the Cursoria, whose legs are all alike, and adapted for running, and whose wings and wing-covers rest horizontally on the body; and the Saltatoria, the thighs of whose hind legs are much larger than the rest, in consequence of which they possess great powers of leaping. In some of the latter the wings meet at an angle when folded, like the two sides of a roof; and the males have the power of making a sharp creaking noise.

The Cursoria contain three well-known forms—

the *Earwig*, *Cockroach*, and *Mantis*. The Mantis family are purely carnivorous insects, of which none are natives of this country. The first pair of legs is enormously enlarged, and forms a very powerful organ of attack. They frequent trees and plants; and the forms and colours of their wings and bodies are often so adapted to those of the leaves and twigs which surround them, as to give them remarkable power of eluding observation. Hence these have been called walking-leaves. One species, the *Mantis religiosa*, is regarded by the natives of the countries it inhabits with superstitious reverence, on account of its occasionally assuming the attitude of prayer. This is, however, the position in which it lies in wait for its prey; the front of the thorax being elevated, and the two fore legs held up together, like a pair of arms, prepared to seize any animal that may fall within their reach. They are extremely voracious insects; and, if kept together without food, will fight, the victor devouring its conquered adversary. Allied to the mantis is a very singular genus, the *Phasma*, of which the different species have received the names of walking-stick, spectre insects, &c. Their bodies are extremely prolonged, and rounded; and in their colour they much resemble dried sticks, previously to the development of the wings, which are usually green and leaf-like. The legs are all equal, so that they are distinguished from the Mantidæ on the one hand, and from the Saltatoria on the other; but they are not able to move rapidly either in the larva or perfect state.

The family Saltatoria consists of numerous species allied to the well-known *Crickets*, *Grasshoppers*, and *Locusts*. Besides the peculiarities already mentioned, they are remarkable for the deposition of their eggs in the ground, which is generally accomplished by means of a long horny ovipositor. The mode in which the sound is produced varies in different species: in the locusts, it is caused by the friction of the posterior thighs, like the bow of a violin, against the wing-covers; in others, it is occasioned by the friction of two talc-like spots, on the inner sides of the wing-covers, against each other. The larvæ of the mole-crickets and the common social locust are among the most destructive of the insect races.

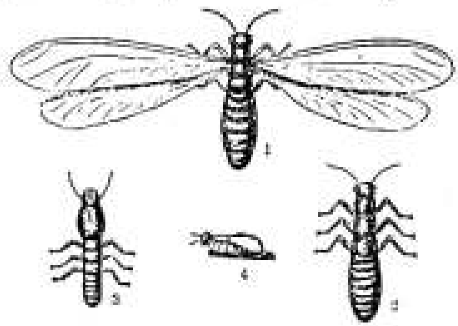
III.—Neuroptera.

The Neuroptera resemble the Coleoptera and Orthoptera in the structure of the mouth, but differ from them in the conformation of the wings. The anterior as well as the posterior pair are here membranous and transparent. In both, the veins form a very beautiful and minute network, subdividing and uniting again, so as to divide the whole surface into a large number of cells, which very much exceed in number those of the wings of any other tribe of insects. The posterior wings are usually as large as the superior, or sometimes even larger; if narrower, they are generally longer.

The body of the insects of this tribe—which contains the well-known *Dragon-flies*, *May-flies*, *Ant-lions*, and *White Ants or Termites*—is generally prolonged, and destitute of any very hard integument. They differ in the character of their metamorphosis as well as in their adult structure; for in some, the metamorphosis is complete, the larva undergoing a marked change of form; in others there is not much difference, except in the absence of wings, between the larva and the perfect insect. By these differences the order may be subdivided into two groups, in the first of which the pupa is active, whilst in the second it is quiescent, except just before the assumption of the perfect state. The first of these groups may be further divided into those which have terrestrial larvæ, such as the *Termitidæ*, and those which are aquatic in their preparatory states, as the *Libellulidæ*, or Dragon-flies, and the *Ephemeræ*, or Day-flies. These pass the first two stages of their lives in water, respiring by means of peculiar organs placed at the sides or extremity of the abdomen. In other respects their larvæ and pupæ nearly resemble the perfect insect. They creep out of the water to undergo the final metamorphosis.

The Ephemeridæ derive their name from the short duration of their lives in the perfect state. They generally arrive at their final change at sunset in the fine days of summer and autumn, along the margin of the streams, &c. in which they have been developed. In this stage of their existence they take no food; after a few hours of apparently happy life, during which they provide for the development of a new generation, they cease to have a place on earth.

The Termitidæ, or White Ants, are terrestrial, active, and carnivorous or omnivorous, in all their stages. In several points of their structure they approach the Orthoptera; whilst in their habit of living in societies they resemble the Hymenoptera. Unlike the social tribes among the former, however, the neuters or sexless individuals in these communities officiate only as soldiers; and those which are here denominated workers, are, in reality, the larvæ, which closely resemble the perfect insect, except in the absence of wings. These



1. and 2. Perfect Termites; 3. Soldier; 4. Worker.

insects commit the most extraordinary ravages, the numbers in each colony being almost incalculable, and their voracity extreme. Their nests are sometimes concealed below the surface of the earth, or in the interior of trees, timbers, &c.; and through these they bore galleries in such a manner, that though the outer surface is left untouched, they fall to pieces on the slightest violence. Sometimes the nests are elevated to several feet above the surface of the ground, and have a pyramidal roof. When arrived at their perfect state, the Termites quit their habitation, and fly abroad during the evening or night in great numbers; they lose their wings before the morning, and many of them, falling to the ground, become the prey of birds, reptiles, &c. The females, however, are sought by the workers, which imprison them in royal chambers (as they have been termed) in the centre of the nest. The abdomen subsequently attains an enormous size, from the quantity of eggs it contains; and these, when deposited, are carefully tended by the workers, and defended by the soldiers.

IV.—Hymenoptera.

In the membranous character of their four wings, the insects of this order resemble the Neuroptera; but they cannot well be mistaken for them. The anterior wings are usually much larger than the posterior; the veins or nervures are much fewer in number than in the Neuroptera, and do not form a close network by their ramifications, as in that order. In some of the minute species the wings are almost, or even entirely, destitute of nerves. Another character furnished by the wings consists in the connection of the anterior and posterior during flight, by means of a series of minute hooks along the front edge of the latter, which catch the hinder margin of the former, so as to produce one continuous expansion. The principal character, however, is derived from the structure of the mouth; for although considered as mandibulate insects, the Hymenoptera are better fitted for imbibing their nourishment by suction than for obtaining it by mastication, their maxillæ being much prolonged and channelled, and even uniting at their base into a tube, so as to form a kind of proboscis. This is well seen in the bee. They are also peculiarly distinguished by a prolongation of the last segment of the body in the females, into an organ which is in one division of the order a *sting*, and in the other an *ovipositor*, or instrument for depositing the eggs, usually possessing the power of boring a hollow for their reception.

The Hymenoptera are further remarkable for the great development of their instinctive faculties, and of their locomotive powers. It is in this order that we find the most remarkable examples of contrivance and skilful adaptation of means to ends; but this adaptation results, it would appear, not from an exercise of *intelligence* on the part of the animals themselves (as in man and the higher Vertebrata), but from their blindly following out a plan laid down for them by the Almighty Designer. This inference may be deduced from the *invariability* of the operations performed by different individuals among the same species, so that a history of the life of one is equally applicable to all. The adjustment of instinctive actions to each other is nowhere more remarkable than in the case of the *social* insects, which are chiefly restricted to this order. The Bees, Wasps, Ants, Saw-Flies, Ichneumons, and Gall-Flies, have attracted the attention of the observer of nature from the earliest period.

The insects of this order undergo a complete metamorphosis, the larvæ being amongst the most imperfect of those of any tribe. In the greater proportion of the order, they are destitute of feet, and resemble little worms. These are dependent upon the instinctive care of the parent for support; which is either provided for by the deposition of the eggs in situations where the future grub will be certain of an ample supply of food, or by the active exertions of the parents, which convey to the young the food they have collected for them. This charge more especially devolves on the *neuters*, or undeveloped females, which constitute the majority of the hive—there being generally only one queen-mother, and comparatively few males. When arrived at their full growth, and after undergoing several previous moultings, the larvæ are transformed into inactive pupæ, in which all the limbs of the future insect are visible, encased in distinct sheaths, and folded on the under surface of the thorax. During this part of their existence they take no food. In their perfect state, these insects for the most part take but little nourishment; and this almost exclusively consists of the nectar of flowers. Many of them, however, such as the Wasps, attack and destroy other insects; but these are often destined, not for their own support, but for the nourishment of the young. In the number of genera and species, this order is inferior only to the Coleoptera. It has been estimated as containing one-fourth of the whole insect population.

The family of Ichneumonidæ may be regarded as peculiarly characteristic of the entomophagous or insect-devouring division. The female deposits her eggs, by means of her sharp-pointed ovipositor, only in the bodies of other insects, chiefly the larvæ of caterpillars, on which the young may feed when hatched. Some of them have a very long ovipositor, which is used to insert the eggs into the bodies of caterpillars that live beneath the bark, or in the crevices of trees; whilst those which have this instrument short, place their eggs in or upon the bodies of caterpillars, or pupæ, to which they can obtain easier access. They do not confine themselves to these situations, however; but employ for the same purpose the eggs or pupæ, still preferring the larvæ when they can find them. The young Ichneumons, when hatched as footless grubs, sometimes in considerable numbers in the body of one larva, devour only the fatty parts, which are not absolutely necessary to life; but when ready to undergo their metamorphosis, they either pierce through the skin, and escape, or else kill their victim, and perform their changes within its body.

The family Formicidæ is composed of the well-known and singularly interesting tribes of ants which are distinguished by their habit of residing under ground in societies, and by the existence of *neuters* among them, by which class the labours of the community are chiefly performed. The males and females, which constitute but a small proportion of each community, are alone furnished with wings; the former are the smallest. The neuters are somewhat smaller than the males, and mostly resemble the females in conformation; but the thorax is much narrower, and contracted in the middle, not having to give attachment to wings.

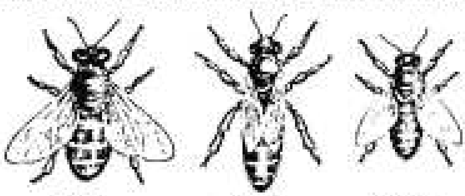
1. Female; 2. Male; 3. Worker.

The nests of ants are differently constructed in the different species, but in all are very curiously and regularly arranged. The males and females leave them as soon as they have acquired their wings, and go forth together into the air. The males soon die, without entering their former abode; of the females, some return, and deposit their eggs in the original nest, whilst others go off to a distance, and become the foundresses of new colonies. They lose their wings at this period, either stripping them off with their own feet, or being deprived of them by the neuters.

The neuters not only construct the nest, but carefully tend the young grubs, supplying them with food, moving them on fine days to the outer surface of the nest to give them heat, and carrying them back again at the approach of night or bad weather, and defending them when attacked by enemies. The winged ants having all perished at the commencement of the cold weather, the neuters only survive the winter. Some of the neuters are larger and rather differently formed from the rest, and appear to be the chief defenders or soldiers of the community. A most remarkable instinct is observed in some species—that of making war upon colonies of smaller ants, carrying captive the larvæ and pupæ of the neuters, and keeping them in slavery when hatched. Ants are well known to be extremely fond of saccharine matters, and they seem greatly to relish the fluid which exudes from the bodies of aphides and coccidæ. Some species, it has been asserted, collect aphides, and keep them, as it were, in pastures, which they connect with their nests by means of galleries excavated along the stems and branches of trees. The foregoing are a few of the chief facts relating to the economy of this tribe, on which many volumes have been written; and it may be safely asserted that there is none whose habits are calculated to afford more of interest and entertainment to those who seek acquaintance with them, either by the recorded observations of others, or by their own.

The family of Vespidæ, or *Wasps*, is distinguished from the other Hymenoptera by their wings being folded, when at rest, throughout their entire length. In general, these insects are social, the communities, however, being small; in such cases, there are neuters which are not destitute of wings. There are also some solitary species among whom no neuters exist. The best known of the Social Wasps, such as the common species of this country, construct their nests with bits of wood, bark, &c. which they separate with their jaws, and reduce to a pulp; and this, when expanded and dried, forms a paper-like substance. With this are built layers of hexagonal cells, one row being joined to the under side of another. The top row is attached, in some species, merely to the under side of a branch, or to the top of a slight hollow, by which it may be in some degree protected; but in others the whole comb is enveloped in a covering, formed by several layers of the same paper-like substance, with one or more apertures. Wasps feed, in their perfect state, upon insects, meat, fruit, &c. and nourish their young with the juices of these substances. A Brazilian species stores up an abundant provision of honey.

The *melliferous*, or honey-bearing *bees*, form two families; in one of which all the species are solitary, and are of only two kinds—males and females; whilst the others mostly live in societies, but are chiefly distinguished from the former by certain peculiarities in the structure of the mouth. Of the solitary Bees—ANDRENIDÆ—which construct nests for themselves, there are many curious varieties, some of which go under the names of Mason, Carpenter, and Upholsterer Bees, from the material with which they work—the first agglutinating bits of sand or gravel; the next excavating wood by means of their powerful jaws; and the last constructing their cells of portions of leaves. The habits of all may be studied in detail with extreme interest. Of the social species, APIDÆ, there are two principal groups—the Humble-Bees, or Wild-Bees, and the Hive-Bees. The common Humble-Bees of this country live in curious underground habitations, in societies usually of fifty or sixty, but sometimes of two hundred or three hundred individuals, all of which, with the exception of one or two fertile females, die during the winter. It is in the Hive-Bees that the arts of construction are exhibited in the most elaborate degree. Their societies consist of but one female, commonly termed the queen; several hundred males, which are known as drones; and about twenty thousand working bees, or neuters. It is by the latter that all the labours of the hive—the construction of the combs, the collection of food, both honey for the adults and pollen for the larvæ, and the nourishment of the grubs—are performed. The accompanying figures exhibit the



Male. Female. Neuter.

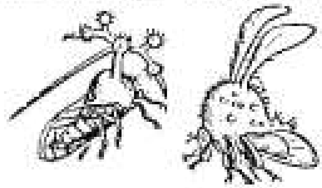
relative sizes and aspects of these three orders. The wax of which the comb is constructed is secreted by the insects themselves, in little scales, which work out from between the segments of the abdomen. These are taken up and kneaded by the jaws, and applied in the proper place. The drones are killed at the end of the summer; but the queen and great part of the workers remain; and when, in the summer, they increase so much as to over-people the hive, colonies are sent forth with young queens, in search of another habitation.

V.—Homoptera.

The insects contained in this order present many curious anomalies of structure and habit, and depart more widely from the general type than is the case in almost any other division of the class; hence it is difficult to assign any general characters which shall include them all. It is in the structure of the mouth that there is the greatest agreement. This is adapted for suction, the tongue being elongated and channelled into a gutter, and being surrounded by delicate lancet-like organs which pierce the tissues of plants. All the insects of this group subsist on vegetable juices; and many of them, from the amount of damage they commit, are very injurious to the cultivator. Some of the females are furnished with an ovipositor, provided with several toothed saws; and with this they make incisions into the leaves or stems of plants, into which they introduce their eggs. The anterior pair of wings is usually similar to the posterior in consistence, both being composed of a firm membrane: that which chiefly distinguishes the Homoptera, however, from the Heteroptera is, that the substance of the anterior pair, whatever be its nature, is the same throughout, and that, when folded, they are roof-like.

The CICADIDÆ are the largest of the order; one species measuring between six and seven inches in the expanse of its wings. Their peculiar characteristic consists in their musical powers. By a peculiar apparatus situated beneath the abdomen, they are enabled to produce a continued sound, nearly monotonous, but of considerable power. In some species, the sound is so loud and shrill, as to be heard at the distance of a mile.

The family CERCOPIDÆ consists of insects of small size, but which are remarkable for the grotesqueness of the forms which many of them assume: some inhabit this country, and are known by the name of cuckoo-spits and frog-hoppers; but the most singular species are confined to the tropics. The curious appendages,



Borydium Globulare. Borydium Cruciatum.

represented in the accompanying figures, of a Brazilian species, result from an extraordinary development of the first segment of the thorax. The insects of this family are often beautifully varied in their colours; they are constantly found amongst plants, and on trees, upon the juices of which they subsist, in all their stages. Of the best-known species of this country, the larva and pupa invest themselves with a frothy secretion, whence the vulgar name is derived. Some of this tribe are employed by certain species of ants for the same purposes as the Aphides, in consequence of their secreting a saccharine fluid.

The family of APHIDÆ, commonly known as *Plant Lice*, is extremely obnoxious, on account of the injuries committed by its members against almost every kind of vegetable. The Aphides live in great numbers upon the surface of the plant, and suck the juices, by means of their proboscis, from the young shoots, leaves, stems, and even roots. They thus greatly weaken its vigour, and often distort young shoots and leaves; some species cause little gall-like excrescences by the irritation they produce. In many of the species, a large proportion of the individuals never acquire wings, in which case the pupa is not to be distinguished from the mature larva or imago states, whilst at certain parts of the year, other individuals of the same species, and of both sexes, acquire wings. The wingless Aphides, which may be seen in the spring and early summer, are all females capable of producing fertile eggs, and from these are reared the winged males and females which are seen later in the season. Their rapidity of production is enormous, nine generations having been obtained within three months. The young are sometimes produced alive, whilst in other cases (according to the season, and other circumstances) eggs are deposited. Many of the *blights* so injurious to the gardener and the agriculturist, consist really of Aphides, although, from the minuteness of the insects themselves, they often escape observation.

The family of COCCIDÆ, sometimes called *Scale Insects*, although ordinarily of very small size, are amongst the most injurious to vegetation of any tribe. Their powers of propagation are excessive, and when they once gain possession of a plant or young tree, its death is almost certain, the minute size of the larvæ rendering it impossible to exterminate them. They furnish, however, some very important products. The bodies of many species are very deeply coloured through their whole substance, and yield dyes of great value, the richness of which seems to depend upon the nature of the plant on which they feed. The species employed by the ancients was a native of the Levant; but that which furnishes the *cochineal* so highly valued at the present time, was originally confined to Mexico, where it feeds on the cacti; it has, however, been introduced, along with its proper food, into Spain and Algiers, and also into the hothouses of this country. About 800,000 lbs. weight of cochineal are annually brought to Europe, each pound of which contains about 70,000 insects. The lac of the East Indies, which is extensively used in the composition of varnishes, sealing-wax, &c. is the product of another species of Coccus.

VI.—Heteroptera.

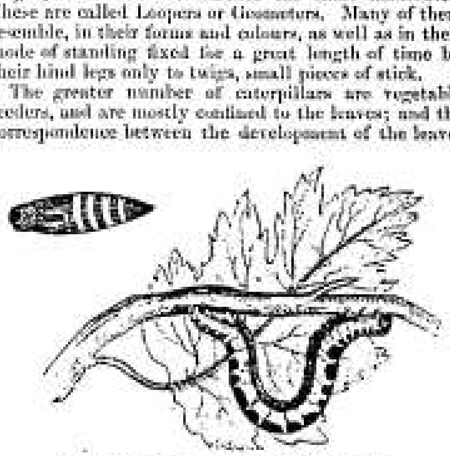
These insects bear a close general resemblance to those of the last order: as in them, the structure of the mouth, which is wholly adapted for suction, indicates that their nourishment consists solely of the juices of plants or animals; but they are at once known from them by the character of the anterior pair of wings, which are coriaceous at the base, and membranous towards their point, and which fold nearly horizontally, partly lapping over each other. By far the greater number of them feed upon the juices of plants; but some of them prey upon other and weaker insects, and a few species, as the common bug, suck the juices of larger animals. The majority of this order are found in tropical climates; and the species which inhabit these regions are mostly ornamented with a great variety of beautiful colours and markings, often vying with the most splendid of the Beetle tribes. Many species, however, are of aquatic habits, and these are all of an obscure black colour. Nearly all the terrestrial species have the power of emitting, when suddenly alarmed or touched, a powerful odour, which is of a pleasing character in some, but in others (as the common bed bug) very offensive. Others seem to eject a poisonous fluid into the wound they make, for the purpose of suction. In some, the wings are altogether undeveloped, or the upper pair is wanting. All the members of the order continue active, and require food, during the various stages of their existence.

VII.—Lepidoptera.

The order Lepidoptera, characterised, as formerly stated, by the downy covering of the wings (which is composed of minute scales, arranged with great regularity upon the membrane itself), contains some of the most beautiful forms of the whole class, as well as some of the largest. The number of species it comprehends is probably as great as that of any other order except the Coleoptera, and may probably number about one-fifth of the whole Insecta. All the members exhibit the well-known forms of *Butterflies* and *Moths;* and there is so much general resemblance among them, that the difficulty of classification is often considerable. The scales from which the order takes its name are generally of an oval form, terminating at one end in a kind of stalk, by which they are attached to the membrane of the wing; and on this they are arranged in rows, overlapping each other like tiles on a roof. They may be easily rubbed off with the finger; and the bare membrane is left, which is then seen to correspond with the wings of other insects. The number of scales covering the wings of the silkworm has been estimated at about 400,000. It is entirely to the scales that the colours of the wings are due; and sometimes these are so brilliant, as to be almost painful to look upon, if a strong sunlight is reflected from the surface. In some species the wings are partially, or even almost entirely, destitute of scales.

The Lepidoptera, in their perfect state, are formed to exist entirely upon fluid nutriment, which they suck up by means of a long trunk, which is usually coiled up spirally under the head. All the other parts of the mouth usually possessed by insects, may be detected in that of the Lepidoptera, but in a different state of development. The antennæ are variable in size, and always composed of a number of joints. The eyes are usually large, and contain numerous facets. The curious phenomena of the metamorphosis are presented to our notice more remarkably, perhaps, in this order than in any other. All the beings commonly known as *Caterpillars*, are the larvæ of Lepidoptera. They are produced from eggs of various forms and curious markings, which have been deposited upon leaves that are to serve as the food of the larvæ when hatched. The three first segments of the larva have each a pair of simple, short, and jointed feet, which are the rudiments of those of the perfect insect. Behind these are a variable number of temporary appendages, called pro-legs, which are thick, short, fleshy limbs, armed at their extremity with a great number of minute hooks, and furnished with powerful muscles. There are usually five pairs of these—four of them succeeding the true legs, and another arising from the last segment of the body. Those possessing pro-legs on nearly every segment, crawl upon all the feet at once, after the manner of the Myriapoda; but those which have only a small number of pro-legs, adopt a different method. They seize fast hold of the objects on which they are stationed with the six true legs at the fore part of the body, and then elevate the intermediate segments into an arch, until they bring the pro-legs behind close to the others; they then disengage the true feet, and retaining hold with the pro-legs, thrust the body to its full length, and then recommence the same manœuvre. These are called Loopers or Geometers. Many of them resemble, in their forms and colours, as well as in their mode of standing fixed for a great length of time by their hind legs only to twigs, small pieces of stick.

The greater number of caterpillars are vegetable feeders, and are mostly confined to the leaves; and the correspondence between the development of the leaves



Caterpillar and Chrysalis of the Magpie Moth.

and flowers of plants on the one hand, with that of the caterpillars and butterflies which are respectively to feed upon them, cannot but strike every one as a beautiful instance of creative foresight. But there are some caterpillars adapted to feed on flowers (such as come forth early in the year); and others attack seeds, roots, and even the woody portion of the stem. Moreover, there are a few which live in this state upon animal matter, such as wool, hides, leather, and fat. Many can digest a considerable variety of alimentary materials; whilst there are others that can only find support on some one kind, as, for example, the leaves of some particular species of plant. Their habits are also extremely various. Some burrow into the substance of leaves; others envelop themselves in the membrane of the leaf itself. Many construct cases or sheaths, either fixed or portable, by agglutinating various substances together; and there are some which live in societies under a tent of silk which they spin in common, and which serves to defend them from the inclemency of the weather. They usually throw off their skin four times before undergoing the transformation into the chrysalis state. For this they prepare by spinning a cocoon, in which they are enclosed during the greater part of that epoch. Some construct this entirely of silk; others attach together portions of leaves, or particles of earth, by silken threads. These threads are formed by a glutinous secretion from glands which seem analogous to the salivary glands of other animals; and this being forced out through a small opening at the end of the lip, hardens as it dries in the air. There are some caterpillars which form no cocoon, but which are contented with suspending themselves, by the attachment of the hinder part of the body, to some solid support, or by a silken thread coiled around them. The *chrysalis*, or nymph, has the whole body enclosed in a tough envelope, under which, however, the form of the parts of the future insect may be discerned. At the moment of the final transformation, it discharges from its intestine a red liquid, which softens one end of the cocoon, and allows the exit of the moth. Generally, one end of this envelope is weaker, or even fitted by the arrangement of the threads for the escape of the insect.

The *Butterfly*, when it throws off its last envelope, and comes forth into the air, of which it is henceforth to be one of the gayest inhabitants, is not altogether perfect, although capable of very soon becoming so. The wings appear at first very slightly developed, and hang loosely by the sides; and it is not until the animal has injected their tubes with air, by taking several full inspirations, that they become expanded so as to serve for flight. From that period, the body is supported by them during by far the greatest proportion of the active state of the insect.

One of the most remarkable of the SPHYNGIDÆ, or Moth family group, is the death's-head moth (*Acherontia atropos*), recognised by the skull-like patch on the back of the thorax. This emits a squeaking kind of sound, sometimes rather loud, but upon the mode in which it is produced entomologists are not agreed. In consequence of the peculiar aspect of its body, the sudden appearance of this insect in large numbers has been popularly regarded as ominous of evil. It is a great enemy to bees, and enters their hives undefended, devouring the honey, and alarming the inhabitants so, that they seem to keep aloof from it.

The genus *Bombyx* is an extremely important and interesting one, as it is by the caterpillar of the *B. mori* that all the silk now employed in Europe is produced. The larva feeds especially upon the mulberry, although it may be grown upon other plants; but as the silk produced by the former is preferable, that tree is grown to a great extent in Italy and the south of France, where the breeding of silkworms is carried on. The quantity of nutriment they require is enormous in proportion to their original size, but probably not greater than that consumed by other caterpillars. The care bestowed upon them, however, draws attention to the fact. The larva is reckoned to weigh, when first hatched, about one-hundredth of a grain; previously to its metamorphosis it increases to ninety-five grains, or 9500 times its original weight. It is reckoned that, for the larvæ proceeding from *an ounce* of eggs, nearly *two thousand pounds* of leaves are requisite. The caterpillars of another species of Bombyx are very remarkable for their curious habits. They live in societies on the leaves of the oak; and spin, when young, a kind of silken tent, divided within into cells. They may be seen to issue from it in the evening in procession. One of them advances at the head, and seems to act as a guide; two then follow; next three; then four; and so on, each rank containing one more than the preceding one: hence they have been called processionary caterpillars. Each spins a separate cocoon; but they are united in regular apposition, laid side by side against each other.

The family TINEIDÆ contains those little moths which are so injurious to woollen stuffs of every kind, as well as to furs, skins, feathers, and other objects of natural history, upon which their voracious larvæ feed. They use the same materials also for the construction of their movable cases or sheaths, which they enlarge with the increasing size of their bodies, both by adding to their extremities, and by slitting them along and inserting a new piece, so as to increase their diameter. In these tubes they undergo their metamorphosis, after closing the orifice with silk.

VIII.—Diptera.

The Two-Winged Insects constitute one of the most extensive orders of the whole class, not only in regard to the number of distinct species, but also from the swarms of individuals of the same species. Many of them also have been constant attendants upon man in all ages. They do not attract attention from their size, however, for there are few that exceed an inch in length; nor is it on account of their beauty, for the majority of them are of dull colours; their forms, too, are rarely elegant, and the transformations of many are unknown. They owe the notice they have attracted chiefly to their habits, and especially to those which affect man and the domestic animals, both in their perfect and early states. However annoying these are, it must not be forgotten that other Diptera are of extreme service, by cleansing the surface of the earth of vegetable and animal impurities; the carcase of any animal would be much more prejudicial in its decomposition, than when principally eaten up by these voracious creatures. The mouth of the perfect insects is formed only for imbibing fluid matter, and in many tribes is furnished with lancets for puncturing the flesh from which they suck the juices; both the channels through which they draw the fluid, and these accessory organs, consisting only of the usual parts of the mouth, altered in form and arrangement.

The CULICIDÆ, or *Gnat* tribe, are distinguished by their beautifully tufted antennæ. Gnats are well known to abound chiefly in damp situations; the reason being, that their larvæ are inhabitants of the water. The mosquitoes which infest many countries, especially in warm latitudes, differ but little from the common gnats. They sometimes appear in such swarms, especially in marshy districts, as to be kept off only by fire.

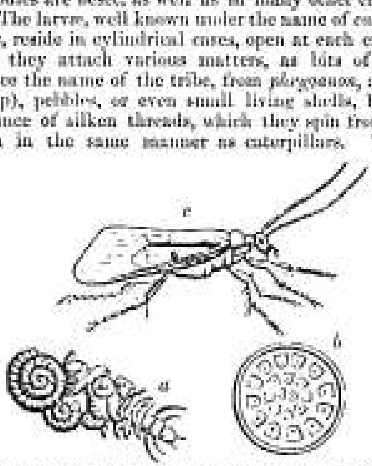
To the Gad-Fly tribe (TABANIDÆ) belong the largest Dipterous Insects, pre-eminently distinguished for the tormenting powers which the different species possess, by piercing the skins, and sucking the blood, of various quadrupeds, and even of man himself.

The form and habits of the MUSCIDÆ, or *Fly* tribe, are generally known: the family is an extremely numerous one, above 1700 species having been recorded as existing in Europe, of which about half are indigenous to this country; and there are probably at least as many more which have not been described. The strong general resemblance which exists among all the species, makes it very difficult (especially when their small size is considered) to discriminate them readily. The larvæ of these insects, commonly known as *maggots*, are soft, verniform, footless grubs, possessing on the head a couple of retractile hooks, by which they can cling to the substances on which they feed. They devour various substances, both animal and vegetable, living, recently dead, or far advanced in putrefaction. The eggs are deposited by the female, as in other instances, in the neighbourhood, or in the very substance of the food which is adapted for the support of the larva, however little to its own liking.

The ŒSTRIDÆ, or *Bot-Flies*, are a family very remarkable in regard to their structure and habits. The perfect insects resemble large meat-flies in form, are very hairy, and generally have these hairs coloured in rings, like humble-bees; but they are seldom seen, the duration of their lives being very short in this condition. Their chief peculiarity consists in the absence of any proper mouth in the imago (in which respect there is an analogy with the Strepsiptera), and in the peculiar habitation of the larva. This is always found in living animals; its situation, however, varying with the species, of which almost every herbivorous mammal has one or more peculiar to it. The egg is deposited by some in situations where the larva may burrow into the flesh, where it occasions inflammatory tumours, the fluids contained in which afford it nourishment. In other cases, the eggs or larvæ, existing upon spots which the animal is in the habit of licking, are conveyed by the tongue into the mouth, whence they pass into the stomach. There they remain until full-grown; and then they quit the body (as do also those that inhabit the flesh), and fall to the ground, beneath the surface of which they undergo their transformations. The larvæ of one species, which inhabit the sheep, are found in the cavities in front of the bones of the skull and higher parts of the nose. Man is subject to the attacks of one or more species, which do not, however, infest this country.

IX.—Trichoptera.

This order is a very small one, and consists but of one tribe, the PHRYGANIDÆ, which have been commonly associated with the Neuroptera. But there seems good reason for ranking them as a separate order, connecting the Neuroptera with the Lepidoptera, for they resemble the latter in the distribution of the nerves of the wings, and in the hairy covering with which both the wings and bodies are beset, as well as in many other characters. The larvæ, well known under the name of *caddice-worms*, reside in cylindrical cases, open at each end, to which they attach various matters, as bits of stick (whence the name of the tribe, from *phryganon*, a twig or chip), pebbles, or even small living shells, by the assistance of silken threads, which they spin from the mouth in the same manner as caterpillars. These



Phryganea: *a*, Larva in its case; *b*, Grating; *c*, Imago.

cases they bear about with them, protruding the three first segments, with their legs, when they creep forwards, and withdrawing these upon the slightest alarm: they never quit the cases of their own accord. Different species appear to prefer different materials for the construction of their cases; but they have the power of employing almost any which fall in their way, when those they prefer are deficient. The food of some of the larvæ is vegetable, but others prey upon smaller aquatic larvæ, such as those of Neuroptera.

When about to assume the pupa state, the larvæ fix their cases to some solid substance beneath the water, and close the two extremities with a kind of grating, that admits of the passage of water through the tube, which is necessary for respiration. When nearly arrived at their perfect form, they make their way out by the pair of hooked jaws with which they are then furnished, and swim about with great activity by means of the two hind legs, crawling also upon the four first. The pupæ of the larger species creep up the stems of plants, &c. and undergo their final change in the air; but the smaller ones merely come to the surface, where they shed their pupa skin in the same manner as gnats, the old envelope serving them as a raft. They live but a short time in the perfect state, taking no nourishment, and engaged only in propagating the race.

X.—Strepsiptera.

This is a small order, containing only a single group of insects; but these are so anomalous in structure, that it is not merely impossible to associate them with any other order, but it is even difficult to assign their proper place in the class. They are all of small size, none being known to exceed a quarter of an inch in length, and they are all parasitic in the larva state upon the bodies of bees and wasps. As they possess less of general interest than of curiosity to the scientific naturalist, they need not here be treated of.

WINGLESS INSECTS.

Besides the foregoing orders, which constitute the true insects, three others must be included in the class, on account of the correspondence in their general structure, although they present only one or neither of the two characters which have been stated to distinguish it—the presence of wings in the perfect state, and the metamorphosis. These three orders are, the APHANIPTERA, or *Flea* tribe, which have the rudiments of wings, and undergo a metamorphosis; the PARASITA, or *Louse* tribe, which is entirely destitute of wings, and undergoes no metamorphosis, but agrees with the true insects in having only six legs; and the THYSANOURA, including the *Spring-tails*, in which there are appendages to the abdomen, representing the legs of the posterior segments, so that these may be regarded as approaching the Myriapoda.

The habits of the common fleas of this country are well known; but there is a West Indian species, which, though of minuter size, is still more obnoxious. This is the *Pulex penetrans*, commonly known as the chigoe, or jigger. It chiefly attacks the naked feet, buries itself deeply in the skin, and then deposits there an immense number of eggs. The larvæ of these, when hatched, produce great irritation, and not unfrequently sores, from which even death has sometimes resulted. Most of the lower animals are infested with one or more species of the louse family, from the attacks of which they are not able to defend themselves; and man is subject to a peculiar disease, which seems very much to favour their production. Their generations succeed each other with great rapidity.

CLASS VI.—ARACHNIDA.

The class Arachnida — including the *Spiders* and their allies—was for a long time confounded with that of Insects, and has been only recently separated. The characters which the members present are perfectly distinct from those either of Insects on the one hand or of Crustacea on the other; nevertheless, they exhibit relations with both those groups.

The Arachnida may be distinguished from Insects by the absence of any division between the head and thorax; the compound mass thus formed is termed the cephalo-thorax. Again, Insects, in their mature state, are always provided with six legs, and no more; the Arachnida have eight of these members. Moreover, the eyes are not compound, but more resemble those of higher animals. From Crustacea they are separated by the softness of their bodies, but still more completely by their exclusively atmospheric respiration. The organs by which this function is performed vary in different tribes. In the *Acari*, or Mites, and their allies, these resemble the tracheæ of insects, and are distributed through the body; whilst in the Spiders, Scorpions, &c. they consist of rounded cavities, or air-sacs, into which the air is admitted by spiracles situated on the abdomen, and which are lined by a membrane plaited into numerous folds, which resemble gills, and lie in apposition like the leaves of a book. On this character is founded the subdivision of the class into *pulmonary* and *tracheary* Arachnida.

The majority of the Arachnida feed upon insects, which they seize alive, or upon which they fix themselves, and from which they suck the juices. Others live as parasites upon the bodies of vertebrated animals. There are some, however, which are only found in flour, cheese, and upon certain vegetables. These last, which mostly belong to the tracheary order, exhibit an affinity to insects not only in their structure, but in their metamorphosis; for they undergo great changes after they come out of the egg, an additional pair of legs being often developed; whilst in the others nothing else than a moult or casting of the skin occurs.

I.—Trachearia.

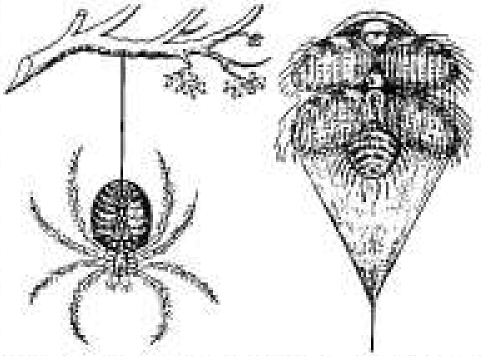
This order contains several remarkable forms, of which the one best known is that of Acaridæ, or *Mite* family, the majority of the species of which, however, are very minute, or almost microscopical. They are very extensively distributed; some being wanderers under stones, leaves, the bark of trees, in the ground, or upon articles of food; whilst others subsist as parasites upon the skin, and in the flesh, of different animals, often greatly weakening them by their excessive multiplication. There are some species which infest insects, especially the carrion beetles. Several of the Mites much resemble spiders in form and habits, as, for instance, the *acarus telarius*, the red spider of hothouses, which forms upon the leaves of various vegetables, especially lime-trees, webs which injure them greatly. The *Ixodes*, of which the various species, known under the name of *Ticks*, are so annoying to some animals, also belong to this group. Although naturally much flattened in form, they acquire by suction a very large size, swelling out like a blown bladder; and they bury their suckers so completely in the flesh, that they cannot be detached without great difficulty. Some interesting aquatic species of this tribe exist.

II.—Pulmonaria.

In this order the respiration is performed by means of air-sacs contained on the under side of the body, and opening externally by stigmata, or little pores; sometimes these apertures are eight in number, four on each side, but sometimes four, or even only two. This diminution appears to indicate a gradual elevation in the character of the apparatus.

The family of Pedipalpi is distinguished from that of Araneidæ principally by the great development of the palpi, which form extended arms, terminated by a pincer or claw. The entire body is clothed with a hard skin. In the *Scorpions*, which constitute the principal part of this family, the abdomen is very much prolonged, forming a sort of tail, which is terminated by a sting furnished with a venomous secretion. The wound of this sting, although very painful, does not seem to be ordinarily dangerous. A small species inhabits this country; but it is between the tropics that the scorpions attain their greatest development. They usually live on the ground, hiding themselves under stones or other bodies, among ruins, where such exist, and dark and cool places generally; even the interior of houses. They run quickly, and curve the tail over the back. They can turn it as an arm of offence or defence.

The Araneidæ, or true *Spiders*, constitute the only other class of pulmonary Arachnida. In these, the palpi are not developed to anything like the same degree as in the scorpion tribe; they rather resemble feet; but the jaws are armed with sharp and hooked fangs, and are perforated near their points, for the emission of a poisonous secretion provided for the destruction of their prey. Nearly all of them are provided with organs, situated at the hinder part of the body, for spinning a very delicate silken thread; but the use to which it is to be applied varies in different species. In some, it forms webs, in which are entangled the insects on which they feed; in others, it is employed to make a delicate lining for their habitation; and in others, it is chiefly used for the fabrication of a sort of cocoon with which the eggs are surrounded. The apparatus provided by nature for elaborating and emitting this silken substance, or *gossamer*, is a beautiful piece of mechanism. Within the animal there are several little bags or vesicles of a gummy matter; and these vesicles are connected with a circular orifice situated at the abdomen. Within this orifice are five little teats, or *spinnerets*, through which the gossamer is drawn, as represented in the accompanying figure. It must not be concluded, however, that there is only one film of gossamer produced by each spinneret; the fact is, these teats are studded with thousands of minute tubes, too small for the naked eye to perceive, and each of these emits a thread of inconceivable fineness. These minute tubes are known as *spinnerules*, and the films which proceed from them unite, like so many strands of a rope, to form the thread of gossamer by which a spider suspends itself. The finest thread



which human mechanism can produce is like a ship's cable compared with the delicate films which flow from the spinnerules of the largest spider. These films are all distinctly separate on coming from the spinneret; but unite, as shown in the preceding illustration, at a short distance, not by any twisting process, but merely by their own glutinous or gummy nature. The spiders are all extremely voracious in their habits, feeding only upon prey which they have themselves killed. When they have got an insect between their claws, either by entrapping it in their web, or by their stealthy mode of pursuit, they plunge their poisoned mandibles into its body, and the bite is usually soon fatal.

The *Mining-Spiders*, found in the South of Europe, construct, in dry shelving situations exposed to the sun, subterranean cylindrical galleries, often two feet deep, and so tortuous, that the traces of them are lost. These they line with a silken tube, forming at its entrance a movable lid, composed of silk and earth, attached to the silken lining by a sort of hinge; and this is adapted, by its size, situation, and weight, to close the opening so precisely, as scarcely to allow its entrance to be distinguished from the neighbouring soil. When the spider enters its retreat, or passes out of it, the door shuts of itself. The *Mygale* spins a sort of cocoon round its eggs, enclosing a hundred or more; they are hatched within it, and the young undergo their first changes before quitting it. The *Clotho* is remarkable for the curious habitation which it constructs for its young. It spins a kind of circular cocoon or tent, which it attaches to the under side of stones, or to crevices in rocks, by seven or eight points, leaving festoons between those, the edges of which are free. At first, this consists of only two folds, but others are gradually added; and beneath them all a lining of peculiarly soft texture is constructed for the reception of the eggs. The young remain in this for some time after they are hatched, and are supplied by the parent with food. The *Argyroneta* forms a winter retreat for itself beneath the water. It spins an oval silken chamber, open at the bottom like a diving-bell, which it attaches by cords to water-plants. It then carries down successive bubbles of air beneath its body, by crawling down their stems; and these bubbles it transfers to its bell until it has filled it. It then takes up its abode in this cell, where it remains for the winter, first closing the mouth of the bell. The *Epeiræ* are among the most remarkable for the strength of their webs; some of the exotic species—noted for the variety of their forms, colours, and habits—spinning nets which are sufficiently strong to catch small birds, and even to annoy man when he happens to come in the way of many together.

CLASS VII.—CRUSTACEA.

The animals composing this group may be regarded as representing in the sea the insects and spiders of the land. They are distinguished by their external shell, formed by a secretion from their own bodies, and by their breathing apparatus, which, unlike that of the other articulata, is adapted for aquatic respiration. The shell is periodically cast and renewed; and the animals have even the power of reproducing limbs which have been lost. The number of legs possessed by the Crustacea is greater than that of perfect insects, being never fewer than four pairs, besides the pair of claws which may be considered as metamorphosed legs. In the lower genera, the number of legs, true and false, becomes so much greater, that they approximate to the myriapoda. As in all other articulate animals, the eyes of the Crustacea are compound.

The class is divided— first into two divisions, one characterised by the possession, and the other by the want, of organs for the prehension or division of the food. Then there are subdivisions, according to the forms of the extremities, the eyes, and other structural peculiarities. Without going into the details of this classification, we shall notice a few of the more remarkable orders, of which the following rank under the first grand division:—

1. Decapoda.	4. Lœmodipoda.	7. Phyllopoda.
2. Stomapoda.	5. Isopoda.	8. Copepoda.
3. Amphipoda.	6. Cladocera.	9. Ostrapoda.

In the order Decapoda, we find the highest general organisation, the largest size, and the most varied habits; it is the one most useful to man, and most interesting to the naturalist. The lobsters, crabs, cray-fish, prawns, shrimps—in fact, nearly all the species that are ever used as food— belong to it. Their growth is slow, but they usually live a long time. Their habits are mostly aquatic; but none of them are killed at once by being withdrawn from the water; and some pass the greater part of their lives in air. They are naturally voracious and carnivorous; the first pair of legs is usually transformed into a pair of powerful claws, by which they seize their food, and convey it to the mouth. This order contains three families—the Brachyoura, or short-tailed Decapods, to which the name of Crabs is commonly given; the Macroura, or long-tailed, such as the Lobster, Cray-fish, &c.; and the Anomoura, in which the abdomen is prolonged, but destitute of a shell, so that they seek protection in the empty shells of Mollusca.

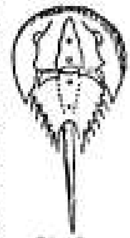
As illustrations of the structure and habits of the Brachyoura, the common *Crabs* will suffice; but a peculiar tribe, that of the *Land-Crabs*, should be specially mentioned. These often live at a considerable distance from the sea, and even burrow under ground. Their gills are kept moist by a kind of spongy structure in the interior of the cavity which encloses them; and from this a sufficient amount of fluid is secreted, to prevent them from being dried up. Some species, though living on land, are confined to damp situations. Others, however, inhabit elevated regions, and migrate towards the sea once a-year to deposit their spawn. The Macroura are distinguished not only by the length of their tail, but by having it expanded at the extremity into a pair of fin-like processes, which afford valuable assistance in swimming. This family is a very extensive one, and contains the largest species of the whole class. The Anomoura are commonly known by the name of Hermit-Crabs, from their remarkable habit of seeking protection in the empty shells of mollusca. The shells they seem to prefer for this purpose are those belonging to the family Trochoidæ. The abdomen or tail is inserted into the upper part of the cavity, of which, after a time, it assumes the perfect form, so that when withdrawn, it presents all the markings of it. The thorax and head occupy the lower part of the spire; and the mouth is closed by one of the claws, which is usually larger than the other, and serves as an operculum when the animal is withdrawn. When they outgrow the habitations they have selected, they quit them, and go in search of others; and they try one shell after another, by slipping the tail into it, until they have found one whose size and form suit them.

The Amphipoda constitute an extensive order, in regard both to the number of species contained in it, and the amount of individuals which are sometimes seen collected together. The greater number of them are marine, but some are found in brooks and reservoirs; all, however, are more or less aquatic in their habits. They are of small size, and swim and leap with agility. The best-known British species is the *Sand-hopper*, which burrows in the sand, and which, unlike the greater part of the order, seldom enters the water.

The Isopoda not only resemble Myriapoda in external form, but in many parts of their internal structure. The greater number live in water; but many species, such as the common Wood-Louse, are inhabitants of the land. Having no special apparatus, however, for keeping the respiratory surface moist, they can only exist in damp places. The *Oniscus*, or Wood-Louse, frequents dark and concealed places—such as cellars, caves, chinks in walls, or hollows under stones. It feeds upon decaying vegetable and animal matter, and only comes forth from its retreat in damp weather. It has the power of rolling itself completely into a ball.

To the order Phyllopoda, which is characterised by the prolonged form of the body, and the flattening of the extremities which adapts them for swimming, belongs a large number of species, whose movements are generally very regular and equable. The *Branchipus*, one of the most characteristic examples, is found, often in great numbers, in small puddles, and most abundantly after heavy rain. The eggs are capable of being dried up without injury, and are hatched soon after being moistened.

The remarkable order Xyphosura, is separated from the foregoing by the absence of organs for conveying food into the mouth. It receives its name from the sword-like prolongation of the carapace, which is used as a weapon by the natives of the regions in which the animals exist. The *Limuli*, or King-Crabs, as they are commonly termed, are peculiar to the East Indies (abounding in the neighbourhood of the Moluccas) and the coast of America. They sometimes attain the length of two feet. Their legs are very short, not extending beyond the margin of the shell. The anterior ones assist in conveying food to the mouth; the posterior are modified for respiration.



Limulus Polyphemus.

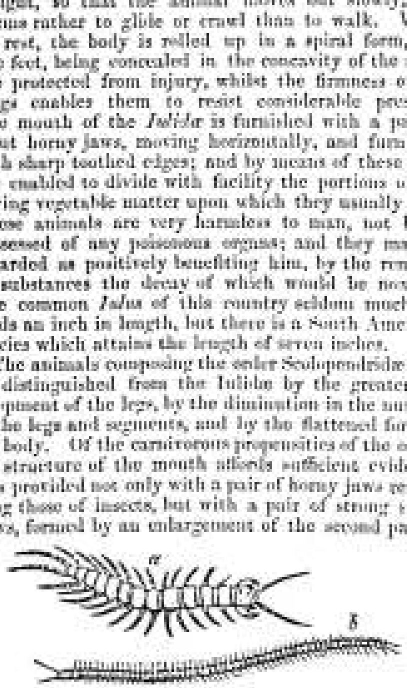
Near the *Limuli* should probably be placed the remarkable group of *Trilobites*, which are at present only known in a fossil state, but which were very abundant in former epochs of the earth's history. (See Geology.)

CLASS VIII.—MYRIAPODA.

The class Myriapoda is the lowest in which we meet with articulated members, or distinct jointed legs, as well as with an articulated body. Most persons are familiar with the common forms of this class—the *Centipedes* (hundred legs) and the *Millepedes* (thousand legs); and a minute description of them is therefore unnecessary. On examining any of these animals, the following points will be observed:—The covering of the body is firm, and of a somewhat horny character, resembling that of many insects. The division into segments is very distinct; a flexible membrane being interposed between each pair of firm rings or plates. The first segment, or head, is furnished with eyes formed upon the same general plan as those of insects; and also with a pair of long-jointed antennæ, which are prebably organs of touch. On the side or under surface of the animal may be seen a row of minute pores, a pair usually existing on each segment, which are the apertures for the admission of air to the respiratory organs. The different parts of the nervous system are repeated in a similar manner, a pair of ganglia being found in every division of the body. The class may be divided into two orders—the IULIDÆ, or *Millepedes*; and the SCOLOPENDRIDÆ, or *Centipedes*.

The Iulidæ, consisting of animals bearing a general resemblance to the *Iulus*, or common Millepede, are the most nearly allied to the Annelida, both in external form and in the arrangement of the several organs. The *Iulus Terrestris*, or Gallyworm, is a species often found concealed under stones, or beneath the bark of decaying timber. Its body is long and cylindrical, and is composed of between forty and fifty hard rings, which, except at the head and tail, differ but little from one another. Each segment gives origin to two pairs of small legs, which arise close to the middle line along the under surface of the body. These are scarcely large or strong enough to support its weight, so that the animal moves but slowly, and seems rather to glide or crawl than to walk. When at rest, the body is rolled up in a spiral form, and the feet, being concealed in the concavity of the spire, are protected from injury, whilst the firmness of the rings enables them to resist considerable pressure. The mouth of the *Iulidæ* is furnished with a pair of stout horny jaws, moving horizontally, and furnished with sharp toothed edges; and by means of these they are enabled to divide with facility the portions of decaying vegetable matter upon which they usually feed. These animals are very harmless to man, not being possessed of any poisonous organs; and they may be regarded as positively benefiting him, by the removal of substances the decay of which would be noxious. The common *Iulus* of this country seldom much exceeds an inch in length, but there is a South American species which attains the length of seven inches.

The animals composing the order Scolopendridæ may be distinguished from the Iulidæ by the greater development of the legs, by the diminution in the number of the legs and segments, and by the flattened form of the body. Of the carnivorous propensities of the order, the structure of the mouth affords sufficient evidence. It is provided not only with a pair of horny jaws resembling those of insects, but with a pair of strong sharp claws, formed by an enlargement of the second pair of



a, Lithobius Forcipatus; *b*, Geophilus Longicornis.

legs, which are perforated at the tip with a minute aperture, through which a venomous fluid is probably instilled into the wounds made by them. Small insects seized in these claws are seen to die very speedily, and in warm countries the bite of the large species of Centipede is a source of great irritation to man, being reputed more injurious than that of the scorpion.

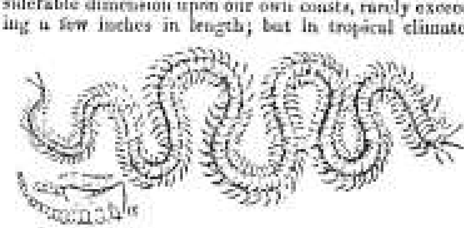
CLASS IX.—ANNELIDA.

The class Annelida is the lowest in which the articulated structure is distinctly manifest. It is composed of animals having a worm-like body, without true jointed legs; and marked by transverse lines that divide it into a succession of rings or segments, which, except the first and last, differ little from each other but in size. Many of them are remarkable for the red colour of their blood; and, on account of this character, they have been regarded as approaching nearer to the vertebrated sub-kingdom than any other class of articulated animals. This is not universally observed, however, for in some species the blood has a greenish tint, and in others it is nearly colourless, as in most of the invertebrata. The body is usually soft and flexible, the rings being possessed of little firmness, and no internal skeleton of any description being present. It is not only flexible, but capable of great alteration in its dimensions, as may be seen in the common earthworm and leech.

The greater part of the class are solely inhabitants of the water, and are provided with external appendages for exposing the blood to its influence, which are analogous in function to the gills of fishes, but which are often distributed over the whole surface, and are also concerned in locomotion. It may be regarded as the *regular* form of these animals to possess such appendages upon every segment; but not unfrequently the body is enclosed in a tube, and then the gill-tufts are collected in the neighbourhood of the head, where they may be protruded from its opening. The earthworm and a few other species are adapted to live on land, and they have a series of air-sacks arranged along the interior of the body on each side, opening externally by orifices, of which a pair may be seen upon each segment. The first segment, which may be termed the head, contains the mouth, sometimes provided with an apparatus of jaws; and also generally furnished with eyes, and with variously-shaped tentacula, which are apparently instruments of touch. The last segment is occasionally destitute of the appendages with which the rest are provided, and these are replaced by a sucker, which is of great assistance in locomotion.

The class is subdivided into orders by the differences in general conformation and habits exhibited by the tribes which compose it; and especially by the character and distribution of the respiratory organs. The first order, DORSIBRANCHIATA, includes those which have the branchial appendages or gill-tufts disposed regularly along the body, sometimes extending its entire length, and sometimes restricted to the segments about the middle. In the next, TUBICOLA, we find worm-like animals inhabiting fixed and permanent residences like the Mollusca. Sometimes they are enclosed in shelly tubes, formed by an exudation from their own surface (as the *Serpula*), and sometimes in casings constructed by the agglutination of foreign substances (*Sabella* and *Terebella*). The disposition of the gill-tufts around the head is the principal character which distinguishes the animals themselves from those of the first order. In the third order, TERRICOLA, the body is destitute of all external appendages, except some minute and almost imperceptible bristles; for the respiratory organs are here developed internally, the animals being formed to crawl upon the ground. And in the last, SUCTORIA, the body is destitute even of these bristles, but is furnished with a sucker at each extremity.

The dorsibranchiate annelids do not attain any considerable dimension upon our own coasts, rarely exceeding a few inches in length; but in tropical climates,

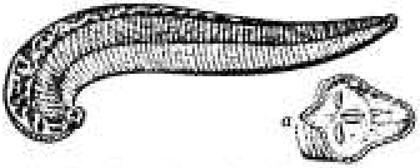


Syllis Monilaris: *a*, lateral appendage magnified.

some species are found of comparatively gigantic proportions, having their bodies composed of 400 or 500 segments, and occasionally measuring four feet from one end to the other. Their general form will be seen in the preceding figure, which represents the *Syllis Monilaris*; and the enlarged view of one of the lateral appendages will show the parts of which it consists. In the centre there is a tuft of delicate bristles, which may be regarded as the chief organ of respiration, the blood being sent into them to be exposed to the air contained in the water: above and below there are separate bristles, much more elongated, of which the lower one has a jointed character; these are instruments of locomotion, and may be regarded as rudimentary legs. The arrangement of these parts differs much, however, in the various families. One of these, the *Aphrodita*, or Sea-Mouse, is well known on our coasts, numbers being often cast up by a storm. The body is flattened, and shorter and broader than that of other Annelida. The back is covered by two longitudinal ranges of broad membranous scales, under which the gills lie concealed. The most common species is about six or eight inches long, and two or three broad. A great part of the body is covered by bristles of brilliant lustre, and of colours which vary with the light; so that the animal is scarcely surpassed in beauty of colouring by any other. The *Arenicola piscatorum*, known to fishermen by the name of *Lob-worm*, is another species common on our coasts, and is eagerly sought as a bait. It burrows, like the earthworm, in the sand; and the place of its excavations may be known by the little heaps which it casts up.

The order Terricola includes very few genera, of which the *Lumbricus*, or common *Earthworm*, is the chief. They live, in general, beneath the surface of the ground, either perforating the dry soil, or burying themselves in mud, where many of them lead a semi-aquatic life. When the earthworm is boring, it insinuates its pointed head between the particles of earth, amongst which it penetrates like a wedge; and in this position, the anterior part of the body is fixed by spines or bristles curved backwards, which prevent it from slipping. The hinder parts are then drawn forwards by a longitudinal contraction of the whole animal—a movement which the spines do not oppose. This swells out the anterior segments, and forcibly dilates the passage into which the head had been already thrust. The spines upon the hinder rings then take a firm hold upon the side of the hole thus formed, and prevent any backward movement; the head is again forced forward; and, by a repetition of the process, the animal makes its way through soils which it would at first have seemed impossible for it to penetrate. The burrowing of earthworms is a process exceedingly useful to the gardener and the agriculturist; and these animals are far more beneficial to man in this way, than injurious by devouring the vegetables set in the soil. They give a kind of under-tillage to the land, performing the same below ground that the spade does above for the garden, and the plough for arable land, and loosening the earth, so as to render it permeable to air and water. It has lately been shown that they will even add to the depth of the soil, and create mould where none existed before. This they do principally by the exercise of their digestive process. They take a large quantity of the soil through which they burrow into their intestinal canal; from this they extract the greater part of the decaying vegetable matter it may contain, and reject the rest in a finely-divided state, forming what are known as worm-casts. By the accumulation of these, a field which was manured with marl, has been covered, in the course of 80 years, with a stratum of new earth averaging a foot in depth.

The order Suctoria contains the common Leech and its allies, which are all of aquatic habits, but not all agreeing in its blood-sucking propensities. Most of the tribe, however, live at the expense of some other animal. The structure of the mouth of the leech is very interesting. It is situated in the middle of the cavity of the anterior sucker; and three little cartilaginous bodies, usually called *teeth*, but more properly *jaws*, are seen to be disposed around it, in such a manner, that the three edges form three radii of a circle. Each of these has two rows of very minute teeth at its edge; so that it resembles a small semicircular saw. It is imbedded at its base in a bed of muscle, by the action of which it is worked in such a manner as to cut into the skin—a sawing movement being given to each piece separately. It is in this manner that the tri-radiate form of the leech-bite is occasioned; each ray being



Leech: *a*, the anterior sucker and teeth enlarged.

produced by a separate little saw. The lacerated character of the wound is very favourable to the flow of blood, which is further promoted by the vacuum created by the sucker. The greater number of the leech tribe are inhabitants of fresh water; some, however, are only found in the sea; and there is one terrestrial species, a native of Ceylon, which appears to be more voracious than any other, and to be one of the greatest pests of that fine island.

CLASS X.—CIRRHOPODA.

The animals composing this class have so many characters in common with the Mollusca, that they have been generally regarded as belonging to that sub-kingdom. The body and its appendages are themselves quite soft; and the skin has the loose spongy muscular character which corresponds with the *mantle* of Molluscs. From its surface is secreted a shell, composed of several pieces, but not differing in general aspect from multivalve shells belonging to that division. Further, the shells are either themselves firmly united at their base to some solid masses, or they are attached by a footstalk; so that the conditions in which the animals exist closely resemble those to which we observe a number of the Mollusca peculiarly adapted. On the other hand, when we examine the animal itself, we find that it is perfectly symmetrical in its form—a character nowhere existing among the Mollusca which are enclosed in shells. Its body is prolonged, and exhibits a tendency to division into segments; and from each of these there arises a pair of appendages on each side, which possess something of a jointed structure. These *cirri*, as they are termed, are long tapering arms, fringed with cilia, or little hair-like filaments; and they have gills at their base. Further, the mouth is furnished with lateral jaws, which no Mollusc possesses; and the nervous system consists of a double cord, with a pair of ganglia in each segment of the body, precisely as in the other Articulata. The most interesting proof, however, that the Cirrhopods belong to this division, is derived from the history of their development. On their liberation from the egg, they present a form much more analogous to that of the lower Crustacea than to that of the adult animal, which they only acquire after a series of metamorphoses. They are furnished with antennæ and eyes, and move freely through the water; but when they become fixed, they lose also these organs of sense. The shell is not formed of simple layers, like that of the Mollusc, but is traversed by a complex series of canals, through which nourishment is conveyed to it.

The Cirrhopoda are divided into two principal groups—the *pedunculated* and the *sessile*. The latter, of which the common *Balanus*, or *Acorn-shell*, is an example, have the base of the shell fixed immediately to rocks; in the former, such as the well-known *Barnacle*, the shell is attached by a peduncle or footstalk, which consists of a tube of leathery consistence, and often of considerable length. In both groups, the animals, not being able to go in search of food, obtain it through currents produced by the action of their cilia. The shell of the common barnacle consists of five pieces, of which two are large valves, somewhat resembling those of a mussel; two smaller pieces are jointed to those near the point; and one unites the valves along the back edge. These cover the whole of the mantle. Barnacles are abundant in all seas, and fix themselves, in preference, to wood; so that a piece of timber which has been for a short time floating in the ocean, is almost sure to be partly covered with them; and ships' bottoms, if not protected by copper, are rendered so foul, as greatly to impede their sailing.

CLASS XI.—ROTIFERA.

The class Rotifera is one composed entirely of animalcules which can only be distinctly seen with the microscope; and it takes its name from the wheel-like organs with which most of them are provided, whence they are commonly known as Wheel-Animalcules. It is only within a very recent period that the complex structure of these beings has been understood, and that they have been separated from the animalcules of simpler organisation. It is on account of the prolonged form of their bodies, the position of the mouth and eyes at one extremity, the occasional marking of transverse lines indicating a division into segments, and, most of all, by the character of the nervous system, when that can be detected, that the Rotifera are ranked in the articulated sub-kingdom. Unquestionably, they bear more general analogy to that than to any other; but they must not be considered as characteristic specimens of it.

The structure of the common wheel-animalcule, *Rotifer vulgaris*—which may be found in many collections of stagnant water, especially such as have been long and freely exposed to the atmosphere—will afford a good illustration of that of the class. The body exhibits a prolonged form when fully extruded; but, as the integument is very elastic, it may be drawn up into a circle, or made to assume a great variety of shapes. At one end, it is furnished with a pair of projections, which are surmounted by circular fringes of cilia. It is by the vibration of these cilia that the currents are produced in the water around, which give an appearance as of the continual revolution of wheels. Between the wheels a sort of head extends forwards, on which a couple of red spots may be observed, which are believed to be eyes. The mouth is situated at the base of this central projection. At the opposite end, the body is prolonged into a kind of tail, furnished with three prongs; and by this the animal fixes itself when working its cilia. These animalcules feed chiefly upon others of smaller size and simpler character. The currents set in motion draw in whatever small bodies are within their scope; and from these are selected what is adapted to afford nutrition. Sometimes the animal folds in its wheels, and moves along a solid surface by the suckers with which its head and tail are furnished, in the same manner as a leech; at others, it remains altogether inert for a considerable period. One of the most remarkable points in its history is its power of being revived by the application of moisture, after having been entirely dried up. This experiment, however, does not always succeed.

CLASS XII.—ENTOZOA.

This class derives its name from the peculiar condition in which the animals composing it exist, most of them being inhabitants, during their whole lives, of the bodies of other animals, generally those of higher organisation, from the juices of which they derive their nourishment. Many of them possess a distinct worm-like form, the body being much prolonged, and exhibiting a division into segments, and the mouth being situated at one extremity. These, therefore, evidently belong to the Articulated series. There are others which, in the absence of all distinct organs, and also in the circularity of their form, seem to approximate more to the Radiata. Some species, formerly assigned to this class, are now known to be lowly-organised forms of Crustacea.

A division of the Entozoa into two sections has been proposed, founded upon the general peculiarities of their structure. In the first and highest, there is a distinct intestinal tube, with an orifice at each end; and traces of a nervous and muscular system, more or less developed, may be detected. This division evidently approximates to the Annelida. It includes, among many other species, the *Filaria*, or Guinea-Worm, which burrows in the flesh of man and other animals in warm climates: if undisturbed, it will often continue its operations for a considerable time without much uneasiness; but, if disturbed, it sometimes occasions the most excruciating pain. When it shows itself externally, it should be extracted slowly, for fear of breaking it, in which case the remainder would retreat, and continue to exist: it grows to the length of several yards. The *Ascaris lumbricoides*, or Round Worm of the intestines, also belongs to this group. It infests not only man, but many of the lower animals, and often occasions severe disease, and even death. It derives its second or specific name from its resemblance to the earthworm. The short active Thread-Worms, sometimes infesting the lower part of the intestine, are another species of the same genus.

In the lower division of the class, there is no distinct alimentary canal; the cavities for the reception of food, as well as those for other purposes, being, as it were, channelled out of the soft, almost homogeneous tissues of the body. Some of these still preserve the worm-like form: such are the so-called eels in vinegar; and the curious little parasites which have been recently discovered to infest the muscles of man. To this group also belongs the *Tænia Solium*, or Tape-Worm, in which we find a remarkable repetition of organs. The body is distinctly divided into joints or segments, which sometimes amount to several hundred, the whole animal occasionally attaining the length of ten feet. These segments are all connected by the nutritive canal, which runs from one end to the other; but the reproductive apparatus is repeated in each division. The head is small, and possesses four mouths, surrounded by a double circle of small hooks. Its existence is essential to the life of the body, the latter dying if it be broken off; but if some of the joints remain attached to the head, it continues to grow and form new ones. In this repetition of parts we see a tendency towards the type of the Polypifera.

One of the simplest of all the Entozoa is the common *Hydatid*, or *Acephalocyst* (headless bag), which seems to consist of nothing but a globular membranous bag, filled with a limpid colourless fluid. It exhibits no motion, or indication of sensation, when stimuli of any kind are applied to it; and it is often difficult to distinguish it from the tissues in which it is found. Its power of reproduction, however, by the formation of *gemmæ*, or buds, between its layers, shows it to be entitled to the rank of an independent being: the young Hydatids are thrown off internally or externally, according to the species. Among the animals associated with this group is the *Distoma*, or fluke, which infests the liver of sheep, and is also found in other domestic quadrupeds, and even in man. It is about an inch in length, and a quarter of an inch in breadth, having the form of a minute sole; and possesses eyes, situated on the most conspicuous part of the head. The power of multiplication in these animals is very great; the ducts of a single liver have been known to contain a thousand, with innumerable germs of others. They usually accompany the disease called *rot* in sheep; but they do not appear to be necessarily connected with it. They most frequently infest sheep that are pasturing on marshy grounds, in the waters of which their germs are probably contained; and it seems to be rather the unhealthiness of the situation than the development of the flukes, which is the real cause of the rot, since flukes infest the healthiest sheep during the autumn and winter months.

MOLLUSCA.

The range of animal forms comprehended under this sub-kingdom is so extensive, that it would be extremely difficult to frame any definition applicable to them all. The highest class approaches Fishes in many points of its organisation; whilst in the lowest we not only lose sight of some of the characteristic peculiarities of the group, but we find a near approximation to the higher Polypifera. In all the Mollusca, the body, as the name imports, is of soft consistence, and is enclosed in a soft elastic skin, lined with muscular fibres, which is termed the *mantle*. This skin, in many instances, is not applied closely to the body, but forms a membranous bag, having apertures (which are sometimes prolonged into tubes) for the entrance and egress of water. Through these the respiratory organs, which are situated within the cavity, are regularly supplied with pure fluid necessary for aërating the blood; and the mouth, when not capable of being projected beyond this cavity, is supplied with food by the same stream.

The Mollusca possess in general a very complicated digestive and circulating apparatus; but the organs of sensation and voluntary motion are comparatively undeveloped. The great bulk of their bodies is made up of the stomach and intestines, the liver and other glands connected with the alimentary canal, the respiratory apparatus, and the ovary for the production of germs (which is usually very large); whilst the muscular system, which in the Articulata forms so large a proportion of the whole structure, is frequently reduced to a few scattered fibres, and in but few instances attains any complexity and power. A considerable number of Molluscs are formed for an existence as completely stationary as that of the Zoophytes, and are dependent for their nourishment on the supplies of food casually brought within their reach by the waves and currents of the ocean; a few have powers of locomotion which enable them to forage actively for themselves; while the greater number wander sluggishly, like the snail, from place to place, devouring with voracity such supplies as they meet with, and being capable of fasting for long intervals when none comes in their way.

It is from the surface of the mantle that the calcareous matter is exuded which forms the shell, in those species which possess such a protection; its particles are held together by a sort of glue, which exists in much larger proportion in some species than in others. In very hard and brittle shells, if the calcareous matter be removed by the action of an acid, the animal matter that remains appears in separate flakes. But in many other shells thus treated, the animal portion retains its form after the removal of the lime; and there are a few in which the (so-called) shell consists only of a substance like horn, without any intermixture of calcareous particles. Such a substance appears to be formed by the young animal before the true shell is secreted; and it is also the first that appears when the animal is repairing the effects of an injury to the old one. It is this that constitutes what is commonly termed the *epidermis* of shells—a covering possessed in their natural state by all that are not enveloped in a fold of the mantle, but which is commonly removed when the shell is preserved, as it obscures the beauty of the exterior. The shell is most solid and massive in those species which lead an inactive life; and is usually light and thin, or altogether deficient, in those whose powers of locomotion are greater. Its thickness often varies greatly amongst different individuals of the same species, according to the roughness or tranquillity of the waters they inhabit.

Taking the general conformation of the animals as a guide, naturalists divide the Mollusca, first, into those having a *head*—that is, a prominent part of the body on which the mouth is situated, with organs of sense in its neighbourhood—and those which are *acephalous*, or headless. Among the former we perceive three very distinct types of structure:—

The Cephalopoda, or *Cuttle-Fish* tribe, have feet or tentacula arranged in a circular manner around the head. In this group we find the nearest approximation to the Vertebrata.

The Pteropoda constitute a small but interesting class, characterised by the possession of a pair of wing-like expansions of the mantle, and by the great symmetry of their bodies. These expansions serve as fins, by which they swim with considerable velocity.

The Gasteropoda form the most extensive group of the whole. The two former are confined entirely to the sea; in this we find species adapted to live in fresh water, and even on land. The Gasteropods have but one muscular expansion or foot, and this proceeds from the under surface of the body, as may be well seen in the common snail.

In each of these orders we observe a considerable variation in regard to the relative size and even the existence of a shell; for whilst there are some species entirely destitute of this protection (such being called naked Molluscs), there are others which possess it in a slight degree, having it generally concealed in a fold of the mantle, and others in which it completely envelops the body, when they withdraw themselves under its protection. In the different species of Snail and Slug, all agreeing closely in general structure, every variety of this kind may be witnessed.

In the headless Molluscs, on the other hand, we find two very distinct groups; in the first of which the shell is constantly present, whilst in the second it is as invariably absent. The general structure of the latter is much inferior to that of the shell-bearing class, and approaches more nearly in several of its characters to the Polypifera:—

The highest class of Acephalous Molluscs is named Conchifera, from the constant presence of a shell, which is nearly always formed of two pieces, or *bivalve*.

The lowest is denominated Tunicata, the shell being replaced, as it were, by a leathery or cartilaginous envelope or tunic, which encloses the whole body.

CLASS XIII.—CEPHALOPODA.

The class Cephalopoda, which is so named from the arrangement of the feet or locomotive organs around the head, must be regarded as the highest among the Mollusca in respect to the complexity of its organisation, and it is the one which approaches most nearly to Vertebrated animals. In the general form of their bodies, and in their adaptation to rapid motion through the water, many species bear a considerable resemblance to fishes, and are, indeed, commonly reputed as such. The name of the class expresses the character which distinguishes it from all others. On the head, which is furnished with eyes resembling those of higher animals, and also with organs of hearing, and perhaps also of smell, are disposed in a circular manner the curious appendages which have received the name of *feet* or *arms*, and to which either term may be justly given, as they are organs of prehension as well as of locomotion. These are usually eight or ten in number; but in the true *Nautilus* they amount to nearly a hundred. The mouth, which is situated in the centre of the circle of arms, is provided with a pair of firm horny mandibles or jaws, of which one is sharply pointed, and overlaps the other when closed, so that the whole very much resembles the bill of a parrot. This beak encloses a large fleshy tongue, roughened with horny prickles; and the œsophagus leads to a muscular stomach, which closely resembles the gizzard of birds. All the Cephalopoda are aquatic, and consequently breathe by gills. These are disposed symmetrically on the two sides, and are covered by the mantle. This envelope includes the whole body, but there is an opening in it which gives passage to the head. Through this opening the water enters to the gills, and it is expelled through a tubular prolongation of the mantle termed the *funnel*, which also serves as the excretory canal.

Most of the Cephalopods possess something analogous to the shells of other Molluscs, although it often exists in a form and position which might almost prevent its being recognised as such. The only species at present known in which the body of the animal is enclosed within it, as in the shells of Gasteropods, are the *Nautilus* and the *Argonauta* (Paper Nautilus). In the former of these the shell is spiral, and is divided by transverse partitions into chambers, in the last or outermost of which the animal lives; and when it wishes to enlarge its shell, it prolongs the mouth of it, which widens as it is prolonged, and throws a new partition across the bottom. The shell of the Argonaut has no such chambers, and the animal, when hiding within it, occupies the whole of its cavity. In the common *Sepia* (Cuttle-Fish), on the other hand, the shell is reduced to the form of an oval plate—commonly known as the *cuttle-fish bone*—which is enclosed within a fold of the mantle, and lies upon the back of the animal. In some of the more slender and flexible species even this is nearly wanting; all that remains of a shell in the *Loligo* (Squid) being a horny plate, somewhat resembling a feather in shape, whence it is termed the *pen*.

The arms of all the Cephalopods are covered with very curiously-constructed suckers, by which they are enabled to take firm hold of anything to which they are applied. These act by excluding the air, and thus producing a vacuum, exactly upon the principle of the boys' leathern sucker. In this manner they are enabled to master animals which it would have been supposed entirely out of the power of their soft unprotected bodies to combat successfully. They are generally agile as well as voracious, and prey upon almost all other classes of marine animals. Their especial articles of food, however, are Fishes and Crustacea; and they are probably the only animals which are able to restrain the inordinate multiplication of the larger members of the latter class. The firm armour and powerful claws of the crab or lobster are no protection against these soft-limbed cuttle-fish, which wind their arms round these bodies, and, fixing every part by means of their suckers, tear apart the divisions of the shell by means of their hard parrot-like bills. So firmly do these suckers adhere, that while the muscular fibres remain contracted, it is easier to tear asunder the substance of the limb than to release them from their attachment.

The species which are unprotected by an external shell are furnished with a curious means of escaping from their enemies. This is the secretion of a dark fluid, which, when emitted by the animal, tinges the water around to such a degree, that it can escape in the cloud it has made. The fluid is usually stored up in a bag communicating with the funnel, through which it is ejected under the influence of alarm. This ink-bag, as it is termed, is collected from the species inhabiting the Indian seas; the ink forms a valuable pigment, known to the artist as *sepia*, the name of the animal which furnishes it.

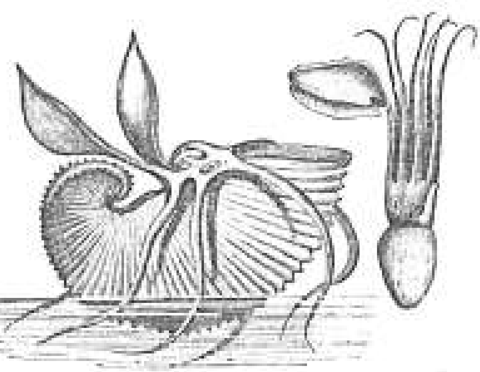
The Cephalopods may be subdivided into two great orders. In the higher division, which approaches the nearest to vertebrate animals, the *branchiæ* or gills are two in number, and the order is termed DIBRANCHIATA; whilst in the one most closely allied to the Gasteropods, the branchiæ are four in number, and the order is therefore termed TETRABRANCHIATA:—

I.—Dibranchiata.

The Dibranchiate order includes all the best-known forms of the class. It is divided into two tribes, in one of which there are but eight arms, whilst in the other there are ten, of which, however, two are different from the rest. The first of these, termed OCTOPODA, may be considered as the highest in point of general organisation; the second, termed DECAPODA, presents many points of approach to the Tetrabranchiata, both in the increased number of arms, and in the presence of an inner circle of short tentacula, as well as in several internal characters. The *Sepia*, or common Cuttle-Fish, is a characteristic example of the DECAPOD family. Some species of it abound in almost all seas. It has two long slender arms, which are furnished with suckers only at their extremities; and by these the animal is said to fix itself, as by anchors, when exposed to a rough sea or strong current. They are probably employed also in seizing prey, which is brought by them within the range of the others. To this family we are also probably to refer the *Spirula*, a little-chambered shell, the animal of which is very imperfectly known; and a large number of fossil chambered shells, known as *Ammonites, Orthoceratites, Belemnites*, &c.; the last of which was probably analogous to the Sepia, including the shell, like the bone of the cuttle-fish, within the body. [See GEOLOGY.]

The OCTOPODS, which form the highest family of the order, have but eight arms, without tentacula; and they are destitute of lateral fins, so that they depend entirely upon the arms for their movement through the water. Accordingly, it is found that these are very large and powerful, and that the body is proportionally short. The arms are generally united at their bases into a kind of circular fin, by the motion of which the animal can swim backwards with great energy. The common *Octopus*, or *Poulp*, of European shores, has the arms six times the length of the body, and each furnished with 120 pairs of suckers. It can leave the water, and creep over the beach, taking hold of the ground before it by the extension of its arms, and then dragging the body towards the point at which the suckers are attached.

A very interesting species of the Octopod group is the *Argonauta Argo*, commonly called the *Paper Nautilus*, from the whiteness and delicacy of its shell. As the animal has little in common with the true Nau-



Shell of Argonaut, with animal in the reputed position.

tilus, it would be much better if the latter designation were entirely abandoned, and the term *Argonaut* substituted for it. The shell is not chambered, but possesses one spiral cavity, into which the animal can withdraw itself entirely; this, however, has no muscular attachment to it, whence it has been supposed by many naturalists that it was only a parasitic inhabitant which had taken up its abode within it, and that the shell, from its resemblance to that of Carinaria, was formed by a gasteropod mollusc allied to that genus. It has been proved, however, by the interesting experiments of Madame Power, that the shell increases regularly with the growth of the animal, which possesses the power of repairing it when injured; so that no doubt can exist that the Argonaut is the original constructor of it.

Of the eight arms of the Argonaut, six taper gradually towards the extremities; but two are expanded into wide membranous flaps. From very early times, this animal has been reputed to swim on the surface of gives passage to the head. Through this opening the water enters to the gills, and it is expelled through a tubular prolongation of the mantle termed the *funnel*, which also serves as the excretory canal.

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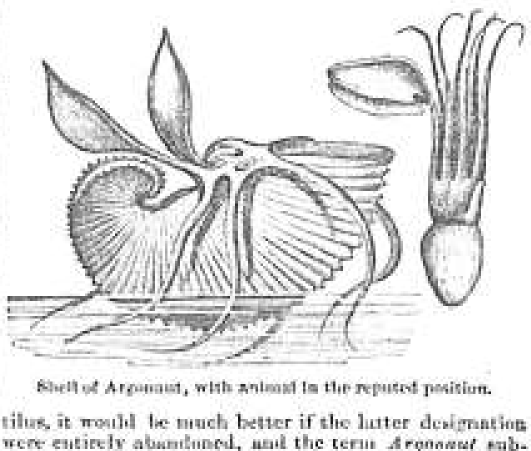

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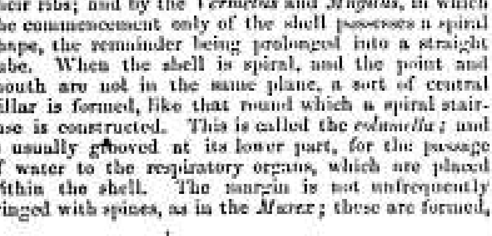
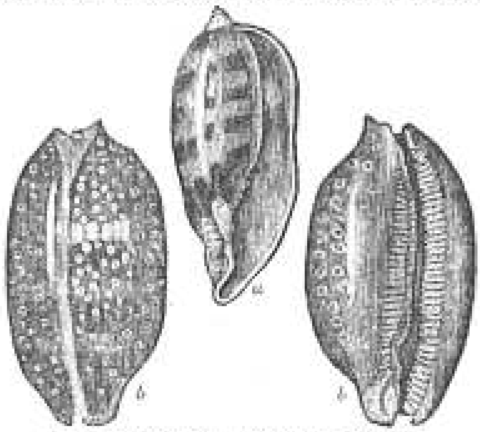
The forms of the Gasteropod shell vary extremely; but those which appear most widely separated may be shown to be connected by intermediate links. The open cone of the Limpet may be regarded as one of the simplest forms; in an allied genus, the *Pileopsis*, we find the point prolonged, and somewhat rolled upon itself; and by various links of this kind, we are brought to the regular spiral of the snail. From this we may return to the long straight form, by the *Scalaria*, in which the coils of the spire touch each other only by their ribs; and by the *Vermetus* and *Magilus*, in which the commencement only of the shell possesses a spiral shape, the remainder being prolonged into a straight tube. When the shell is spiral, and the point and mouth are not in the same plane, a sort of central pillar is formed, like that round which a spiral staircase is constructed. This is called the *columella;* and is usually grooved at its lower part, for the passage of water to the respiratory organs, which are placed within the shell. The margin is not unfrequently fringed with spines, as in the *Murex;* these are formed,



Murex Tenuispina.

like similar appendages in the Conchifera, by prolongations of the mantle; and the dissimilar number of them in different specimens has caused the arrangement of many species, which, now that the habits of the animal are better known, prove to be but different forms of the same. For it has been ascertained that the animal has not only the power of forming new spines, but of removing old ones, especially such as would interfere with the continued growth of the shell. The edge of the mantle is applied against their bases, and a kind of absorption of shelly matter seems to take place—a notch being formed, which causes them to be easily broken off. Various analogous changes are produced by a similar process in other shells, the portions first formed being wholly or partially removed. Sometimes the walls of the older portion are thinned, for the purpose of lightening the shell; and in other cases the top of the cone is altogether removed, a groove having been formed around its interior, which renders it so weak, as to be easily broken off. In the latter cases, the animal previously withdraws itself from the part to be separated, and throws a new partition across, by which the top of the shell remains closed after the division. A shell thus deprived of its apex is said to be *decollated.*

It is not only by such removals that the form of univalve shells undergoes a great change. Sometimes additions are made to them which completely alter their figure, so that two individuals of different ages would be scarcely supposed, at first sight, to belong to the same tribe. In all these cases, however, the form of the young shell may be traced in that of the adult. In the young shell of the *Cypræa (cowry)*, for example, the edge is sharp, and the mouth, or opening, of considerable breadth. This state continues as long as the shell is increasing in size; but when it has arrived at adult age, the outer lip is thickened, and brought so near the other, as to leave but a narrow chink between



Cypræa Exanthema: *a*, young shell; *b*, *b*, adult.

them. At the same time, a prolongation of the mantle on each side deposits a new layer of shelly matter on the outside of the previous one; and as the two prolongations meet along the back (the line of their junction being usually evident on the shell), this additional coat, which is very hard and *porcellanous* in its texture, encloses the whole previous shell.

The *operculum* is principally confined to the aquatic Gasteropods. It is sometimes of the same texture as the shell itself, and sometimes horny. It does not always close the entire mouth of the shell, but it is sometimes made to fit it, at all stages of growth, with the most beautiful accuracy. Some of the land species also possess an operculum; but in general they are destitute of it, and they form during hybernation a temporary closure to the mouth of the shell, by a viscid secretion, which hardens into a thin plate, and includes within it a bubble of air. Behind this, a second, and even a third similar partition is occasionally found, as in the common snail.

The subdivision of this extensive class into orders, is effected by arranging the different tribes according to the character and position of the respiratory organs. Cuvier presents the following orders:—Pulmonea, Nudibranchiata, Inferobranchiata, Tectibranchiata, Heteropoda, Pectinibranchiata, Tubulibranchiata, Scutibranchiata, Cyclobranchiata.

Of the order Pulmonea, the greater part live on land, but some are aquatic. They all feed chiefly upon vegetables, and many of them exclusively so; but some are extremely voracious, and will devour almost any organised matter that falls in their way. They are diffused through all climates, particular species being restricted to each. Those without a shell, commonly known as Slugs, constitute the family Limacinæ. In the common *Slugs*, as in most of the terrestrial species of this order, we observe a prominent head, with four tentacula, and at the end of the longer pair the eyes are situated. These tentacula can be drawn inwards, by a process resembling the inversion of the finger of a glove. On the back there is a kind of shield, or disk, formed by the mantle, which sometimes encloses a small shell. This shield covers the pulmonary sac, the opening of which is on its right side, and the head can be withdrawn beneath it. The snails and their allies, constituting the family HELICINÆ, are closely allied to the slugs; differing in little else than the possession of a shell, into which the body may be withdrawn. The common garden snail of this country, and the *Helix pomatia*, or edible snail of France and Italy, are well-known examples of the family. More striking ones are to be found, however, in tropical climates; where some species of the genus *Bulimus* attain to great size, the eggs being as large as a pigeon's. In some species, the direction of the coils of the shell is opposite to what it is in the generality of spiral shells: such are said to be *reversed*.

The order TECTIBRANCHIATA shows an approximation towards that disposition of the gills which characterises the great bulk of the class; the animals composing it are marine, and live chiefly on the shore, or on floating sea-weeds. A very characteristic example of the order is the *Aplysia*, commonly termed Sea-Hare, which is abundant on many parts of the British coasts. Its vernacular name is probably derived from the peculiar form of the superior pair of tentacula, which are flattened and hollowed like the ears of a hare. The head has a very distinct neck. The branchiæ consist of leaflets arranged in a complex manner, and situated on the back, beneath a fold of the mantle, which also encloses a flat horny shell. The digestive apparatus is very complicated, consisting of a membranous crop, like that of birds, a gizzard, having cartilaginous walls, and a third stomach, beset with sharp hooks in its interior. These animals feed on sea-weed. They are very sluggish in their movements; but have a peculiar means of defence, consisting of a deep purple liquid, which they can discharge from the edge of the mantle when alarmed, and by which the surrounding water is discoloured, so that they cannot be discerned.

The order PECTINIBRANCHIATA is not only by far the most numerous in the whole class, but contains the animals which may be regarded as its most characteristic members. They have all two tentacula and two eyes, sometimes raised on stalks, as in the snail. The mouth is prolonged into a sort of proboscis, and the tongue is furnished with little hooks, or recurved spines, which enable it to wear down the hardest bodies by slow and oft-repeated action. The cavity in which the gills are fixed occupies the last whorl of the shell; and in some of the order there is a tubular prolongation of the mantle, termed the *siphon*, for the purpose of conveying water into this cavity, so that the animal can breathe without leaving its shelter. By the presence or absence of this organ, and by the form of the shell, which here appears to bear a sufficiently constant relation with that of the animals, this large group may be arranged under the following families:—1. TROCHOIDÆ, in which there is no siphon, and which have the mouth closed by an operculum: of this the common periwinkle is a characteristic example, though very small in proportion to tropical species. 2. CAPULIDÆ, which have a wide open shell, very much like that of the limpets, without operculum or notch at the margin for the passage of a siphon. 3. BUCCINOIDÆ, which have a spiral shell, and a canal at the end of the columella for the passage of the siphon: this is sometimes extremely prolonged, as in the Murex; and the genera exhibiting this character are all carnivorous in their habits. To this family belong the animals forming the greatest number of marine univalve shells preserved in the cabinets of collectors.

The order SCUTIBRANCHIATA is a small one, containing but two principal genera, which do not differ widely from the limpets, except in the disposition of the gills. The shells are very open, without an operculum, and the greater number are not in any degree spiral. In the *Haliotis*, the shell is slightly twisted; and from a faint resemblance it is thought to bear to the ear of a quadruped, it has been called the Sea-Ear. This animal, in its living state, is one of the most beautiful of Gasteropods, on account of the variety and richness of its colours. Its shell, when the surface is polished, possesses a pearly lustre, with resplendent metallic hues. It is consequently much sought for as an ornament.

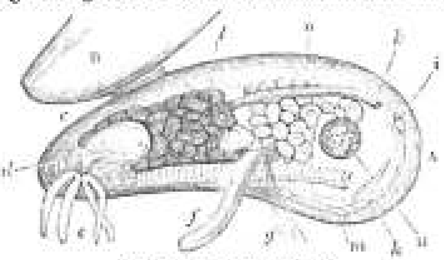
The general form of the *Limpets*, which principally compose the order CYCLOBRANCHIATA, is well known; and the peculiarity in the position of their gills has already been mentioned. Closely allied to the limpets in general structure, but differing remarkably in the formation of the shell, are the *Chitons* (*chiton*, a tunic), of which some small species inhabit our shores, but which attain to much greater size between the tropics. Their shell, which is of a leathery or horny structure, is composed of a number of plates arranged behind one another with great regularity, and connected by a very complex series of ligaments and muscles, which reminds the naturalist of those which unite and move the different segments in articulated animals.

CLASS XVI.—CONCHIFERA.

The Molluscs belonging to this class are, in common with the Tunicata, destitute of a head; that is, the mouth is not situated upon a prominent part of the body, nor assisted in its choice of food by organs of special sensation in its neighbourhood, but the entrance to the stomach is buried between the folds of the mantle. The part of the structure of these animals which is best known is the *shell*. This is composed of particles of lime, exuded from the surface of the mantle, in combination with a glutinous secretion, by which they are united together. If one of the valves of a bivalve shell be examined, it will be seen to consist of a number of layers, of which the outer one is the smallest, each inner one projecting beyond the one that covers it. This is more evident in such shells as that of the oyster, in which the layers adhere loosely together, than in others in which they are more compact. The shelly matter is thrown out at intervals from the surface of the mantle; and as the animal enlarges at each interval, the new layer extends beyond the old one. In this manner a constant relation is preserved between the size of the animal and that of its shell; and the addition of the newly-formed portions, not to the edge only, but to the interior of the whole previous shell, strengthens the latter in proportion to its increase.

The valves are connected together in various ways. In the first place, they are jointed by a *hinge*, which is in some instances so firm and complicated, that it holds them together when all the soft parts have been removed. This hinge is sometimes formed by the locking of a continuous ridge on one valve into a groove in the other, and sometimes by a number of little projections, or *teeth*, which fit into corresponding hollows in the opposite valve. In the neighbourhood of the hinge (sometimes outside, sometimes inside, or both) is fixed the *ligament*, which is composed of an elastic animal substance; this answers the purpose of binding the valves together, and at the same time of keeping them a little apart, which may be regarded as their natural position. When the animal wishes to draw the valves closely together, it does so by means of the *adductor* muscle, which is fixed to the interior of both valves at some distance from the hinge, and of which the insertion can be easily traced by a somewhat rough depression of the interior surface of each valve.

In order to describe the general structure of the Conchifera, it will be advantageous to select some particular illustration; and the common *mussel* is well adapted to this purpose. On opening such a shell, it is seen that the two valves are lined by a membrane, divided into two halves along a considerable part of the edge of the valves, but united near the large end. In some Conchifera, as will be presently seen, the two halves of the mantle are separated along their whole extent; whilst in others, as in the Tunicata, they are completely closed, with the exception of the two orifices for the ingress and egress of water, which are sometimes drawn out into long tubes. In the mussel, the water enters through a slit in the closed part of the mantle, and passes out by another in its neighbourhood; but the water thus introduced is principally for the supply of the gills, as the mouth, or entrance to the stomach, is placed at the small end of the shell, where the mantle is quite open, and can take in food from the surrounding water, which comes into free contact with it. The gills in all Conchifera consist of four ribbon-like fringes, fixed to the mantle along the edge of the shell most distant from the hinge.



Interior of common Mussel.

A, right valve; B, left valve; c, hinge; d, stomach; e, tentacula or feelers; f, foot; g, byssus; h, branchial orifice; i, vent; k, termination of the intestine; l, liver; m, gills; n, adductor muscle; o, ovarium.

Near the small end of the shell is seen the stomach, with the short tube leading to it, the orifice of which is furnished with four tentacula or feelers. To the right of this is seen the long and complicated intestinal tube, with the liver lying in separate masses amongst its folds. And nearer the larger end, the cavity of the shell is chiefly occupied by the ovarium, in which the eggs are formed. Close to this is the adductor muscle, by which the valves can be drawn together with considerable force. The intestinal tube is seen to terminate near the opening at the posterior (or right-hand) extremity of the shell, which discharges its contents, and serves for the exit of the respiratory current.

The foregoing description will apply, with slight variations, to the structure of almost all Conchifera; but we have now to notice two organs, which are absent in some, and in others more largely developed than in the present instance. From the lower part of the shell, passing out between the separate edges of the mantle, is seen the *foot*, a fleshy muscular organ, somewhat resembling the tongue of higher animals, and not containing any hard support, or being protected by any envelope. This foot, which is the only special locomotive organ possessed by the Molluscs of this class, serves a great variety of purposes, sometimes enabling the animal to leap with considerable agility along a hard surface, sometimes being used to bore into the sand or mud, and at others serving only to affix the animal to some firm support. From the base of this foot there proceeds, in the mussel, a band of hair-like filaments, forming what is called the *byssus*, from a Greek word of the same name, signifying fine flax. These sometimes exist in great abundance, and serve, by being fixed by their extremities to the shore or bottom of the sea, to anchor the shell, and yet to allow the animal freedom of motion within certain limits. In many cases the byssus is altogether absent.

Of the Conchifera, some, as the oyster, are attached to one spot during all but the earliest period of their lives; others adhere by the byssus, or by the foot, by which they obtain a certain range; and others are free during the whole of their lives, swimming and leaping with considerable agility. Some appear to be directed in their movements by powers of sight; and in these are perceived small red spots at the edges of the mantle, which are believed to be eyes. The Conchifera do not appear to have much choice of food, nor are they provided with any other means of obtaining it than the ciliary action, which introduces constant currents of water into the mouth. In general, they do not attain a great size, but they are, on the whole, larger than any Molluscs except the Cephalopods. A few species attain considerable dimensions—a *Pinna* having been known four feet long, and a *Tridacna* (Giant Clamp-shell) having been found to weigh 600 lbs. They are distributed over the whole globe, principally frequenting the shores or shallows. Each region has certain species peculiar, or most abundant in it, and there are few which are not limited to one hemisphere. The temperate zone appears as favourable to the development and multiplication of some species as the torrid zone to others; but the largest kinds are found only in warm latitudes.

In the subdivision of this class into orders, the degree in which the two lobes of the mantle adhere along the margin of the shell, is the character chiefly rested on; the presence or absence of the foot, and of the byssus also, are important characters; and along with these, the structure of the hinge should be attended to. On these grounds, the five following orders are established by Cuvier:—1. Ostraceæ, the *Oyster* tribe, in which the two halves of the mantle are separated the whole way round, and the foot absent, or very small: they are usually fixed by the shell to solid bodies. 2. Mytilaceæ, the *Mussel* tribe, in which the mantle remains open in front (at the end where the mouth is situated), and closed behind, an aperture being left for the egress of the fluid. They have a foot strong enough to crawl by, and commonly affix themselves by a byssus. 3. Chamaceæ, or *Clamp-shells;* in these the mantle is closed, with the exception of three apertures, two of which are for the ingress and egress of water, and the third for the passage of the foot, which is here usually more powerful. 4. Cardiaceæ, or *Cockle* tribe, in which the mantle is not only closed, but extended at the respiratory apertures into tubes of greater or less length. The foot is very strong. 5. The Inclusa, in which the mantle has only one opening for the passage of the foot; at the posterior end it is prolonged into tubes of great length, that can be extended far beyond the shell, as in the common *Solens*, or Razor-shells.

The Ostraceæ exhibit the nearest approach to the Tunicata, both in the absence of the foot, the entirely fixed condition of the body, and in the low grade of their general organisation. The shell itself is usually fixed by adhesion to other masses; in a few, the animal is attached by a byssus. Their continued abundance in the British seas, notwithstanding the large quantities constantly being consumed, is less surprising when we reflect upon their astonishing fertility, as many as 1,200,000 eggs having been detected in a single individual. The *Pectens*, or *clams*, as they are commonly called, have a hinge like that of the oysters, but differ in having the surface of the valves raised up into ribs, and in having two angular projections, commonly termed *ears*, by the sides of the hinge. Many of them are very elegantly coloured, and they are the most active of the whole order, being entirely unattached, and swimming with greater quickness than would have been expected from their imperfect means of locomotion. The *Anomiæ* are nearly allied to the oysters, but have a remarkable peculiarity in the structure of the shell. The

Anomia Ephippium.

greater part of the adductor muscle passes through a fissure in one of the valves, to be attached to a third plate, sometimes shelly, and sometimes horny, by which the animal adheres to foreign bodies; the remainder joins one valve to the other. Thus we have a *multivalve* shell formed by an animal which, both in structure and habits, corresponds closely with the bivalve oyster.

The foregoing tribes of Ostraceæ, and many more which might be enumerated, are distinguished by the presence of only one adductor muscle; in the remainder of the order, as in most other Bivalves, there exists a second. Among these may be mentioned the *Etheria*, which is a sort of fresh-water oyster; and the *Avicula*, that furnish the greater number of the pearls so highly prized as ornaments, and commonly called *Pearl Oysters*, from their general resemblance to the same tribe. The pearl is produced from the same substance as that which lines the shell, and which is commonly known as mother-of-pearl. It seems usually to result from some irritation of the mantle, which causes it to excrete an unusual quantity of pearly matter at one spot; and grains of sand, or other small particles, which, by getting between the membrane and the shell, seem to have caused such an irritation, are often found in the centres of pearls. Sometimes, again, pearls are found at points where the shell has been pierced by a boring mollusc; and it has been proposed to cause the formation of pearls by perforating the shell; but the specimens so produced have seldom that regularity of form which is as important to their value as is their size or lustre.

The order Mytilaceæ is well represented by the common *Mussel*, which has been already described. The various species of this group are extensively diffused; and from their abundance in particular localities, and their palatability, they serve as important articles of food. The *Anodon* is a fresh-water mussel, closely allied in general conformation to those inhabiting the sea, but differing remarkably in the absence of teeth in the hinge, whence the name of the genus is derived. The *Unio* is another fresh-water genus, having a more complicated hinge. It is remarkable for the pearly aspect of the lining of the valves, and for producing small pearls, sometimes in considerable abundance. These are not so pure in their colour, however, as those of the Avicula, and are but little esteemed. Some species of Unio are common in the lakes and rivers of Britain, but the greater number—and these the most remarkable for their size and colour—are peculiar to North America.

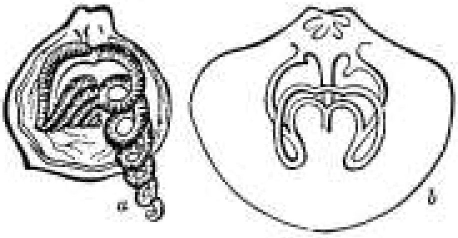
The order Chamaceæ includes but a comparatively small number of species, most of which are peculiar to tropical climates. The most remarkable is the *Tridacna gigas*, or Giant Clamp-shell, of the Indian Ocean, which sometimes attains the weight of many hundred pounds. Smaller specimens are often brought to this country; the valves being used to receive water from small fountains, &c.; and on the continent they are employed as reservoirs of holy water in the churches. The foot has a structure so tough, that, to separate the shell attached by it, it is necessary to chop it with a hatchet, like a cable. The animal being edible, is sought by the natives of the islands near which it lives, especially the Moluccas. It is usually seen in water a few feet deep, with its valves slightly separated; a pole is pushed down between them, which alarms the animal, and causes it to draw the valves together. The pole is thus firmly grasped, and by this the shell may be lifted from its bed.

In the animals of the order Cardiaceæ, or *Cockle* tribe, we usually find greater activity than in any others of the class. Here the foot comes to be a very important organ, possessed of great muscular power, and capable of being applied to a variety of uses. Many of the *Cardiaceæ* bury themselves in sand or mud; and it is in such that we find the respiratory orifices prolonged into tubes. In the common cockle, however, these tubes can scarcely be said to exist, the orifices not being prolonged beyond the shell. Its foot is very large, and can be bent nearly double in the middle; by doing this, and then suddenly straightening it, the animal is enabled to take considerable leaps. The hinge is very beautifully constructed; and the two valves lock closely together. The *Trigonia*, so called from the three-cornered shape of its shell, a very interesting genus, abundant in former ages of the globe, but now restricted to the shores of New Holland, seems allied to the cockle in the structure of its hinge and shell, in the size of its foot, and in its general organisation, although its mantle is divided into two lobes along the whole margin of the valves, as in the oyster.

In the order Inclusa we usually find the valves, when joined together, presenting more or less of a cylindrical form, as in the common Razor-shell of our shores. A hollow is left at each end, and from one the foot is projected, through a passage in the mantle, whilst the other gives exit to the respiratory tubes, which are often prolonged to a great length. The animals live almost uniformly buried in sand or mud, in rocks or wood. The *Solen*, or Razor-shell, is a very characteristic example of the order, which contains, however, some forms that depart very widely from it. The foot, which can be projected from the lower end, is firm and pointed, and serves as an admirable boring instrument, by the use of which the animal can burrow in the sand with great rapidity, sinking very deep when alarmed. The *Pholas* is a very interesting genus, the animal of which nearly resembles that of the Solen, although the shell is formed of several pieces—namely, two principal portions, and a variable number of accessory pieces. Some species of this genus bore in mud, others in rocks, and a few in wood—all of them hiding or lurking; hence their name, from *pholeos*, a lurking-place. Their action seems purely mechanical. They fix themselves firmly by the powerful foot, and then make the shell revolve; the sharp edges of this commence the perforation, which is afterwards enlarged by the rasp-like action of the rough exterior; and though the shell must thus be constantly worn down, yet it is replaced by a new formation from the mantle.

We now pass on to some very remarkable forms of this order, in which the bivalve character of the shell gradually disappears, being replaced by a new structure, of which no examples have been yet seen. The *Teredo*, or Wood-worm, as it is commonly termed, is an animal of the same general organisation as the Pholas; but its valves are smaller in proportion to the body, and its tubes still more prolonged—at least when the animal may be regarded as full-grown. By means of the mechanical action of its valves, it perforates timber, in the same manner as the Pholas penetrates stone. As it advances, the respiratory tubes are prolonged, so that their orifice remains at the entrance of the burrow, which is very small in proportion to the cavity formed by the animal as it increases in size. This orifice is furnished with a pair of valve-like shelly plates, termed *palmulæ*; by the action of which a current of water is driven towards the body of the animal, to serve for its respiration, and at the same time to supply it with food. The gallery is lined by a calcareous exudation from the surface of the tubular prolongation of the mantle, which forms a kind of secondary shell. The Teredo is an animal extremely destructive to timber, especially in warm climates, from which it seems to have been originally introduced into the seaports of Europe. In other genera the valves are lost in the shelly tube, so that the ordinary structure of the class is no longer apparent.

Besides the orders now described as composing the class Conchifera, there is a very curious group which should also be included in it, although established as a separate class by many naturalists. This is the group Brachiopoda, containing only three genera at present known—namely, *Terebratula*, *Lingula*, and *Orbicula*—but formerly of much greater comparative importance. These animals have all bivalve shells, differing in no essential particular from those of the Conchifera in general. The two former genera are attached, however, by a footstalk proceeding from an opening in one of the valves near the hinge, to solid substances. There are not only several muscles provided for the closure of the shell, but another set to open it—an organisation which no other Bivalves possess. The most peculiar part of their structure, and that from which they derive their name, consists in the presence of two very long arms, or tentacula, between the origin of which the mouth is situated. These can be projected to a considerable distance from the shell, or drawn in and coiled up spirally within it. They do not appear, however, to seize upon prey; but rather, by means of the cilia with which they are fringed, to create currents which may bring food to the mouth. In the Terebra-



Terebratula:
a, valve with the spiral arms; *b*, valve with arms removed.

tula, these arms are fixed at their bases to a very curious framework within the shell, the use of which is uncertain; but it is believed to aid, by its elasticity, in separating the valves from each other. This framework is most complex in the species in which the arms are shortest. The species of Brachiopoda at present known live at great depths in the ocean; and many of their peculiarities seem to have reference to that particular condition. They are distributed through all latitudes.

CLASS XVII.—TUNICATA.

The lowest and simplest of the molluscous classes is that to which the name of Tunicata has been given, in order to mark the peculiar structure of the animals composing it. They bear a general resemblance to those which form bivalve shells, but are of inferior organisation. They are peculiarly distinguished from them, however, by the entire absence of any shelly envelope; and by the possession, instead of it, of a *tunic* or external coat, of greater firmness than the rest of the structure, which surrounds the whole body, and affords it protection, besides being the medium of its attachment to the substances upon which these animals usually rest. This external tunic is extremely variable in colour, consistence, and form. Sometimes it is dark, and of leathery toughness; sometimes even cartilaginous; and in many species it exudes a glutinous matter, by which particles of sand, gravel, comminuted shells, &c. are attached together, so as to form an additional envelope, possessed of great firmness. Sometimes, on the other hand, the whole body is extremely soft and delicate in its structure, and the tunic a thin transparent membrane.

The greater number of the animals of this class are attached, during the principal part of their existence, either to each other, or to solid bodies. In a few species, a number of individuals are united by a stem which contains vessels establishing a connection amongst them all; so that they closely resemble the compound Polypifera. More commonly, however, they live in societies, each individual being distinct from the rest, but a number adhering together to form one mass, which is often enclosed in a common envelope. In other instances, each animal is completely separate from the rest, although a number are found in the same locality. Where this is the case, the animals are severally fixed to rocks or other solid masses, either by the adhesion of the tunic, or by a sort of footstalk prolonged from it. The whole activity of the life of these molluscs may be said to consist in the transmission of a current of water through a cavity within the mantle, by which the purposes of respiration and the supply of food are at once accomplished. The class is divided into two orders—the Ascidiæ and Salpæ—with reference to the arrangement of the two orifices through which this current passes.

RADIATA.

The general fact, that, in every complete natural group, there are some members which exhibit most plainly its characteristic peculiarities, while there are others in which these cannot be distinctly traced, or are altogether obscured, is nowhere more evident than in this sub-kingdom. For whilst in some we find the *radiated* arrangement of parts almost invariably preserved, and, if left at all, only slightly departed from, we can only trace it indistinctly in others, and in others, again, it cannot be at all perceived. Thus, when we examine a Star-Fish, a Medusa, or a Sea-Anemone, we observe that they all have a circular form, that the mouth is in the centre of one of the surfaces, and that the several parts arranged round these are but repetitions of one another; and an internal examination would show the contained organs to have the same character. If from these we pass to certain other species of the same groups, we should find the external form slightly modified, being prolonged or shortened in one particular direction, and the disposition of the interior organs no longer radiated. Again, in the Sponges, all trace of a circular arrangement of parts disappears. Yet these, and other groups in which the radiated type is equally absent, must be associated with the classes more characteristic of it, on account of their general conformity of structure, and in some instances their very close alliance.

The great diversity, not only in form, but also in degree of organisation, that exists amongst the Radiated classes, prevents much being stated of their general characters that shall be applicable to all of them. Thus, although the skeleton is external in some species, as the Sea-Urchin and Star-Fish, it is internal in others, as the Corals and some of the Jelly-Fish. Although most of them have a distinct mouth and stomach for the reception of aliment, others imbibe it, like plants, only by absorption through their exterior. Although some exhibit a high degree of sensibility, others are so apathetic, as scarcely to manifest any feeling of injury when severely wounded.

The class Polypifera, containing the *coral-forming animals*, may perhaps be regarded as the most characteristic of the group. These animals usually associate themselves together into compound masses, of which every part is capable of existing independently of the rest, and each polype exhibits in itself the radiated structure, which cannot be detected in the entire mass; but all have a certain degree of connection with each other, which may be compared to that existing among the different buds of a tree. Even the species which do not form solid structures, such as the Sea-Anemone, remain almost constantly attached to the same spot.

The Acalephæ, commonly termed *Sea-Nettles*, or *Jelly-Fish*, have no such tendency to aggregation, and never attach themselves to solid bodies, but wander at large through the ocean. By these characters, and by their extreme softness, the animals of this class are readily distinguished.

The Echinodermata also live solitarily, and have the power of free movement, except in a few species which approach the Polypifera; but they are readily distinguished from the Acalephæ by the density of their texture, and especially by the roughness of the integument, which is usually beset with prickles or spines, as in the Star-Fish and Sea-Urchin.

In the two following classes, no distinctly radiated structure can be seen:—

The POLYGASTRICA, which are generally known as *Animalcules*, are beings of extreme minuteness and general simplicity of structure. In the absence of distinct organs for the various purposes of the economy, they correspond with the lower Radiata, but they differ in the extreme activity of their movements. A separate division of the Animal Kingdom might almost be formed for them alone, so difficult is it to assign them any place in the ordinary scale. Some of them exhibit a tendency to associate into compound structures, like the Polypifera.

The PORIFERA, or *Sponge* tribe, are of all animals those which approach nearest to plants, in the absence of the characters peculiar to the kingdom in which they are placed, and in the want of definiteness of form. Certain movements exhibited by them, however, and their close affinity with some of the Polypifera, render it convenient that they should be classed among animals.

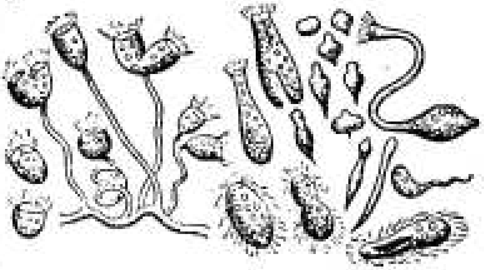
CLASS XVIII.—POLYGASTRICA.

This class includes the greater part of those minute beings termed *Animalcules*, which have been, from the time of the discovery of the microscope, such fertile sources of wonder and delight both to those who have themselves observed them, and to those who have heard from others of their marvels. Previously to that epoch, it was not suspected that beings existed of such minuteness as to be invisible to the eye, much less was any idea entertained of the extreme smallness of many species; and still more improbable and absurd would the statement have been deemed, that such beings are not of rare occurrence, but abound in every drop of stagnant water, and even exist in the whole mass of the ocean. Yet such has been shown to be the fact.

Animalcules may be obtained without difficulty for microscopic examination during the warmer part of the year, by skimming the surface of ponds, especially those in which the water exhibits a red or green tinge, or in which it is covered with duckweed, or with the slimy film which may often be noticed. Many curious species frequent these situations; but the commoner ones may be obtained with even less difficulty, by placing soft vegetable matter, of almost any description, in vessels with water, and exposing the mixture to the sun and air for a few days. As soon as decomposition begins actively to take place, animalcules may be detected in the fluid, and in a short time they often crowd it most densely. These are generally at first of a simple kind; but new species soon prevail, and those first seen disappear. Different kinds of vegetable matter seem to favour the development of the different species; and there are some species that can be produced in no other way than from an infusion of some particular substance.

In the class Polygastrica are included all the most minute species of true animalcules, and some among the larger ones; but as a whole, the beings composing it are smaller than the Rotifera, and far smaller than those of any other class. The largest among them are but with difficulty seen by the naked eye; and of the dimensions of the smallest the mind can scarcely form an adequate conception, although they may be numerically stated. The class takes its name from the belief entertained by the celebrated Prussian naturalist Ehrenberg (who has devoted almost his whole life to the study of microscopic forms of existence), that the animals composing it are especially characterised by the possession of many distinct stomachs or digestive sacs.

The bodies of these animalcules are of soft consistence, and very transparent, so that they resemble flakes of very thin jelly. Their forms are extremely variable; and in some species, the same individual at different times alters its shape so completely, that it could scarcely be recognised. Indeed many mistakes have occurred from this cause. The softness of the tissues of the Polygastrica is also seen when, in swimming, they encounter an obstacle; there seems scarcely any limit to the change of form to which many will submit, in order to pass the obstruction. They are not all so flexible, however; for in some species the body is enclosed in a siliceous sheath of very great delicacy, which gives support and protection to the still more delicate structures it contains. It is the accumulation of such sheaths that has given rise to the collections of Fossil Infusoria (as they have been termed), which will be hereafter noticed. Sometimes the whole body is contained within the sheath; whilst in other instances a sort of trunk or foot may be projected from its opening.



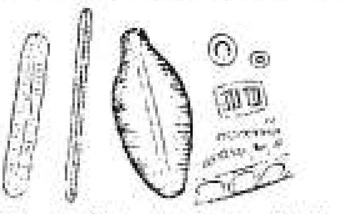
Various Forms of Animalcules.

The bodies of the Polygastrica are usually fringed with cilia, by the vibrations of which they are assisted in their own movements, and also in the acquirement of their food. Sometimes these cilia are disposed along the whole extent of the edges of the body; in other instances they surround the mouth only, and from that part they are seldom absent.

For some time after the discovery of the Infusoria, it was supposed that they must obtain their nutriment by absorption through the substance of their bodies, for no mouth, stomach, or alimentary tube could then be discerned. But by placing them in water, through which very small particles of colouring matter (such as indigo or carmine) were diffused, it was perceived that these particles are introduced into the interior of the body, and are collected in cavities hollowed from the general mass. And subsequently, the improved powers of the microscope have enabled an entrance to the interior of the body or mouth to be discovered in almost every instance, and a second orifice in a considerable number of species. The mouth is commonly furnished with a border of cilia, and sometimes with a set of projecting bristle-like teeth, which are used in laying hold of smaller animalcules, on which the possessor of this apparatus feeds. The introduction of food into the cavity of the body in those species which are destitute of this appendage, may be best watched by diffusing colouring particles through the water in which they are swimming. They are seen to be drawn into the mouth by the vortex or whirlpool occasioned by the action of the cilia; and soon after entering it, they are observed to be united together into little round balls, as if they had been compressed in a small spherical cavity. These balls are sent, one after the other, into the general cavity of the body, where they seem to lie in the midst of a soft gelatinous pulp, and in which they perform a slow revolution—the foremost ones escaping at intervals from the second orifice, whilst new ones are being pushed in from the mouth behind. This is all that can as yet be stated with certainty in regard to the digestive apparatus; since the opinion of Ehrenberg, that the whole body is occupied by a series of small, distinct globular cavities or stomachs, connected by an intestinal tube, is not adopted by other naturalists. Nothing will therefore be said of his classification of these animalcules, which is principally based upon characters furnished (according to his idea) by the arrangement of the stomachs.

The largest species of the Polygastrica probably never exceed 1-20th of an inch in length; the smallest at present known are about 1-2000th of a *line* in diameter; but there is no reason to suppose that this is by any means the limit of minuteness. They usually multiply by spontaneous division, the body of the parent splitting into two or more parts, each of which soon becomes a perfect being, capable of going through the same process. From observations which have been made upon the species in which these changes are most rapidly effected, it has been calculated that, under the most favourable circumstances as to food, temperature, &c. a hundred and forty million millions may be produced in four days!—a degree of fertility which assists in explaining the almost universal diffusion of these creatures, and their sudden appearance in such countless swarms.

Our ideas of the vast amount of animal life existing in this class have lately received a considerable extension, by the discovery that their remains, minute as they are, not unfrequently accumulate into masses of great extent. It is only of those species in which the bodies are covered with an envelope containing earthy matter that the remains can be thus preserved; and the substance formed by their aggregation seems to be an impalpable powder, such is the minuteness of each particle. Such substances have long been known under various names. One is the Tripoli, or Rotten-



Fossil Remains of Animalcules, forming Tripoli.

stone, used in the arts for polishing metals: another is the *berg-* or *mountain-meal*, used in Sweden, on account of its supposed nutritious qualities, mixed in bread with flour and the inner bark of trees in times of scarcity. Both these, as well as many other substances, consist entirely of the siliceous shields or envelopes of animalcules, closely allied to, if not identical with, species at present existing; and the quantity of animal matter which is dried up in the latter, and which may be determined by the effect of heat (this dissipating the animal portion, and leaving the siliceous particles unchanged), is sufficient to account for its nutritious properties.

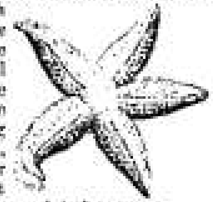
CLASS XIX.—ECHINODERMATA.

The class of Echinodermata, comprehending those well-known animals, the *Asterias* (Star-Fish) and *Echinus* (Sea-Urchin), takes its name from the prickly skin with which most of the tribes it includes are provided. But this is not a universal character; for some of the species, which border upon other groups, have a skin destitute of any appearance of spines. There is little difficulty, however, in distinguishing the animals of this class from all others, for in nearly the whole of them the radiated structure is very evident; and they are the only animals among the Radiata which have the power of moving from place to place, and have at the same time an integument firm enough to resist external pressure.

Although the character and degree of organisation in the different subdivisions of this class may be regarded as about the same, the form of the organs, and the mode in which they are arranged, are very different, so that it will be better to describe each group separately. The class may be distributed into three orders: the STELLERIDA, including the Star-Fishes and their allies; the ECHINIDA, including the Echinus and its allies; and the HOLOTHURIDA, a group less commonly known, and differing much from the others.

I.—Stellerida.

The common *Asterias*, or Star-Fish, which may be taken as a type of the order Stellerida, is covered with a tough leathery skin, beset with prickles. The animal has the form of a star, with five or more rays springing from a central disk. In the middle of one side of the disk is situated the mouth, and this side, according to the usual habits of the animal, must be considered the lower one, or that by which attachment and locomotion are performed. The mouth opens into a globular stomach, which sends out prolongations into the several rays; but there is no intestine in this animal, nor any second orifice to the digestive cavity, so that the indigestible portions of its food, which consists of young shellfish and the like, are rejected by the mouth.



Asterias: upper surface.

The order Stellerida includes a large number of forms, having a general resemblance to the *Star-Fish*, but differing much in the relative proportion of the body and rays. Thus, in some species the arms seem to make up the entire animal, no central disk being present, save that formed by their union. In others, the arms appear simply appendages to the central disk, to which the stomach and other important organs are confined. In several instances the arms send off lateral appendages; and these occasionally again subdivide, so that a branch-like structure is produced, such as we find in the *Comatula*.

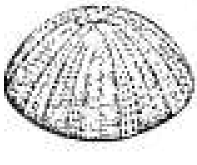
A very remarkable tribe, included among the Stellerida—once a group very important in its numbers, and in the extent of its diffusion through the sea, but now presenting only two or three comparatively small species—is that known under the name of *Crinoidea*, or Lily-like animals. These are formed much upon the plan of the Comatula, but they are attached by a jointed stalk to solid substances, usually to the bottom of the sea. They thus remind us of the Polypifera, which they seem to connect with the Echinodermata. This group contains two principal subdivisions—the *Encrinites* and the *Pentacrinites*. The former are distinguished by the roundness of their stems, the joints of which being flat and perforated in the centre, are known under the local names of wheel-stones, St Cuthbert's beads, &c. The latter have pentagonal stems. [See GEOLOGY.]

II.—Echinida.

In the Echinida we find the body usually of a somewhat globular shape, and enveloped in a firm shell, composed of a very regular series of plates jointed together. In the Echinus, the shell of which is commonly known as the Sea-Egg, we observe two orifices situated at the poles, as it were, of the globe. The larger of these orifices is the mouth: at the smaller one the intestinal tube terminates. The mouth, as in the star-fish, is generally directed downwards. It is furnished with a very curious apparatus of teeth, which are worked by powerful muscles, attached to projections of the shell, that may be seen on the inner margin of the mouth; and their points can even be protruded beyond the mouth, so as to lay hold of prey brought to them by the long tubular feet. By the action of the teeth, the food is ground down before it passes into the intestinal tube, which is here of considerable length, and takes a couple of turns round the shell before its termination. Round the second orifice of the shell are disposed the ovaria, which are very largely distended with eggs at some seasons, and are eaten under the name of the *roe of the sea-egg*.

It is the exterior organisation of these animals, however, that presents us with the greatest sources of interest. On looking at the Echinida in their living state, we see that most of them are covered with spines of considerable size, instead of with such small prickles as the Asterias bear. Moreover, these spines are seen to be movable at their bases, and their power of motion is due to their peculiar connection with the shell. Each spine is spread at its root into a cup-like form, and the hollow of this cup fits upon a little knob or tubercle projecting from the surface of the shell, so that a complete ball-and-socket joint is formed. The spines are connected to each other, and held on the shell by the skin which covers the latter, and which is attached around their roots; and it is by the contractions of this skin that they are moved.

On looking at the exterior of the shell of an *Echinus*, it is seen that the tubercles are arranged with great regularity, and that the larger ones are confined to particular rows of plates, which are hence called *tubercular* plates. Between these are smaller plates, commonly bearing smaller tubercles, and perforated with a number of minute holes, for the passage of the tubular feet; these are called *ambulacral* plates. The tubular feet, like the spines, are much longer than in the star-fish. They are always capable of being projected beyond the spines; and, taking an attachment by the suckers at their extremities, they can cause the shell to roll, as it were, upon the points of these. In some species, the spines are five or six inches long, whilst the diameter of the body is much less. The tubular feet often escape notice, on account of their transparency; and the animal appears to be walking upon its spines, when it is merely resting upon them as fulcra, and drawing itself forwards by these curious organs. It is to be remembered that the body will weigh much less in water than in air, and thus may be supported upon spines of great delicacy.



Shell of Echinus: a, a, tubercular plates; b, ambulacral plates.

These animals are generally found on sandy shores, and especially in little nooks secluded from the direct influence of the waves. Some of them excavate hollows in the sand by means of their spines, and one species even works its way into solid rock. Their food is of a mixed quality. Fragments of shells, Crustacea, and other marine animal products, are found in their stomachs, as well as portions of sea-weed. They obtain their prey whilst lurking in their hollows, by allowing their tubular feet to play loosely in the water around; and when any small animal touches the sucker at the end of one of them, it is soon secured by the assistance of others, and drawn within the range of the teeth.

III.—Holothurida.

In this order we find the characters of the class remarkably blended with those of the Articulata. The body is not enveloped in a hard shell, but in an elastic skin, destitute of spines or prickles. It retains, in some species, the globular form, but in many it is very much prolonged, so as to be almost cylindrical, and thus to resemble that of the Worms; and it is occasionally even marked by transverse bands, indicating a division into segments. Still, however, a distinctly-radiated conformation may be seen around the mouth; and some of these animals look as if a star-fish were set as a head on the body of a large worm. In the general conformation of the internal organs they correspond with the Echinida; but they are in some respects more complex, and the respiratory organs are constructed upon the plan of those of the Articulata. They thus form a very interesting link of connection between the Radiated and Articulated sub-kingdoms.

The skin of most of the Holothurida is so very elastic, that they can change their size and form in a remarkable degree. They are capable, too, of swimming with considerable rapidity, and some of them crawl like slugs upon solid surfaces. Small species are occasionally found in British seas; but on some tropical shores they are very abundant, and grow to the length of eighteen or twenty inches. They are sometimes eaten by the poor on the Neapolitan coast; but in the Malay Archipelago they are regularly sought, and conveyed to the Chinese market, where, under the name of *trepang*, they bring a high price.

CLASS XX.—ACALEPHÆ.

The name of the class next to be described, the Acalephæ, is derived from the stinging power possessed by nearly all the animals composing it. The word is the Greek term for *nettles*; and by the designations *sea-nettles*, *stung-fishes*, &c. these animals are popularly known; as well as by another, also expressive of a character by which the group is distinguished—*jelly-fish*. It is rather difficult to give any description of the structure of the class that shall include all the members of it, so much do they vary among each other. They all differ from the Polypifera in being unattached to solid bodies, and in having the power of freely moving through the sea; and they differ from the Echinodermata in not being covered with a dense integument. Their extreme softness is one of their most remarkable characters. Some of them attain considerable size, yet with an almost entire absence of a solid framework; indeed it is only in a few species that any such exists. They consist of a sort of network of animal filaments, the interspaces between which are filled up with water; and so large a proportion does this bear, that it drains away when the animal is kept out of its element for a short time, leaving but a thin film of membrane behind it.

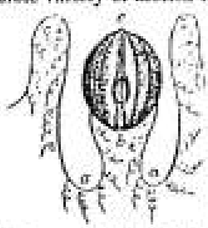
One of the commonest forms of this class is the *Medusa*, which is often seen floating in vast numbers on calm sunny days at a little distance from the shore. The animal consists of a large umbrella-shaped disk, from the under surface of which hang down four broad and long tentacula. Both disk and tentacula exhibit a very beautiful assemblage of colours, like those of the rainbow, when the rays of the sun are reflected from their surface. On the under side of the disk is seen the mouth, situated in the centre, and surrounded by the origins of the tentacula. This is the entrance to a stomach, which lies in the middle of the disk, and is surrounded by four ovarial chambers, having separate

Medusa: a, under surface, showing the mouth in the centre, surrounded by the tentacula, and the ovarial chambers exterior to the origins of these; b, side view, showing the tentacula hanging down in their natural position.

external orifices. The membrane of the disk extends much beyond the stomach and ovarial chambers (which may be described as occupying the part corresponding to that included between the metallic stretchers of the umbrella), and this broad free margin is endowed with muscular powers, and performs a series of undulations, by which the animal is propelled through the water. The extreme softness of the tissues of these *Medusæ* is an obvious reason why they should not expose themselves to the rough surface of the ocean, where they would be beaten to pieces by the waves—or to the proximity of the shore, from which they would soon receive fatal injury. Although so soft, however, they have the power of mastering prey of much firmer structure; and hard Crustacea, as well as other marine animals of high organisation, supply them with food.

An interesting species, allied in general form to the Medusa, but differing from it in a remarkable particular, is the *Rhizostoma* (root-mouth). No mouth is seen in the centre of the inferior side of the disk, but the stomach sends canals into the substance of the tentacula, which terminate in a number of minute pores at the extremity of those organs. By these small pores, as by the roots of plants, nourishment is absorbed into the system, for the ends of the tentacula fix themselves like suckers upon the surface of the animal they have grasped, and imbibe its juices. These and other Acalephæ which move through the water by the undulations of their membranous disk, are included in the order PULMONIGRADA. All the Acalephæ of this order exhibit a very regular disposition of their parts around a centre, so as to be truly *radiated* animals. Some of them attain a diameter of two or three feet.

Another interesting species of this class is the *Beröe pileus*, a small animal not unfrequently found on the coast of Scotland. When at rest in the water, it looks like a bright globe of jelly, about half an inch in diameter. An opening is seen at each pole of the globe, one of which is the mouth, and the other the termination of the alimentary canal, which runs right across the body. Its surface is marked by eight bands, running, as it were, from pole to pole; these bands seem to be of firmer texture than the rest of the body, and on them are placed the rows of cilia, which can act either together or separately, so as to give every possible variety of motion to the body; hence this animal, and others resembling it, are said to belong to the order *Ciliograda*. The Beröe usually swims, by means of them, mouth forwards, and thus a current of water is driven into the stomach without any further effort on the part of the animal. But it is provided with other means of obtaining its food, in two long tentacula, which arise from the posterior part of the body, and are furnished with a number of lateral filaments; these can all be withdrawn and folded into two cavities, excavated, as it were, in the substance of the body, and are easily unrolled when required for use.



Beröe: *a, a*, tentacula; *b*, mouth; *c*, termination of intestinal canal.

The Acalephæ inhabit all climates, but the largest forms are to be seen in tropical seas.

CLASS XXI.—POLYPIFERA.

The animal character of the beings composing the class Polypifera was formerly doubted, as that of the Sponges is at present. The structures which they form, known as Corals, Corallines, &c. have often so much of the plant-like aspect, and sometimes also of an apparently woody structure, that, even in recent times, naturalists have been deceived into a belief in their vegetable nature.

Another popular error in regard to this group, is the attributing the formation of coral to *insects*, and the supposition that it is their habitation, constructed under the same circumstances as the comb of Bees, or the pyramids of the Termites. The real fact is, that the masses of *coral*, *madrepore*, &c. as well as the *sea-fans* and other similar structures, with many smaller and more delicate ones—of which some are ranked among the *sea-weeds*, and others commonly known as *corallines*—are the *skeletons* of the animals by which they are produced, and are to be regarded as parts of the living structure, so long as the flesh which clothes or lines them retains its vitality.

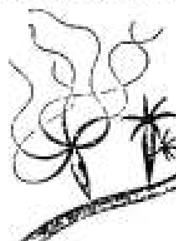
If, for example, the stem of the common *red coral* be examined when clothed with its living flesh, its surface is seen to be scattered over with polypes, the structure of each of which bears some resemblance to that of the sea-anemone; but these, so far from being independent of one another, like so many sea-anemones attached to the same rock, are connected by a system of vessels which traverse the flesh, and bring them all into communication. Nevertheless, any one of these would live if detached from the rest, and would gradually produce others, until a new structure was formed, similar to that of which it was originally a part. Moreover, if a piece of the gelatinous flesh be stripped from the stem, *this* will be competent to form both new polypes and a new skeleton.

Such compound beings, then, of which the polypes only form a part (like the leaves or flowers of plants), are not improperly termed Polypifera, or Polype-bearing Animals. But there are many kinds of Polypes which have no tendency to this kind of aggregation, and which are never found but in a solitary state. Such are the *Sea-Anemones*, and the *Hydra*, or fresh-water polype. And various degrees of intimacy of connection between the polypes of compound structures may be traced in different species.

The class may be divided into four orders, characterised by four distinct types of structure: in each of these we shall find polypes existing almost or altogether independently of one another; and species closely allied to these, in which they are intimately associated. As the distinguishing characters of the orders cannot be understood without a knowledge of the structure of the polypes belonging to each, it will be better to proceed at once to the description of them, the amount of popular information on the subject being small. We shall begin with the one generally accounted the simplest.

1.—Hydroida.

The *Hydra*, or fresh-water polype, the type or leading example of this order, is a minute animal, often found in great abundance, clustering round aquatic plants in stagnant pools. It seems to consist only of a kind of bag, constituting the stomach, round the mouth of which is disposed a circle of long arms, or *tentacula*, whilst the opposite end is prolonged into a foot, terminated by a kind of sucker, by which the animal attaches itself. Although little able to move from place to place, the hydra secures an abundant supply of food by its arms, which serve as so many fishing-lines. When any aquatic worm or insect touches one of these, it is entrapped by it, and other arms are speedily brought to its assistance; so that by the simultaneous contraction of the whole, the prey is conveyed to the mouth, even if strong enough to make powerful resistance. Not unfrequently it can be seen to move about violently within the stomach for some little time; but the powerful digestive secretion speedily begins to act upon it, and its soft parts are dissolved, the hard ones being usually ejected by the mouth. When this solution has been performed, the fluid which results from it is seen to be distributed by a kind of circulation through the walls of the stomach and the arms.



Hydra.

Nothing in the history of the hydra is so remarkable as its power of being multiplied by division, and of repairing the effects of other rough treatment. In regard to this, there really seems no limit. Not only can the body reproduce the arms, the mouth re-form the tail, and the tail the mouth; but from a minute fragment, the perfect hydra is reproduced, so that an individual cut up into forty or fifty pieces, will be converted into as many separate polypes. Two bodies, also, may be grafted together by the side, the tail, or in any other way; and monsters with two heads, two tails, &c. may be easily produced. The power of any one part to perform the functions of the rest, is remarkably shown by the fact, that the polype may be turned inside out; so that what was before the lining of the stomach becomes the external integument, and *vice versâ*, without its comfort being perceptibly impaired.

The hydra is not known to subdivide spontaneously, however, but it propagates itself by a process resembling the budding of plants. A little knob first projects from the side of its body, this enlarges, and from the top of it are seen to spring a number of small processes, which are the arms. In the centre of these an opening appears, constituting the mouth of the young polype, which gradually assumes the form of its parent, and begins to catch prey for itself. Still, however, the cavity of its stomach communicates with that from which it was at first prolonged; but the passage is gradually narrowed, and at last obliterated. When quite independent, the young polype detaches itself from the parent, and has no further relation with it. Several of these buds may spring from the same polype at once, provided it be well supplied with food, and the temperature be warm; and a second generation may even show themselves upon the first, whilst still continuous with the parent structure.

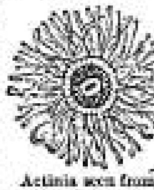
The entire substance of the hydra is soft, and no part seems possessed of greater firmness than the rest. In some other species, however, we find a tendency to the consolidation of the exterior into a kind of horny tube or sheath; and when a number of polypes are associated together, a compound structure is thus produced. In these compound structures, of which the Sertularia is an example, the cells are connected by stems and branches, in the same manner as the buds of a plant; and through the base of each cell there is a canal lined by an extension of the lining membrane of the polype, and uniting with the channels which pass through the whole structure. Thus all the polypes are brought into connection with each other, and with the general mass or polypary.

Portion of Sertularia: *a, a*, polype-cells with polypes; *b, b*, ovarial vesicles.

These polyparies, formed by the association of hydraform polypes, are among the most graceful and elegant of all the structures with which this class presents us. They are of minute size, when compared with the massive productions of other tribes; and the uniform absence of stony deposit gives them a degree of flexibility which adds much to their gracefulness. There are few shores on which some species may not be picked up. They are commonly mistaken for sea-weeds.

II.—Helianthoida.

A common form of polype—apparently so different from the hydra, that the relationship between them would not have been suspected by an uninformed observer—is the *Actinia*, or sea-anemone. There are probably no shores over the whole globe, except the very coldest, on which some species of this interesting creature are not to be found. The mouth is in the centre of the upper surface, and is surrounded by tentacula; and these are numerous, and arranged in several rows. The under side forms a large sucker, or disk; by this a very firm hold is taken of the rock or other surface to which the animal adheres. The stomach does not occupy the whole cavity of the body, but only the central portion; and the space between its wall and the outer integument is divided, by vertical membranous partitions passing directly from one to the other, into a number of radiating chambers, in which the germs of young *Actiniæ* are produced, and sometimes nearly matured. The tentacula of the sea-anemone can be contracted in the same manner as those of the hydra; and they are furnished with a sort of sucker at their extremities, by which they can draw towards the mouth any substance which comes in contact with them. These animals are extremely voracious. Shell-fish and small Crustacea appear to be their usual diet.


Actinia seen from above.

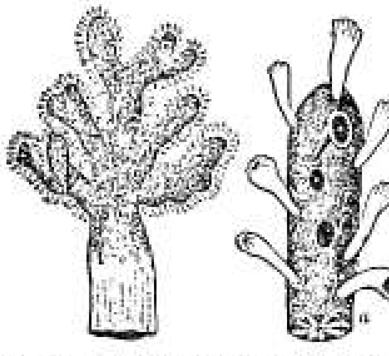
There are some of this order which form a stony deposit in the substance of their base, and in the membranous partitions between the radiating chambers. Of these, one small species inhabits the British seas; it belongs to the genus *Caryophyllia*. A very beautiful coralline formation of this description is that produced by the *Fungia*, an animal allied to the sea-anemone, and inhabiting only tropical seas. It consists of a thick round plate, sometimes several inches in diameter, from one surface of which arise thin vertical plates, radiating very regularly from the centre to the circumference. From the presence of these thin plates, or *lamellæ*, the whole of this group of corals and madrepores have been designated as *lamelliform*. The individual polypes belonging to such structures are connected by a gelatinous flesh enveloping the whole, which seems to answer to the membranous pith lining the stems of the compound Hydroïda. It is by this flesh, rather than by the polypes themselves, that much of the stony mass is deposited, as may be seen by examining many species in which the intervals between the cells are considerable. The variety of aspect which these masses present is very great; but there is little difference, so far as is known, in the structure and habits of the individual polypes, which form part of the beings in their living state.

None but *stony* corals are formed by Polypifera of this order; but there are many of that description which do not belong to it, of which we shall hereafter speak. However, it is to this order that the greater part of those species belong which are concerned in erecting the massive structures known at present under the names of coral reefs and islands, as well as those which appear to have existed in still greater amount in former epochs of the earth's history, and to have given origin to the greater part of the limestone rocks which constitute so large a proportion of the crust known to us. This order may be denominated that of *Actiniform* polypes, from the general resemblance of the animals composing it to the sea-anemone; or *Helianthoida*, from their similarity in aspect, when expanded, to the sun-flower.

III.—Asteroida.

The next order of Polypifera is one which brings us nearly to the form of the sponge. In the compound groups we have been last considering, the polypes form an important part of the general structure; and in some instances each may be regarded as existing almost for itself alone, even where many are united by the connecting fleshy matter. But in the group to be next treated, the polypes seem quite subordinate, and the general mass appears to have (as in the sponge) much more of the character of a single individual. In these structures we observe, too, that the hard basis or skeleton is seldom so distinct from the living tissue as in the lamelliform corals, the two often passing into each other by almost insensible gradations. The density of the skeleton varies considerably in the different species. Sometimes it is of a spongy character, as in the *Alcyonium*; at others of a stiff, horny texture, as in the *Gorgonia*, or Sea-Fan; and occasionally of a stony hardness, as in the Red Coral.

The *Alcyonia* are found abundantly on many parts of the British shores, and are known to fishermen by the names of *dead-man's-hand*, *sea-fingers*, *sea-paps*, &c. from their flabby texture, and the peculiar forms they present. Their structure is spongy, but they have



Alcyonium: *a*, portion enlarged, showing the Polypes.

usually a more distinct envelope than the true sponges, and this has sometimes a leathery character. Their interior is traversed by a series of canals, which ramify and inosculate with each other.

The polypes themselves have some resemblance to the sea-anemone, but they are usually much smaller, and of more delicate structure. There are, however, some important differences, upon which the character of the order is founded. The tentacula, instead of being numerous, and arranged in several rows, are only eight in number, and form one circle; they are broad, and almost leaf-like, instead of being round and slender; the mouth is situated in the midst of them, and leads to the stomach, which occupies the centre of the body; around the stomach are the *ovarial chambers*, separated by radiating partitions, but only eight in number; the stomach opens into the canal, upon the end of which the polype is placed, and all the fluid which enters the mass appears to be taken in through these mouths; the ovarial chambers also communicate with the canal beneath; indeed they may be said to be a continuation of it, for the partitions between them are prolonged downwards into the canal, forming plaits or folds of its lining membrane, in which the ova or germs are developed; so that these are produced from the general mass rather than from the polype—and the whole structure may be regarded as a higher kind of sponge.

The polypes are capable of being drawn entirely within the protuberances on the surface of the Alcyonia, and even these projections become flattened when the animals are in a state of great contraction. In this condition they are often left by the tide, and if then placed in a glass of clear water, their gradual expansion may be watched. The protuberances from the surface first show themselves, and the polypes, one by one, appear at their summits, and slowly expand their tentacula, until the whole surface appears covered with delicate blossoms. The entire mass then not unfrequently swells to twice or thrice its original size. If any one of the polypes be irritated, it shrinks into its hiding-place, but those near it are not affected. If the irritation of the part be prolonged, however, those in the neighbourhood gradually show themselves influenced by it, and draw themselves in; and in this manner the whole mass may be ultimately affected. The same results, however, may be produced by irritating a portion of the spongy substance intermediate between the polypes. From this it is evident that sensibility to impressions is not confined to the polypes alone, but that the whole mass must be regarded as possessed of animal properties.

There is one species in this order which differs from all the rest in the consolidation of the exterior rather than of the interior tissue; so that a stony *tube* is formed instead of a central stem. This is the *Tubipora musica*, of which the skeleton is known as Organ-pipe Coral. The polypes are not here connected by any system of vessels or uniting flesh; each lives for itself alone, but a number (probably all produced from the same stock, and by offsets from each other) unite for mutual support in one structure. Each polype has a cylindrical form, and its exterior membrane is progressively consolidated into a stony tube, which is thus gradually increasing in length by new deposits at its upper end. At certain intervals, the soft membrane (which is always projecting beyond the mouth of the tube) is flattened down into a sort of collar, which is consolidated likewise; and the collars of the neighbouring tubes, coming in contact with one another, form a sort of floor or shelf, which greatly strengthens the mass. After this collar is formed, the tube is continued as before for another period, when a similar floor is again produced by the simultaneous action of the polypes composing this beautiful structure.

To this order the term of *Alcyonian Polypifera* (from the name of one of its principal groups), may be conveniently applied; it is also known by the designation of Asteroida, from the star-shaped form presented by the tentacula when expanded. Its most luxuriant kinds are natives of tropical seas; thus the *Alcyonium poculum*, or Neptune's cup, which abounds in the neighbourhood of Singapore, is one of the most bulky species at present existing; but the smaller tribes abound in our own seas. No massive stony polyparies are formed by the animals of this order.

IV.—Ascidioida.

The last order of Polypifera far surpasses all the rest in the complexity of its organisation. They seem more independent of one another than they are in the associated groups of the others; but they are not known to exist in an absolutely isolated condition. They all agree in two essential points—the possession of a second external orifice to the digestive cavity, and the presence of cilia on their arms. By these they are distinguished from the other Polypifera. The latter of these characters has been embodied in the term *cilio-brachiata* (ciliated-armed), which is very appropriate. They have also been called *Bryozoa*, from their fancied resemblance to mosses; and *Ascidioida*, from their affinity to the *ascidiæ*, a group in the lowest or tunicated class of molluscs.

The members of this order seem to attain their full development under a less constantly elevated temperature than that required by the Helianthoida. Stony corals are formed by them in many seas of the temperate zone, and the more delicate species abound on our own coasts. This fact is interesting, when we compare the fossil with the recent coral formations.

When we consider the vast extent of the coral formations, which are at the present time effecting so remarkable a change on the surface of the globe, we cannot but be struck with the enormous amount of animal existence that must be concerned in producing them. Much error has prevailed on this subject, however; and in some points exaggerations have been produced through superficial observation. But here, as in almost every department of nature, the truth, as disclosed by a more careful examination, is far more wonderful than the showy covering in which the common love of the marvellous may have enveloped it.

It is generally stated that the coral masses, forming reefs or islands, are built up from the depths of the ocean. This is not strictly true; for it is well ascertained that none of the species which form the massive stony structures of which these are composed, can exist at a greater depth than from 100 to 120 feet. It is evident, then, that supposing the relative level of the land and sea to have been always the same as at present, these coral structures must be based on the summits of submarine mountains or ridges of hills, which rise from the bottom of the ocean, like corresponding hills and ridges upon the dry land; since deep water is almost always to be found in their neighbourhood. This is probably true to a certain extent. There is reason to believe that solid rock exists at no great depth beneath the surface of some of the islands; and there are many in which it forms part of them, a cone of rock rising out of the water, incrusted with a terrace of coral. Moreover, it may be stated as a general fact, that there is no part of those seas in which the temperature, depth of water, and other circumstances, are favourable to the operations of the coral-polypes, in which they are not constantly at work; and thus channels are being constantly rendered narrower and shallower, and harbours are being blocked up which were formerly accessible. But this takes place with less rapidity than is generally imagined.

The coral islands of the Pacific and Indian Oceans constitute a large proportion of the groups with which that vast area is scattered. In some instances they are considerably elevated above its level; but in general their surface is but little raised above it. As the polypes do not build above low-water mark, it does not become at once apparent how even this elevation is attained. It is to be remembered, however, that in the tropical ocean there is an almost constant succession of waves driven by the trade-wind from east to west. These, dashing against the windward side of the islands, break off blocks from the masses of coral, which they cast upon the summit. An accumulation of these blocks, consolidated by smaller fragments, and by the sand resulting from their constant friction, gradually produces a firm rocky superstratum. The surface of this, decomposed by the atmosphere, forms a calcareous soil, which is well adapted to the growth of many kinds of plants; and their seeds being drifted by the sea, or brought through the air by birds, take root in it, so as speedily to cover the island with a luxuriant vegetation. The growth and decay of successive crops gradually covers with a thick layer of mould the previous chalky soil; and this affords support to the most beautiful kinds of tropical plants, which the humidity of the insular atmosphere enables to flourish to a degree rarely seen on continents.

Several of the coral islands take the form of *rings*, containing large basins of water communicating with the sea, which are termed lagoons. These were probably erected on the craters of submarine volcanoes; of the existence of many of which beneath the Pacific Ocean there can be no doubt. They first rise to the surface in the form of circular reefs; the windward side is gradually raised above the sea-level by the process already described; but an opening usually remains at the leeward side, through which the water that washes into the central basin may flow out. As the whole ring is gradually elevated, however, the source of this overflow diminishes, and gradually ceases; the leeward channel is filled up by the growth of coral, and the lagoon is cut off from the sea. This basin, also, is at last filled up by the accumulation of fragments of coral, and by the growth of the more delicate species in its interior; and at last one nearly uniform surface is produced.

There is reason to believe, however, that in many instances the coral extends to a much greater depth beneath the surface than that in which the animals are known to live; and the question then arises, In what manner was it formed? A careful examination of the islands of the Pacific Ocean shows us that many of them, which rise considerably above the surface, are entirely composed of coral. Now, as the coral polypes never build above the level of the sea, it is evident that some subterranean movement, probably of a volcanic nature, must have lifted these islands from the bed of the ocean. In some instances, the height at which coral may be found is very great—not less than eight or nine thousand feet. It is not improbable, then, that as the bottom of some parts of the ocean is rising, that of others should be falling. If a coral island had been originally formed in the usual way, and had then gradually sunk in the water, the polypes would have continued to build it up to the surface; and thus almost any thickness of coral-formation may be produced, by a corresponding slow subsidence.

One of the most extraordinary coral growths known, is the barrier-reef which stretches along the shores of New Holland, at a distance of usually more than a hundred miles from the coast. This is above a thousand miles long; and for several hundred miles has no break wide enough to give passage to a ship. It is scarcely conceivable that a submarine ridge of hill should exist, a thousand miles in length, and approaching everywhere within one hundred feet of the same elevation; for such a ridge is nowhere seen on the dry land. But it is easy to account for this remarkable structure, if we suppose that the ridge was formerly more or less elevated above the surface; and that its different parts gradually became incrusted and capped with coral as they were submerged, after which the growth would continue upon the same parts, until the whole, being thus depressed and covered, became the continuous mass which is now witnessed. That such depressions *are* taking place in some islands of the Pacific, is a fact substantiated not only by the traditions of the natives, but by observations made since they have been visited by Europeans.

There are many instances in which the coral structures of comparatively recent origin have undergone a metamorphosis, which causes them to lose in some degree their original aspect. Large masses, when long exposed to the air, become changed into a solid, often somewhat crystalline rock, in which the traces of organic structure are very indistinct, and with which the *mountain* or *secondary limestone* closely corresponds. This is observed in the Bermudas. Moreover, the coral sand often becomes agglutinated, by the percolation of water through it, into a very hard stone: it is in such a mass that the human skeleton, found on the shore at Guadaloupe, and now placed in the British Museum, is imbedded. This stone, when minutely examined, is seen to consist of a number of rounded grains, cemented, as it were, together; and it closely resembles the rock known to the geologist as *oolite*. Further, where shallow water exists around coral islands, the bottom is found to be covered with a layer of white mud, which is formed by the decay of the animal matter that held together the particles of carbonate of lime in the stony corals, and these are consequently set at liberty in a finely-divided state, and fall to the bottom in a form which, if dry, would constitute *chalk*. Thus we may trace very distinctly the mode in which some of the principal kinds of limestone strata may have taken their origin in coral formations.

Now the mountain limestone, as it is termed—a rock very abundant in Britain, extending over large areas beneath the coal-fields, and sometimes exhibiting an unbroken thickness of nearly 200 feet—is in some parts evidently composed of accumulations of shells, stems of encrinites, &c. But in many others the remains of corals are very distinct; and these are so blended with the rocky mass, as to make it appear probable that the latter also was once in the state of coral, but was gradually changed by the process just described. Further, the collections of other animal remains (shells, fishes, and the like) are just such as we should expect to find on the margin of a coral reef existing at that epoch; and a similar process of fossilisation is taking place on the coral shores of the present epoch—the imbedded series of animals only being different. The great thickness of the beds of this rock may be accounted for, in the same manner as the depth of the coralline masses of modern formation.

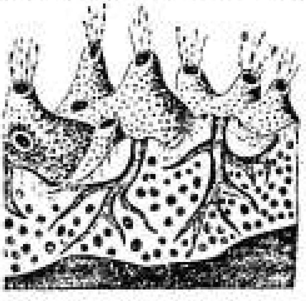
There are observed, in rocks of more recent formation, appearances which still more clearly indicate that they, too, were originally formed by coral polypes. These are often found only within narrow limits, as if they had been reefs or islands of small size. Thus we find a stone called coral-rag in Oxfordshire; and very distinct coral beds in the crag of the eastern coast of England. It is interesting to remark, that the remains of coral which are found in the older limestones, all correspond with those at present abounding near the equator, and exhibit the *lamelliform* character; whilst they are gradually replaced in the newer strata by species more allied to those at present existing in temperate climates. This is one of the many facts which tend to prove that this part of the earth had at some former period a much higher temperature than at present.

We see, then, that vast as are the works of the existing species of this class, they are probably far surpassed by the accumulations of former ages, which constitute, in some form or other, a large proportion of the solid rocks of the terrestrial crust. And thus we see the exemplification of a principle which has frequently come under our notice—that in the economy of Nature nothing is insignificant; and that the most gigantic effects may be produced by the continuous multiplication even of the humblest among the living inhabitants of the globe.

CLASS XXII.—PORIFERA.

Of all the beings usually known under the designation ZOOPHYTES, the *Sponges* and their allies, constituting the class Porifera, appear to have the best claim to the title, since they present so complete an admixture of the characters of plants and animals, that it is difficult to say to which division of the organised world they properly belong. Like plants, they are fixed to one spot during the whole of their lives, subsequently, at least, to their first development; they seem to possess no sensibility, for they can be torn or wounded in anyway, without showing by their movements any indication of being affected by the injury; and they do not appear to have that power of executing voluntary motions which must be regarded as the distinguishing characteristic of animals. On the other hand, they present a structure which is not analogous to anything found in plants, but is similar to that of beings undoubtedly belonging to the Animal Kingdom; with these beings they are connected by intermediate forms, presenting a regular gradation of increasing complexity of structure and variety of function; and there are certain movements, both in the adult and in the undeveloped sponge, which are more analogous to those seen in higher animals, than to any observed in plants. On the whole, however, the evidence for the animal character of the sponges seems to preponderate; and they will be accordingly considered here. Still, there is no doubt that, if they are included in the Animal Kingdom at all, the lowest place in the scale should be assigned to them.

The common sponge is a sufficiently characteristic form of the class, to serve as the foundation of a general account of the structure which prevails in it. On looking at its exterior, we observe that it is covered by a number of closely-set and minute orifices; and that larger openings are disposed at intervals among these. The former are termed *pores*, the latter *vents*. On cutting into the substance of the sponge, it is seen to consist of a sort of network of filaments, interlacing together in such a manner, as to leave large channels and spaces of various forms, which communicate with each other. The large channels terminate in the vents; and on tracing any one of them into the substance of the sponge, it is seen to divide and send off ramifying branches, which at last lose themselves in the spongy network that lies around them; and this communicates with the pores on the external surface. The interlacing fibres, of which the walls of the large canals, and the spongy tissue between them, are alike composed, entirely consist of a sort of horny *animal* matter, as may be perceived by burning a small portion. In other species we find *spicula*, or needle-like crystals, of silex or of carbonate of lime, disposed amongst these, giving to the structure much greater firmness, but depriving it, more or less completely, of that elasticity which is so useful in the common sponge.



Section of Living Sponge.

The substance known as *sponge* is, however, but the skeleton of the animal; the whole substance being beaten and soaked in dilute muriatic acid with a view to bleach it, and to dissolve any adherent portions of lime, before bringing it to market. When alive, the fibrous network is clothed, within and without, by a thin gelatinous substance, very like the white of an egg. This lines all the passages, and covers the exterior; but it drains away when the sponge is removed from the water. In this the peculiar vital endowments of the being appear to reside. These are manifested not only by its slow, but regular growth, but by a curious circulation of fluid constantly taking place within the mass. When a sponge is examined in its living state, beneath the water, a constant current is seen to issue from the vents; being made evident by the disturbance of the water, and by the movement of particles floating in it. It may also be ascertained that a constant flow of water takes place inwards through the pores; for small solid particles upon their edges are occasionally seen to be sucked in. No intermission can be detected during the life of the sponge in these currents, which evidently have for their object to convey the nutritive matter contained in the water into the interior of the mass, and also to carry off the particles which are to be excreted, since thin films detached from the living tissue are seen to pass out from the vents along with the fluid ejected from them.

The relative position of the *pores* and *vents* differs much in the different kinds of sponge. Sometimes all the former are on one side, and the latter on the other. Not unfrequently, the vents are placed on the summit of little conical prominences, which look like craters of a volcano; and the streams issuing from them, when seen under a microscope, may be likened to a miniature eruption. Occasionally the sponge assumes the form of a hollow cylinder, which hangs at one extremity from a rock; the pores are all upon the exterior surface, whilst the vents open into the interior cavity, and their united stream rushes out with considerable energy from the lower end of the cylinder.

Sponges may be multiplied, like plants, by artificial division, each portion becoming a new individual; but it does not appear that this is their natural mode of increase. They propagate by detaching little round gelatinous bodies, termed *gemmules*, from their living tissue; which in time develop the original form of the parent. These are produced in the network between the large canals, into which they find their way; when mature, they pass out of the vents in the current which sweeps through them, and by which they are conveyed to a distance. In these gemmules a peculiar motion, like that of animalcules, may be seen for some time: they swim hither and thither; at last they fix themselves, and begin to deposit the horny or earthy particles which are to form their skeleton; and the system of canals gradually shows itself in their substance. When once they have fixed themselves, they seem to lose all power of further movement, and remain during the rest of their lives attached to the same spot.

Some kinds of sponges are found on almost all shores; and some frequent deep water, whence they can only be obtained by dredging. It is in this manner that the sponge of commerce is procured from the Mediterranean, the Grecian Archipelago, and the other localities it frequents. Sponges are not confined to the sea, however, for there is a species which inhabits fresh water.

With the notice of this group we appropriately close the subject of SYSTEMATIC ZOOLOGY.

NATURAL PHILOSOPHY.

Natural Philosophy is a term of wide import, and has reference to all those branches of physical science which treat of existing bodies, their constitution, their motions, their mutual connections, and their influence on each other. By existing bodies we mean those made known to us by our senses; for a body standing in no connection with our senses, has, so far as we are concerned, no existence. The province of the natural philosopher is therefore to trace the connection subsisting between the varied phenomena brought under his knowledge by means of the senses, and so to arrange them, that they may elucidate each other, and manifest their mutual dependence. When we have established the connection of one phenomenon with another, we are said to have *explained* it; and a natural *law* is obtained as soon as the unchangeable link of connection between the natural phenomena is understood, even should we remain ignorant of the final cause. In this enlarged sense, the science may be considered as embracing all that can be known of the heavenly bodies, of the air, and of the earth and its varied materials and productions. It is usual, however, to divide it into two great branches—*Natural History*, treating of the nature of individual objects, and arranging them into systems, according to their different characters; and *Natural Philosophy*, which endeavours to lay open the laws of the material universe. The former embraces zoology, botany, geology, &c. which are commonly distinguished as *natural* sciences; and the latter mechanics, optics, chemistry, and other departments known as the *physical* sciences. It is also not unusual to employ the term *physics*, in contradistinction to that of *chemistry*, because the former refers more especially to laws not depending upon any change in the constitution of bodies, whereas the latter treats of phenomena almost wholly depending upon such changes. In the present sheet, we shall confine our explanations to the laws and properties of matter and motion, reserving mechanics, hydrostatics, pneumatics, optics, acoustics, electricity, and other branches of natural philosophy as above defined, for subsequent treatment.

I. MATTER AND ITS PROPERTIES.

Matter—or that of which all bodies are composed whose existence is made known to us by means of the senses, or by the test of philosophic experiment—is possessed of various properties, some of which are essential to its existence, while others are only accidental or contingent. The essential properties of matter—are Impenetrability, Extension, Figure, Divisibility, Inertia, and Attraction.

Impenetrability is that quality of bodies in virtue of which each occupies a certain portion of space, and excludes other bodies from existing in the same place at the same instant. In the usual sense, we call any hard body, such as a stone, impenetrable, because it firmly resists our efforts to pierce it. But, as it is understood philosophically (although we can condense, pierce, and remove the greater number of them), all bodies are alike impenetrable, because they equally possess the property of excluding other substances from the spaces which they occupy. This, in fact, is saying no more than that two things cannot be in the same place at once, which is a self-evident truth, whether we apply it to a single particle of matter or a large mass.

Every body, or portion or particle of matter, possesses a certain *extension* or magnitude. It is impossible to form a conception of matter, however minute may be the particle, without connecting with it the idea of its having a certain bulk, and filling a certain extent of space. In common phraseology, we express this property of bodies by the word *size*, or *volume*.

The next property demanding our attention is the *figure* of bodies. Figure, or form, is the result of extension, for we cannot have the idea of a body possessing length, breadth, and depth, without its having some kind of figure, however irregular. The volume of a body has no relation to its figure. Bodies which have the same figure, may possess very different volumes; and bodies may have the same volume, but possess very different figures. Thus two masses of matter may have the same volume, although the one be round, and the other be square.

Matter is divisible into parts, and these parts may again be subdivided into other parts. By this is meant *divisibility*, or separability. To the practical subdivision of matter it seems impossible to assign a limit; and many of the instances of it which may be found in philosophical investigations almost exceed credibility. The thinnest part of a soap-bubble, which is a thin shell of water and the matter of soap, does not exceed in thickness the 2,500,000th part of an inch. The useful arts also furnish many striking examples; but it is in the organised world that the most astonishing proofs of the extreme divisibility of globules, or particles of matter, are to be found. Animalcules—that is, animals which are so small, as to be invisible to the naked eye, and which, by means of microscopes, are seen floating in water—are in some cases so minute, that it would require a million of them to form the bulk of a grain of sand. As these animalcules possess, in every case, a perfect organisation, to enable them to perform all the functions of life, the smallness of their different parts, and the extreme minuteness of the particles of matter which compose them, are too exquisite to be made the subject of calculation: the imagination is lost in the contemplation of their wonderful economy! The effluvium or odour which excites the sensation of *smell*, consists of an incalculable number of particles of matter floating in the atmosphere, and so minute, as to be altogether invisible to the eye. The effluvium given forth by a single grain of musk has been known to perfume an apartment for twenty years, and yet, at the expiry of that period, there was no sensible diminution of the little mass from which the odour-yielding particles had proceeded.

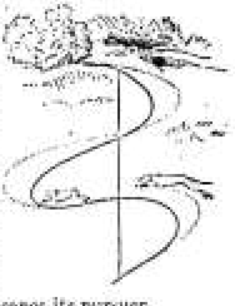
But although divisibility extends far beyond the limits perceptible to sense, it must not be assumed, remarks Professor Müller, that it is wholly unlimited; for to adopt such an assumption, were, in other words, to admit that the size of the ultimate undivisible particle is null, while it is evident that, if the ultimate particle have no extension, it cannot enter into the composition of an extended body. It is upon these considerations that the natural philosopher bases the hypothesis that all bodies are composed of minute particles, which cannot be further disintegrated, but are undivisible, and therefore termed atoms. This fundamental view of the constitution of bodies is now universally embraced by the natural philosopher and the chemist as the atomic theory. In speaking of small particles, without actually wishing to designate them as ultimate portions or atoms, it is usual to employ the term *molecules*, which is synonymous with particles of a mass.

Molecules of matter are never destroyed or lost, although they may disappear from our immediate observation. Under certain circumstances, they may again be collected into a body without change of form. Mercury, water, and many other substances may be converted into vapour, or distilled in close vessels;

without any of their particles being lost. In such cases there is no decomposition of the substances, but only a change of form by the heat; hence the mercury and water assume their original state again on cooling. When bodies suffer decomposition or decay, their elementary particles, in like manner, are neither destroyed nor lost, but only enter into new arrangements or combinations with other bodies. When a piece of wood is heated in a close vessel, such as a retort, we obtain water, an acid, several kinds of gas, and there remains a black, porous substance, called charcoal. The wood is thus decomposed or destroyed, and its particles take a new arrangement, and assume new forms; but that nothing is lost, is proved by the fact, that if the water, acid, gases, and charcoal be collected and weighed, they will be found exactly as heavy as the wood was before distillation. In like manner the decay of animal or vegetable bodies in the open air, or in the ground, is only a process by which the particles of which they were composed change their places, and assume new forms. The decomposition of animals and vegetables beneath the surface of the earth fertilise the soil, which nourishes the growth of plants and other vegetables; and these, in their turn, form the nutriment of animals. Thus is there a perpetual change from death to life, and from life to death, and as constant a succession in the forms and places which the particles of matter assume. Nothing is lost; not an atom of matter is struck out of existence.

Inertia means passiveness, or inactivity. Thus matter is perfectly passive in submitting to any condition in which it is placed, whether of rest or motion. When at rest, it shows an inability or reluctancy to move; and when in motion, it shows an equal inability or reluctancy to come to a state of rest. It is obvious that a rock on the surface of the earth never changes its position in respect to other things on the earth. It has of itself no power to move, and would therefore for ever lie still, unless moved by some external force. Now it is just as true that inert matter has no power to bring itself to rest when once put in motion, as that it cannot put itself in motion when at rest; for having no life, it is perfectly passive both to motion and rest, and therefore either state depends entirely upon external circumstances. Many instances might be given of the tendency which matter has to remain in the condition in which it happens to have been already placed. The following are among the most instructive:—When the sails of a ship are loosened to the breeze, slowly and heavily at first the vessel gets into motion, but gradually its speed increases, as the force by which it is impelled overcomes the inertia of its mass. A great force is necessary at first to set a vehicle in motion; but when once this is effected, it goes onward with comparative ease, so that, in fact, a strong effort is necessary before it can be stopped. If a person be standing in it when it is suddenly set a-going, his feet are pulled forward, whilst his body, obeying the law of inertia, remains where it was, and he accordingly falls backwards. On the other hand, if the vehicle be suddenly stopped, and the individual be standing in the same position as formerly, the tendency which his body has to move forward—for it acquired the same motion as the carriage by which it was borne along—will cause him to fall in the opposite direction.

The following are familiar examples of the inertia of matter:—Upon the tip of the finger let a card be balanced, and a piece of money—say a shilling—laid upon it. Let the card then be smartly struck, and it will fly from beneath the coin, leaving it supported upon the finger. This arises from the inertia of the metal being greater than the friction of the card which passes from beneath it. Coursing, or hare-hunting, affords another striking illustration of inertia. In that field sport, the hare seems to possess an instinctive consciousness of the existence of this law of matter. When pursued by the greyhound, it does not run in a straight line to the cover, but in a zig-zag one. It *doubles*—that is, suddenly changes the direction of its course, and turns back at an acute angle with the direction in which it had been running. The greyhound, being unprepared to make the turn, and therefore unable to resist the tendency to persevere in the rapid motion which it has acquired, is impelled a considerable distance forward before it can check its speed and return to the pursuit. But in the meantime, the hare has been enabled to shoot far ahead in the other direction; and although a hare is much less fleet than a greyhound, by this scientific manœuvring it often escapes its pursuer.

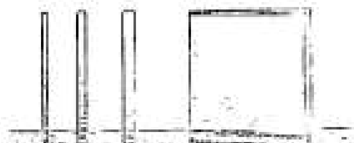


We have now arrived at a most important property—*attraction*—which it is desirable should be carefully studied. It is a fundamental law of nature, ascertained by Sir Isaac Newton, that every atom or particle of matter has a tendency to approach, or to be attracted towards, another atom or particle. This forms one of the leading principles in modern natural philosophy. Experience and observation demonstrate that this power of mutual attraction pervades all material things, and though unseen, except in its results, is ever present with us—is the cause of particles of matter adhering to each other, and forming solid masses—of these masses assuming in many instances a round or globular form—of the falling of bodies to, and their stability on, the earth—and is one of the causes of the whole of the planetary bodies moving in their paths in the heavens. Attraction is of different kinds, although some of these may be merely modifications of others, and has received different names, according to the circumstances under which it acts. The force which keeps the particles of matter together, to form bodies or masses, is called *attraction of cohesion*. That which inclines different masses towards each other, is called *gravitation*, *or attraction of gravitation*. That which causes liquids to rise in tubes, or in very confined situations, is called *capillary attraction*. That which forces the particles of different kinds of matter to unite, is called *chemical attraction*. That which causes the magnetic needle to point constantly towards the poles of the earth, is *magnetic attraction*. And that which is excited by friction in certain substances, is known by the name of *electrical attraction*.

Attraction of cohesion acts only at insensible distances, as when the particles of bodies apparently touch each other. This kind of attraction may be described as the quality in nature which causes matter to cohere or stick together. It is much stronger in some bodies than in others. It is stronger in the metals than in most other substances, and in some of the metals it is stronger than in others. In general, it is most powerful among the particles of solid bodies, weaker among those of fluids, and least of all, or almost entirely wanting, among elastic fluids, such as air and the gases. Thus a small iron wire will hold a suspended weight of many pounds, without having its particles separated; the particles of water are divided by a very small force, while those of air are still more easily moved among each other. These different properties depend on the force of cohesion with which the several particles of these bodies are united.

When the particles of a body can be suspended in the air in a fluid state, they will, if not under the attractive influence of some other body, arrange themselves, by virtue of the same law, around a centre, and take a spherical or round form. Thus a small quantity of dew suspended on the point of a thorn or leaf, becomes a globule, because in that case the attraction of the particles towards their own centre is greater than the attraction of any neighbouring body. Tears running down the cheeks, drops of rain, and hail, are all examples of this tendency in insulated fluid bodies to assume the globular form. When two perfect globules of mercury are brought into contact, they instantly unite together, and form one spherical drop. The manufacture of shot is also a striking illustration. The lead is melted, and poured into a sieve at the height of about two hundred feet from the ground. Each stream of lead, immediately after leaving the sieve, separates into little globules, which, before they reach the ground, are cooled, and become solid: thus is formed the shot used by sportsmen. To account for the globular form in all these cases, we have only to consider that the particles of matter are mutually attracted towards a common centre, and in liquids, being free to move, they arrange themselves accordingly. In consequence of this law of nature, it is considered probable that the planetary bodies, including our earth, were originally in a fluid or gaseous state—that in that state they unavoidably assumed a spherical form, and were then consolidated into their present consistency.

The force by which small tubes, or porous substances, raise liquids above their levels, is called capillary attraction, from *capilla*, the Latin word for a hair. In a wet tea-cup, or other vessel containing liquid, you may perceive the liquid at the sides rising above the level of that of the other parts of the surface; this is caused by attraction. If two glass plates be brought very near each other, so as to stand parallel with their flat sides in almost mutual contact, and then their lower end be dipped into a vessel of water, the fluid will rise up between the plates, and the height to which it rises will be greater the nearer the plates are to each other.



The water rises very little on the outsides of the plates, for this attraction is insensible at even moderately small distances. If a glass tube, with an exceedingly small or capillary bore, be dipped in water, the fluid will rise in the interior of the tube; and the smaller the bore, the higher does the water ascend. A great variety of porous substances are capable of this kind of attraction. If a piece of sponge, or a lump of sugar, be placed so that its lowest corner touches the water, the fluid will rise up and wet the whole mass. In the same manner the wick of a lamp will carry up the oil to supply the flame, though the flame is several inches above the level of the oil. If the end of a towel happens to be left in a basin of water, it will empty the basin of its contents; and, on the same principle, when a dry wedge of wood is driven into the crevice of a rock, and afterwards moistened with water, as when the rains fall upon it, it will absorb the water, swell, and sometimes split the rock. The lower parts of the walls, and also the earthen floors of cottages, are in the same manner apt to become damp, by the attraction of the moisture upwards from the ground—hence the necessity for clearing away all wet earthy matter from the foundations of houses.

Besides these varieties of attraction, there are, as already said, chemical, magnetic, and electric attraction; but as these will be respectively alluded to under the heads CHEMISTRY and ELECTRICITY in the present series of treatises, they do not require particular notice here. We now proceed to consider the kind of attraction which seems to unite all ordinary masses and particles of matter—namely, the *attraction of gravitation*:—

As the attraction of cohesion unites the particles of matter into masses or bodies, so the attraction of gravitation tends to force these masses towards each other to form others of still greater dimensions. The force of attraction increases in proportion as bodies approach each other, and by the same law it must diminish in proportion as they recede from each other. Attraction, in technical language, is inversely as the squares of the distances between the two bodies; that is, in proportion as the square of the distance increases, in the same proportion attraction decreases, and so the contrary. Thus, if at the distance of 2 feet, the attraction be equal to 4 pounds, at the distance of 4 feet it will be only 1 pound; for the square of 2 is 4, and the square of 4 is 16, which is 4 times the square of 2. On the contrary, if the attraction at the distance of 6 feet be 3 pounds, at the distance of 2 feet it will be 9 times as much, or 27 pounds, because 36, the square of 6, is equal to 9 times 4, the square of 2.

The gradual diminution of attraction as the distance increases, is exemplified in the following table. In the upper line, the distance is expressed by progressive numbers; in the lower corresponding squares the diminution of attraction is indicated by the common arithmetical fractions:—

Distance	1	2	3	4	5	6	7	8	and so on.
Attraction	1	$\frac{1}{4}$	$\frac{1}{9}$	$\frac{1}{16}$	$\frac{1}{25}$	$\frac{1}{36}$	$\frac{1}{49}$	$\frac{1}{64}$	and so on.

It is here seen that at the distance of 8, the attractive force is diminished to a 64th part of what it was at 1.

The attractive force of matter is also in proportion to the numbers of the atoms of matter which a body contains: the attraction, therefore, does not proceed from the mere surface of a body, but from all the particles which individually compose it. Some bodies of the same bulk contain a much greater quantity of matter than others: thus a piece of lead contains about twelve times as much matter as a piece of cork of the same dimensions; and therefore a piece of lead of any given size, and a piece of cork twelve times as large, will attract each other equally. The attractive power of any mass acts from the centre. At all equal distances from the centre the attractive power is equal; for instance, in a body perfectly spherical, the attraction to the centre would be the same at all parts of the surface. The distance of the centre of a sphere from its surface is called the *semi-diameter* of that sphere—that is, the half of its thickness. At a point as far from the surface of a sphere as its semi-diameter, its attractive power is diminished to a fourth. At three distances, the attraction is a ninth; at four distances, a sixteenth; and so on. When we wish, therefore, to ascertain the relative amount of the attraction which any mass of matter exercises over another, the rule is, to inquire how many semi-diameters of the one the other is distant from it, and then to multiply that number by itself. The result shows how many times the attraction at this distance is less than at the surface of the former. The moon, for instance, is distant 240,000 miles from the earth, or as much as sixty semi-diameters of the earth; 60 multiplied by 60 gives 3600; consequently, the attraction exercised by the earth upon the moon is a 3600th part of what it would exercise upon the same mass at its own surface. If the earth were a perfectly spherical body, its attraction would be equal everywhere at the level of the sea. As the surface at the pole is about thirteen miles nearer the centre than the surface at the equator, the attraction is stronger at the former than at the latter place: it gets proportionally weaker as we advance towards the equator, on account of the increase of distance from the centre. Hence a mass of iron which is considered a pound weight in Britain, would be less than a pound on the coast of Guinea, and more than a pound in Greenland, for weight is only a result of attraction. If we ascend a mountain, the effect is the same as if we proceed towards the equator—we are always getting farther from the centre of attraction, and consequently weights become lighter. On the top of a hill four miles high, a ball of four thousand pounds weight would be found to be two pounds lighter.

Pressure downwards, or weight, is in philosophical language termed GRAVITY; and under that head it is hereafter treated, in connection with the phenomena of falling bodies.

The attraction of bodies is mutual, and in proportion to the quantity of matter they contain. Therefore, every body, however small, exerts some degree of attraction upon the mass of the earth. Any body which comes immediately under our observation, is so small in comparison to the earth, that its attractive force is altogether unappreciable; but if it were of great density, and of dimensions approaching to those of the earth, then we should see the earth rise to meet the body, or fall towards it. The heavenly bodies, when they approach each other, are drawn out of the line of their paths or orbits by mutual attraction. It is found by experiment, that a plumb-line suspended in the neighbourhood of a mountain, is sensibly attracted towards the mountain from the true vertical line. The mutual attraction of matter is exemplified by the diminution of the weight of bodies as we penetrate into the earth. At the depth of a mile, a body weighing a pound would be found to be lighter than at the surface. This is in consequence of the attraction of the matter of the shell of the earth, which is exterior to the point, being nothing, in consequence of the attractions of its particles on this point counteracting each other; hence the only efficient attraction on it arises merely from the smaller sphere below the point; and therefore the nearer the point is to the centre, the less is this internal sphere, and the less, therefore, is its attraction on the point. Were we to proceed to the centre of the earth, we should there find that weight altogether ceased, because the attractive power would be equal on all sides. Were there a cavity at the earth's centre, the body would hang suspended in space.

The attraction of the earth's mass performs an important function, in binding the atmosphere, which is an elastic fluid, around the surface of our planet, and in causing the air to perforate every open crevice and pore in the superficial substances of the globe. The attractive force, in this respect, produces what is called *atmospheric pressure*—the air being pulled or pressed down by a force equivalent to about 15 lbs. on the square inch, at the level of the sea, and diminishing in proportion to the distance above that level.

THE REPULSIVE QUALITY IN MATTER—HEAT.

While attraction tends to unite and compress the particles of matter, there is another and equally universal principle, known in familiar language by the appellation of *heat*, the tendency of which is to keep the particles of matter at a certain degree of expansion. Heat is often, in scientific works, named *caloric*, from the Latin word for heat. Heat pervades all things, but some in greater degrees than others: even ice has been found to contain a certain portion of it. In fact there is no such thing in nature as positive cold.

The absolute nature of this universal principle is unknown. We only know it by its effects, and the sensations it produces. Some have conjectured that it is a fluid; others think it is a quality or affection of matter, resulting from electrical action. From its producing no sensible difference in the weight of any substance, it has been called an *imponderable body*. Light, magnetism, and electricity are also termed *imponderables*. When the heat of any particular substance, as ice, stone, or wood, is not sensible to us, it is called *latent* (that is, concealed) heat. We may very readily detect its presence in a piece of wood or metal by rubbing or friction. If a metallic button, for instance, be rubbed on a table, it will soon become too hot to be held by the fingers.

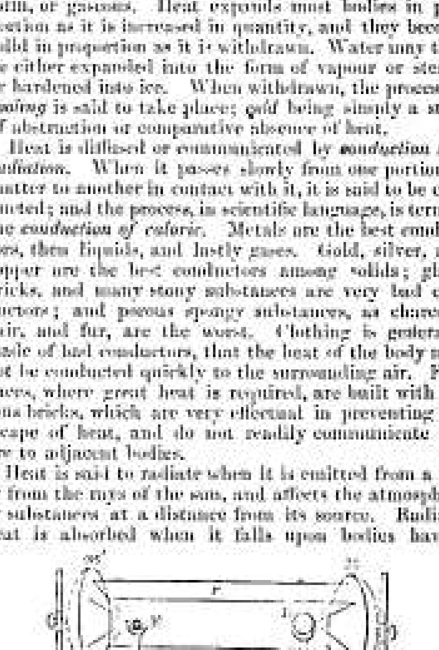
Heat, in its extreme form, becomes fire. Thus, if an ungreased wheel be rapidly turned for a long time on its axle, so much heat will be excited, that both wheel and axle will burst into a flame. The effects of powerful friction are known to savage nations, among whom it is common to produce fire by rubbing two sticks together. Two pieces of flint struck together, or a flint struck hard upon a piece of steel, evolve sparks of fire. By such means many important purposes are served; for instance, the discharge of firearms. Fire can also be evolved from the common atmosphere, by compressing a quantity of it suddenly in a tube, at the bottom of which a piece of tinder has been placed. The evolution of heat by these means, and other circumstances, lead to the conclusion that heat is an element mixed up with the atoms of matter, which it serves to keep at a lesser or greater distance from each other. Thus, as we squeeze the pores of a sponge together, and disengage the liquid which they held in cohesion, so, when compressing or rubbing a portion of matter, do we disengage the heat which it retained amongst its component molecules. In all cases of the development of heat by pressure, hammering, and friction, the cause is the squeezing together of particles which had been kept asunder by the latent fluid, and which fluid must, as a matter of necessity, come forth and make itself sensibly felt or seen.

Heat, then, is a principle of *repulsion* in nature, and in this capacity its uses are as obvious as those of terrestrial gravitation, to which it apparently acts as a counterpoise. The force of attraction is so powerful, that unless for a counteracting principle of repulsion, all bodies would hasten into close contact; there would be no air, no water, no vegetable or animal life; all would be a uniform dead solid mass, and the earth itself might perhaps be reduced to a small portion of its present bulk.

By pervading all things, heat modifies attraction, and, according to circumstances, regulates the density or solidity of bodies. Hence we possess in nature a beautiful variety of substances, some solid and hard, like stone and wood; others soft, or of the jelly form; a third class liquid, like water; and a fourth kind aëriform, or gaseous. Heat expands most bodies in proportion as it is increased in quantity, and they become solid in proportion as it is withdrawn. Water may thus be either expanded into the form of vapour or steam, or hardened into ice. When withdrawn, the process of *cooling* is said to take place; *cold* being simply a state of abstraction or comparative absence of heat.

Heat is diffused or communicated by *conduction* and *radiation*. When it passes slowly from one portion of matter to another in contact with it, it is said to be conducted; and the process, in scientific language, is termed the *conduction of caloric*. Metals are the best conductors, then liquids, and lastly gases. Gold, silver, and copper are the best conductors among solids; glass, bricks, and many stony substances are very bad conductors; and porous spongy substances, as charcoal, hair, and fur, are the worst. Clothing is generally made of bad conductors, that the heat of the body may not be conducted quickly to the surrounding air. Furnaces, where great heat is required, are built with porous bricks, which are very effectual in preventing the escape of heat, and do not readily communicate the fire to adjacent bodies.

Heat is said to radiate when it is emitted from a fire or from the rays of the sun, and affects the atmosphere or substances at a distance from its source. Radiant heat is absorbed when it falls upon bodies having



painted or rough surfaces, such as are presented by bricks and other porous solids, by many kinds of stony matter, and numerous animal and vegetable substances, and makes them warmer as it is taken up. But brilliant and polished metallic surfaces absorb little heat; they reflect or turn it back again. Thus if a red-hot iron ball (B) be placed in the focus of a concave metallic mirror (M), its radiant heat will pass from it to the mirror, and be reflected in parallel rays (*r r*). If these rays be intercepted by a second mirror (*m'*) placed at the distance of a few feet, they can be collected into a focus (F), and made to act upon a thermometer, ignite tinder, phosphorus, &c. In this manner it is possible to set fire to substances at a considerable distance from the source of heat.

As already mentioned, heat can be brought into action in most substances by percussion and rubbing. It is also produced by the burning of certain inflammable substances, as coal and wood; and in this manner its chief purposes in domestic economy are effected. But the most remarkable source of heat is the sun; though whether this luminary is a burning mass, throwing off warmth like a common fire or red-hot ball, or produces the effect by some peculiar and unknown operation, is as yet uncertain. Heat, besides being produced by the sun's rays, and by the friction and combustion of inanimate substances, is evolved by chemical action, a familiar example of which is observable in fermentation. It is by means of a natural chemical action in connection with the circulation of the blood, that heat is resident and sustained in most living animals. A stoppage of the circulation of the blood, as every one knows, leads to an absence of animal heat, or a very considerable degree of coldness. On the contrary, quick circulation of the blood, and active muscular motion, are productive of heat.

Heat is unequally distributed over the globe. At and near the equator, where the rays of the sun are sent in the greatest degree of directness, the greatest heat prevails. In the parts of the earth adjacent to the north and south poles, he transmits his rays so slantingly, as to have little power; and there, accordingly, the air is seldom of a genial mildness. The higher we ascend in the air, the colder it becomes; the summits of very high mountains are always covered with snow. In penetrating into the body of the earth, after gaining a certain depth, the heat becomes greater in proportion as we descend. The interior of the globe is thus by many believed to be at a very elevated temperature, if not in a state of ignition. On the surface, great expanses of sea tend to equalise and temper the degrees of heat and cold in their neighbourhood, and extensive continents have the contrary effect.

The degrees of heat and cold in the atmosphere are called its temperature; and for ascertaining this correctly, with reference to a standard, a very ingenious instrument has been invented. This is called the *thermometer* (a word signifying heat-measurer). It is a glass tube with a bulb at the bottom, into which mercury or quicksilver is put, with a scale of figures along the tube to mark the rising of the quicksilver. This instrument differs from the barometer, inasmuch as the quicksilver is sealed up close from the air. The atmospheric heat, however, affects the metallic fluid in the bulb, and, according to its warmth, causes it to expand and rise in the tube. (For further explanation, see METEOROLOGY.) Our common thermometer has a graduation from No. 1, near the bulb, to 212, the degree of heat of boiling water. In the scale of figures, 32 is marked as the freezing-point — that is to say, when the mercury is at the height of 32, *water freezes*; and the more it is below that point, the more intense is the frost: 55 is reckoned moderate heat, and 76 summer heat, in Great Britain: 98 is the heat of the blood in the average of living men.

The rising of mercury in the tube of the thermometer offers a familiar example of the repulsive power of heat in expanding or dilating bodies. Common experience affords many such examples. A bar of iron is longer and thicker when hot than when it is cold. The iron rim of a wheel slips easily into its place when hot, and gripes or binds fast when it becomes cool. When heated from 32 to 212, air expands 3-8ths of its volume, alcohol 1-9th, water 1-22d, and hammered iron 1-273d. In these, and all similar instances, the expansion arises from the heat lodged among the atoms of matter pressing outwards on all sides, according as it is excited.

When the temperature of the atmosphere falls below the freezing-point (32), which it does principally from the weakness of the sun's rays in winter, the phenomenon of frost, or freezing, ensues. Freezing is a process of congelation, or properly crystallisation, produced by the withdrawal of heat, and by which water assumes the form of ice. When the temperature of the atmosphere rises above the freezing-point, the ice melts, and is resolved into its original element. When the temperature of the atmosphere is below the freezing-point, the particles of water which are upheld in the clouds are frozen in their descent, and reach the earth in the form of flakes of snow. If this freezing take place after the particles have become united into rain-drops, we have hail instead of snow. When the descending flakes of snow come into a temperature above the freezing-point as they approach the earth, they are apt to melt, and in such a case fall in the shape of sleet, which is half-melted snow or hail.

Heat has a constant tendency to preserve an equilibrium in all situations; hence its diffusion through nature, and many of the ordinary phenomena in relation to temperature. When we touch a cold substance with our hand, a portion of the heat of the hand rushes into the substance, and leaves the hand so much deficient of its former heat. On the same principle, when we touch a substance which is warmer than the hand, some of the heat rushes into the hand, and renders it hot. When we pour a quantity of hot water into that which is cold, an equalisation of the two temperatures immediately ensues. When the air at any particular place becomes heated or rarefied, it ascends by virtue of its greater lightness, leaving a vacancy, which the neighbouring air rushes in to supply. This is one of the chief causes of winds. The same principle is observable in the case of heated apartments. If the door of a heated room be thrown open, a current of cold air immediately rushes in to supply the deficiency in the rarefied atmosphere.

Evaporation is always accompanied by the withdrawal of heat, or production of cold, when no heat is directly applied; the heat necessary for the production of the vapour is then derived from surrounding objects, as in the case of dew forming on plants.

In the great operations of nature, the withdrawal of heat to produce intense cold, and the application of heat to produce great warmth, ordinarily take place gradually. Thus, although water freezes at a temperature of 32, it is some time before frost is completely effectual in changing the aspect and condition of liquid bodies; and when the temperature rises a few degrees above 32, after a frost, the ice and snow which have been formed do not vanish immediately; indeed ice will remain unthawed for several days after the temperature has risen some degrees above the freezing-point. By this slow process, either in the absorption or evolution of heat, animal and vegetable structures are not liable to the injury which would ensue from instantaneous changes in the condition of their component or elementary fluids.

Water is increased in volume by freezing, which circumstance explains the ordinary phenomena of the bursting of water-pipes, and other similar occurrences, during frost. When a vessel of moderate strength is filled with water, its expansion, when it is converted into ice, by exposure to a freezing temperature, causes the vessel to burst. If the vessel is not brittle, but possessed of considerable tenacity, as a leaden water-pipe, the rupture will seldom be observed during the continuance of the frost while the water remains in a solid state, but it readily appears when thaw takes place, as the water is then forced out with a velocity corresponding to the vertical height of the column of water in the pipe. The fissures of rocks, too, are widened by the freezing of the water which may happen to lodge in them before frost; and this process, therefore, is a powerful agent in the disintegration of rocks. Portions of steep banks, also, from a similar cause, tumble down after thaw; for the moisture in them expands when frozen, and thus rends them to pieces, which, however, during the frost, are bound together as by cement, and fall down whenever thaw dissolves the moisture.

Heat has a powerful effect in causing certain bodies to shrink and diminish in volume. This happens with those substances which do not liquefy, such as wood and clay. The contraction arises from the heat carrying off the watery particles from the bodies, and thus allowing the constituent atoms to come more closely together. As wood becomes drier, its fibres are sometimes split asunder, so as to emit loud cracking noises, which, in the case of household furniture, are ascribed by the ignorant to supernatural causes.

Heat is further treated of under the articles METEOROLOGY, PNEUMATICS, and CHEMISTRY.

ACCIDENTAL PROPERTIES OF MATTER.

While the beautiful and extensive variety of form in bodies—solid, liquid, gaseous, and the different modifications of them—are to be traced to the operation of chiefly two great leading principles in nature—attraction and repulsion; the peculiar forms or characters which bodies assume from the influence of these and other causes, are usually classed under the term *accidental properties of matter*. The following are these properties:—Density, Porosity or Rarity, Compressibility, Elasticity, Dilatation, Hardness, Brittleness, Malleability, Ductility, and Tenacity.

Density signifies closeness of texture, or compactness. Bodies are more dense when in the solid state, less dense when in the condition of liquids, and least dense of all when gaseous or aëriform. In this manner the degree of density is in agreement with the closeness of the atoms to each other. The density of bodies may generally be altered by artificial means, as is afterwards mentioned. The metals, in particular, may have the quality of density increased by hammering, by which their constituent particles are brought nearer to each other. The denser in substance that a body is, it is the more heavy or weighty. In speaking of the density of different solid and liquid bodies, the term *specific gravity* is used to denote the comparison which is made. Thus the specific gravity of a lump of lead is greater than an equal bulk of cork; or the specific gravity of water is greater than that of an equal quantity of spirituous fluid. For the sake of convenience, pure distilled water, at a temperature of 62°, has been established as a standard by which to compare the specific gravity or relative weights of bodies. Water, as the standard, is thus said to be 1. When, therefore, any body, bulk for bulk, is double the specific gravity of water, it is called 2, and so on to 3 and 4 times, up to 22 times, which is the specific gravity of platinum, the heaviest known substance. Common air is sometimes taken as a standard with which to compare gases, being a more simple mode of comparing the relative weights of aërial substances. But all the solids and liquids are estimated with reference to water as the standard. The following table exhibits the specific weights of a few of the more familiar substances:—

Platinum, coined,	22·100	Porcelain, china,	2·384
... wire,	19·267	Sulphur, natural,	2·033
Gold, coined,	19·325	Ivory,	1·917
Mercury,	13·568	Boxwood,	1·330
Lead,	11·352	Oak, old,	1·170
Silver,	10·474	Amber,	1·078
Copper, hammered,	8·878	Mahogany,	1·063
... fused,	7·788	Milk,	1·030
Steel,	7·816	Sea-water,	1·026
Iron, wrought,	7·788	Water, distilled,	1·
... cast,	7·207	Claret,	·994
Tin,	7·291	Alcohol, absolute,	·792
Antimony,	6·712	Linseed oil,	·953
Diamond,	3·520	Ash-wood, dry,	·845
Flint Glass,	3·329	Beech,	·852
Marble,	2·837	Cork,	·240

Any body of greater specific gravity than water, will sink on being thrown into water; but it will float on the surface if its specific gravity be less than that of water. A body, such as a piece of wood, after floating a certain length of time on water, will imbibe such a quantity of liquid, that its specific gravity will be gradually increased, and in the course of time it may sink to the bottom.

Porosity is the quality opposite to density, and means that the substance to which it is applied is porous; that is, full of small pores or empty spaces between the particles, and that the body is comparatively light. The instances of porosity are numerous in every department of the material world, but those which are connected with animal and vegetable bodies are the most remarkable. Bone is a tissue of pores or cells, and, when seen through a microscope, may be said to resemble a honeycomb. Wood is also a tissue of cells or tubes. If the end of a cylinder of straight wood be immersed in water, whilst the other is forcibly blown into, the air will be found to pass through the pores of the wood, and rise in bubbles through the water. When a gas is comparatively light, it is said to be *rare*, or to possess *rarity*.

By *compressibility* is meant that quality in virtue of which a body allows its volume to be diminished, without the quantity or mass of matter being diminished. It arises of course from the constituent particles being brought nearer to each other, and is effected in various ways. All bodies are less or more capable of being diminished in bulk, which is a conclusive proof of their porosity. Liquids are less easily compressed than solid bodies; nevertheless they, to a small extent, yield, and go into smaller bulk by great pressure. The water at the bottom of the sea, by being pressed down by the superincumbent water, is more dense or compact than it would be at the surface. Atmospheric air and gases are much more easily compressed than liquids, or even than many solids. Air may be compressed into a hundredth part of its ordinary volume. When at this state of compression, it has a great tendency to expand and burst the vessel in which it is confined.

Some bodies have the power of resuming their former volume or shape when the force which diminished it is withdrawn. This quality is termed *elasticity*. Steel is one of the most elastic of metallic bodies, but its elasticity is not nearly so great as that of India-rubber, which, though twisted, drawn out, or compressed in different ways, always resumes its original form. The aëriform fluids—atmospheric air and the gases—are all exceedingly elastic; and so are liquids, such as water, but to a smaller extent.

Dilatability is that quality of bodies by which they are enabled to be expanded or enlarged in their dimensions, without any addition being made to their substance. *Hardness* is the quality which is the opposite of softness, and does not depend so much on the density of the substance, as the force with which the particles of a body cohere, or keep their places. For instance, glass is less dense than most of the metals, but it is so hard, that it is capable of scratching them. Some of the metals can be made either hard or soft: steel, when heated to a white heat, and then suddenly cooled, as by immersion in water, becomes harder than glass; and when cooled slowly, it becomes soft and flexible. *Brittleness* is that quality by which bodies are capable of being easily broken into irregular fragments, and it belongs chiefly to hard bodies. Iron, steel, brass, and copper, when heated, and suddenly cooled, become brittle. *Malleability* is the quality by which bodies admit of being extended by hammering. Some of the malleable metals are gold, silver, copper, zinc at the temperature of boiling water, lead, iron, and some others. Several of the metals possess the opposite quality of brittleness. Gold is the most malleable of all metals, and it may be hammered so thin, as to be translucent, or permeable to light. By *ductility* is understood that property by which metals may be drawn to wire. The most malleable metals are not the most ductile. Tin and lead may be rolled into thin leaves, but cannot be drawn into wire. The most ductile metal is platina, which can be drawn into wire as fine as the threads of a cobweb. *Tenacity* is the quality by which bodies are not easily torn asunder. Steel is the most tenacious of all substances: a wire of this metal, one hundredth of an inch in diameter, will support a weight of 134 lbs.; while one of the same size of platina will sustain only 16, and one of lead only 2 lbs.

II. MOTION AND FORCES.

Motion is the change of place; that is, of the part of space which the body occupies.

Matter, according to the definitions given of its properties, is perfectly passive, or inert. It has been described as possessing the property of inertia, and in this respect it is said to possess an unwillingness or reluctance to move; but these phrases are only figurative, and are used for the purpose of conveying a forcible idea of the passiveness of its character. It is also, in consequence of this property of inertia, or passiveness to submit to any condition to which it is subjected, that a body, when once in motion, will continue to move continually with the same velocity, and in the same direction, till it be disturbed by some external cause.

Any instance of rest which comes under our observation, is only rest in a *relative*, not an *absolute* sense; that is, it is rest as relates to the earth, but not rest as relates to the universe; for though the stone which falls to the ground lies at rest on the earth, the earth is always in motion, and therefore the stone is no more at rest than the insect which sits upon a moving wheel is at rest. Hence, in speaking of bodies coming apparently to a state of rest, we must always recollect that it is only relative, not positive or absolute rest. It is supposed that there is no such thing as absolute rest in creation. All the planets are in motion round the sun; and the sun itself has a motion on its own axis: it is also believed by many astronomers that the sun has an onward or progressive motion in space, besides its rotatory movement; and thus, perhaps, revolves round some distant centre, with all its planets in its train.

Common experience would lead to the conviction that rest is more natural for matter than motion; but this conviction is founded on a limited consideration of circumstances. The reason why we see ordinary moving bodies coming to a state of rest — such as a wheel stopping after having been whirled on its axle, a ball stopping after rolling on the ground, or an object falling to the earth after being thrown upwards—is, that they are sooner or later arrested in their progress by the earth's attraction or their own gravity, by the friction or rubbing against some other body, or by the opposition presented to them by the atmosphere. Except for these three prevailing causes of impediment and stoppage, all bodies, once set in motion, would go on moving for ever. Taking this expanded view of things, and dismissing the erroneous impressions arising from what is obvious only to our limited experience, we find that there is nothing more remarkable in perpetual motion than in perpetual rest.

It is only, however, in the great works of creation, or the heavenly bodies, that perpetual motion is observable. The planetary bodies are under the ever-acting impulses of centrifugal and centripetal forces, and are not impeded by friction, or by the atmosphere, for they move in space, or in a comparative vacuum. Many ingenious attempts have been made to produce perpetual motion on mechanical principles in terrestrial objects, but they have all necessarily failed, as no human effort can destroy gravity in bodies, or altogether prevent friction in movement.

In regard to bodies on the earth, of which a state of rest is the ordinary condition, motion is produced by certain agencies, or impelling causes, either belonging to the phenomena of nature, or to art. The property of capillary attraction causes a motion in liquids under certain circumstances; the winds blow, and cause motion; rivers, in flowing down their channels, and the action of the tides, likewise produce motion; thus there exist many natural causes of motion, which are taken advantage of by man in the economy of arts and manufactures. Motion in the animal economy is produced by a principle of life; but of the nature of this principle mankind are ignorant, and nothing here requires to be said regarding it. The causes of motion about to engage our attention are those which consist of *forces*, whether natural or artificial; and which forces have the property of impelling inanimate objects from a state of rest to a state of motion, of stopping them when in motion, or of altering the character of that motion. These forces are also called *powers*.

Motion, according to the mode in which the force acts, is susceptible of innumerable variations. As the moving body is affected, so may it move rapidly or slowly, proceed in a straight line, turn in a circle or curve; it may move with uniform or irregular speed, or be retarded or accelerated. The body may also move upon, or in respect of, another body which is also moving. Some of these peculiarities in motion will immediately engage our attention; meanwhile, it has to be explained, that, for the sake of convenience in language, and accuracy in the application of terms, certain words are used to define the nature of motion in bodies, and the forces affecting them.

Motion is said to be *common* to two or more bodies when they move in contact, or together; or when, though not in contact, they are carried along in a similar manner, and with the same velocity; that is, when they have a motion in common, or participate in the same motion. Motion is said to be *absolute*, when a body actually moves from one point of space to another, or when it proceeds towards, or when it passes, another which is at rest. Therefore setting aside the idea of the earth's revolution and rotation, we should say that a vessel moving on the sea has an absolute motion, while the land is fixed or stationary. Motion is said to be *relative*, when the motion of one moving body is considered in reference to that of another moving body. Thus if two bodies move in the same direction, their relative motion is the difference of their motions; if they move in opposite directions, it is the sum of their separate motions.

When a force, applied to any material object, is resisted or counteracted, so that no motion ensues, it is called a *pressure*; and forces so counteracted are said to *balance* each other, or to be in *equilibrium*.

The degree of speed in the motion of bodies is called *velocity*. Velocity is measured by the space or distance passed over, with an invariable motion, and in a given time, as one second. Thus if a body, in one second, with an invariable motion, pass over twenty feet, its velocity is said to be twenty feet per second.

When a motion is invariable, it is said to be *uniform*; if it be gradually increasing, it is said to be *accelerated*; and if it gradually decrease, it is said to be *retarded*. A force is said to be *accelerating* or *retarding*, according as it produces an accelerated or retarded motion.

Forces are either *instantaneous* or *continued*. The former is an impulse, like a stroke; the latter acts without intermission. When a continued force remains always of the same intensity, it is called a *constant* force. Other continued forces are said to be *variable*.

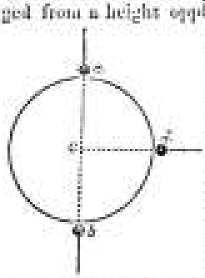
A body, in moving, possesses a force which is called its *momentum* or *moving force*. Momentum is very different from velocity. A light body and a heavy body may move at the same velocity, but the momentum of the light body will be small in comparison with that of the heavy one. The light one, on coming to a state of rest, will perhaps fall harmlessly on the ground, while the other, by its momentum, will strike *forcibly* on the earth, or destroy any object which opposes it. Momentum is proportionate to the mass and velocity of bodies, and by multiplying the weight by the number of feet moved over per second, we find that the momentum is the product. Thus if a body of twelve ounces move with a velocity of twenty feet per second, its momentum is (twelve times twenty) two hundred and forty. In ordinary language, the term *impetus* is used to signify the violent tendency of a moving body to any point.

Before entering upon a consideration of motion as produced by ordinary forces, it will be appropriate to describe the effects produced upon bodies when simply falling—that is, moving downwards towards the earth, when the supports which upheld them are withdrawn.

PHENOMENA OF FALLING BODIES—WEIGHT.

Attraction, as already explained, is a force inherent in nature, by which particles and masses of matter are drawn towards each other. This force, it has also been stated, increases in proportion to the quantity of matter which the attracting body contains, and it also increases as the bodies approach each other. Further, it has been mentioned that this powerful and subtile quality in matter is the cause of the falling or drawing of bodies downwards towards the earth, and thus produces what is termed *weight* or *gravity*. Gravity, then, is simply the tendency which any substance has to press downwards in obedience to the law of attraction, as exemplified in the phenomena of bodies falling from heights to the ground, when the supports which upheld them are removed.

All falling bodies tend directly towards the centre of the earth (*c*) in a straight line from the point where they are let fall. If, then, a body be let fall in any part of the world, the line of its direction will be perpendicular to the earth's centre. Consequently, two bodies (*a b*) falling on opposite sides of the earth, fall towards each other. Suppose any body to be disengaged from a height opposite to us, on the other side of the earth, its motion in respect to us would be upward, while the downward motion from where we stand would be upward in respect to those who stand opposite to us, on the other side of the earth. In like manner, if the falling body (*d*) be a quarter, instead of half the distance round the earth from us, its line of direction would be directly across or sidewise—that is, at right angles with the lines already supposed.



It will be obvious, therefore, that what we call *up* and *down* are merely relative terms, and that what is down in respect to us, is up in respect to those who live on the opposite side of the globe. Consequently, *down* everywhere means towards the centre of the earth, and *up* signifies from the centre of the earth. The velocity or rapidity of every falling body is uniformly accelerated or increased in its approach towards the earth, from whatever height it falls, if the resistance of the atmosphere be not reckoned. If a rock be rolled from the summit of a steep mountain, its motion is at first slow and gentle; but as it proceeds downwards, it moves with perpetually-increased velocity, seeming to gather fresh speed every moment, until its force is such that every obstacle is overcome; trees and rocks are dashed from its path, and its motion does not cease until it has rolled to a great distance on the plain.

The same principle of increased velocity in bodies as they descend from a height, is illustrated by pouring treacle, honey, or any thick sirup from an elevated vessel. The bulky stream, which is perhaps two inches in diameter where it leaves the vessel, is reduced to the size of a straw or thread on reaching its destination; but what it wants in bulk is made up in velocity, for the small thread-like stream at the bottom will fill a vessel just as soon as the large and slow-moving stream at the outlet; the velocity is indeed so great, that the stream has not time to sink at once into the mass below, but falls in overlaying folds. From the same principle, a person may leap from a chair without danger; but if he jump from the house-top, his velocity becomes so much increased before he reaches the ground, as to endanger his life by the fall.

It is found by experiment, that the motion of a falling body is increased, or accelerated, in regular arithmetical progression. In other words, in every second of time during its descent, it acquires an additional rate of speed, the rate regularly increasing by the accumulation of the preceding additions. A dense or compact body, when falling freely, passes through a space of 16 feet 1 inch during the first second of time. Leaving out the odd inch for the sake of even numbers, we find that the space fallen through in a given time is determined by the following arithmetical computation:—Ascertain the number of seconds which a body occupies in falling. Take the square of that number (that is, the number multiplied by itself), and multiply the square by 16, which is the number of feet fallen during the first second, and the result is the amount of feet which the body altogether falls. For example, if a ball occupy 3 seconds in falling, we take the square of 3, which is 9; then we multiply 9 by 16, which gives 144 as the result, and that is the number of feet fallen. Again, if we find that the ball occupies 4 seconds in falling, we take the square of 4, which is 16, and multiplying 16 by 16, the result is 256, which is the number of feet fallen. And so on in every other case.

It is not always easy, by the above mode of calculation, to arrive at a correct result as to the height fallen by bodies, and all that can be expected is an approximation to a true result. This arises from bodies being of different bulks, and receiving different degrees of opposition from the atmosphere in their descent. It is a common supposition that large and heavy bodies fall more quickly than small and light ones. This opinion, which was maintained even by philosophers, until Galileo rectified the mistake, perhaps originates in the error of confounding *momentum* with *velocity*. Be this as it may, it is now an established truth in science, that all bodies, of whatever density, fall with the same velocity. Thus a ball containing a pound of lead falls with the same velocity as a ball containing an ounce. This equality in the rate of falling is, however, disturbed by the quality of figure and bulk of bodies. A solid ball of gold will fall more quickly than the same quantity of gold beat out into a thin leaf, because, in the case of the leaf, the resistance from the atmosphere on a large surface impedes the descent. Thus bulky and porous substances are prevented from falling with the same velocity as those which are compact.

If the atmosphere were removed, all bodies, whether light or heavy, large or small, would descend with the same velocity. This fact is ascertained by experiments performed with the air-pump. When a piece of coin, for instance a guinea, and a feather, are let fall at the same instant of time, from a hook which has held them at the top of the exhausted receiver of an air-pump, they are observed to fall at an equal rate, and to strike the bottom at the same moment. Hence it is demonstrated, that were it not for the resistance of the atmosphere, a bag full of feathers, and one of coins, would fall from a given height with the same velocity, and in the same space of time.

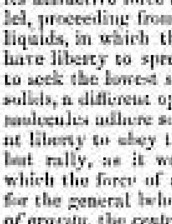
It has been stated that the attraction of gravitation increases in proportion to the quantity of matter which the attracting body contains. Thus the mass of our planet, the earth, exerts a force of attraction which produces the phenomena of weight, and the falling of bodies with a certain velocity. In consequence of the different size and density of the sun and planetary bodies, attraction is much stronger in some of them than others, and consequently the weight of bodies differs in each. On the surface of the sun, our pound would weigh upwards of 27 pounds, and a body would fall upon it 434 feet the first second; on the surface of Jupiter, our pound would weigh about 2 pounds 4 ounces; and on the moon, it would weigh only the fifth part of a pound.

As a body, in descending to the earth, receives increasing accessions to its velocity during every successive second, so when a body is projected upwards from the surface of the earth, its velocity decreases in the same proportion, till it comes to a state of momentary rest, when it instantly begins to descend with a gradually-increasing velocity, which at any point in the descent is equal to its velocity at the same point when ascending. In this calculation, however, we omit the influence of the atmosphere, which would cause the final velocity in the descent to be less than the original velocity with which the body was projected upwards.

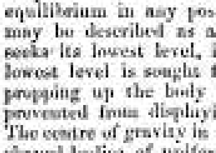
THE CENTRE OF GRAVITY.

Terrestrial gravitation, as already explained, does not act on the mere surface of bodies, or according to their bulk, but is exerted in reference to all the particles or atoms individually which compose the mass of a body. As the earth is nearly of a spherical form, its attraction is the same nearly as if it proceeded entirely from the centre. On account of the great size of the earth, compared with that of any ordinary body at its surface, its attractive force acts in straight lines, sensibly parallel, proceeding from the earth's centre. In the case of liquids, in which the atoms slightly cohere, the atoms have liberty to spread themselves over the earth, and to seek the lowest situation for repose. In the case of solids, a different operation is observable. In them the molecules adhere so closely together, that they are not at liberty to obey the law of gravitation individually, but rally, as it were, round a common centre, upon which the force of attraction may be considered to act for the general behoof. This centre is called the *centre of gravity*, the *centre of inertia*, or the *centre of parallel forces*.

Every solid body or dense mass possesses a centre of gravity, which is the point upon or about which the body balances itself, and remains in a state of rest or equilibrium in any position. The centre of gravity may be described as a point in solids which always seeks its lowest level, in the same manner that the lowest level is sought for by water; for it is only by propping up the body that the centre of gravity is prevented from displaying the same mode of action. The centre of gravity in round, square, or other regular-shaped bodies, of uniform density in all their parts, is the centre of these bodies. When a body is shaped irregularly, or when there are two or more bodies connected, the centre of gravity is the point about which they will balance each other.



Any square or angular body which we may place on the ground will remain stationary, or safely at rest, provided an ideal line, drawn from its centre of gravity, and passing to the ground in a direction perpendicular to the earth's surface, fall within its base, as in the annexed fig. A point below A is the centre of gravity; and from that point the line of direction goes downward to B, which is within the edges of the base. An object of this form, and so placed, will stand. If the line of direction from the centre of gravity fall without the outer edge of the base, as from A to B, in the next fig., then the object will not remain balanced on its base; it will fall over, and attain some position in which the line of direction falls within the boundary of the base on which it stands. By keeping this simple principle in view, stability and safety will generally be secured in the erection of objects of art, such as houses, monumental edifices, spires, and obelisks, as well as in the lading of coaches, carts, and other vehicles, and the piling of timber or any kind of goods in heaps. In every instance, the base ought to be sufficiently broad to admit of the line of direction from the centre of gravity falling within it.



A small amount of experience seems to point out the propriety of erecting all kinds of structures with a base wide enough to secure stability; nevertheless, in opposition both to experience and the simple principles of science, we often find that stage-coaches are laden in such a manner, that their centre of gravity is liable to too great a change of position, and that they are overturned, to the personal injury, and even loss of life, of the passengers. The error in these instances consists in raising the centre of gravity too high. At first, perhaps, the centre of gravity is so comparatively low, that, in the case of swaying to a side, the line of direction would fall within the edge of the wheel, and no danger would ensue; but it is common to go on piling masses of goods or luggage, or placing a number of passengers, on the roof of the vehicle, so that the centre of gravity becomes considerably elevated; so high, indeed, that when the carriage is swayed, or jolts to one side, the line of direction is thrown beyond the wheel, and the vehicle will consequently fall over. In the annexed cut, a loaded vehicle is represented crossing an inclined plane, or we may suppose that its wheel on one side has come in contact with a stone S, which has raised it above the level of the other wheel, so as to incline the body of the vehicle very considerably from the horizontal. The centre of gravity is represented in two different positions—a lower, with the line of direction L C; and a higher, with the line of direction U C. Had the vehicle not been high laden, the line of direction would have remained as L C, and as it falls within the wheel or base, the vehicle would have maintained its balance; but being now laden to a considerable height, the line has risen to about the place where it is marked descending from C to U, beyond the base; consequently the vehicle must overturn.

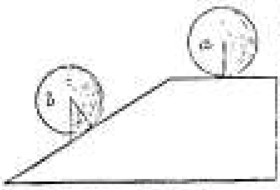
There are instances in which bodies will not be overturned, although the line of direction falls considerably beyond the base. These exceptions to a common rule are observable in the case of rapidly and smoothly moving bodies, in which centrifugal force acts as a counterpoise to the weight of the body. A familiar example of this kind occurs in the case of skaters, in making their circular turns on the ice, in which they bend, or lean greatly, beyond the perpendicular without falling. This peculiarity in moving bodies will engage our attention under the head Centrifugal Force. The tendency which leaning bodies have to fall, may also be counteracted in some measure by the cohesion of parts. Thus there are many instances of walls, steeples, and towers inclining sensibly from the vertical line, and yet, by the strength of the cement which binds them, they have stood for ages.

Whatever raises the centre of gravity, or narrows the base, allows the line of direction to pass more easily without it, and diminishes the stability. Hence the imprudence of rising up in carriages or boats, when in danger of being upset; and hence, as we have just mentioned, the danger of high-loading of vehicles. Lately, an improvement has been effected in stage-coach building, by which a chief part of the load is placed as low as the axle of the wheels; and by this means the danger of overturning is almost entirely averted.

The centre of gravity of a body is not always in the substance of the body. Thus the centre of gravity of a circular ring is in the centre of the circle; of an elliptic or oval ring, in the centre of the ellipse; and of a hollow cylindric tube, it is in the imaginary axis of the tube.

In a drum, for instance, the centre of gravity is a point in the centre of the drum, where there is nothing but air.

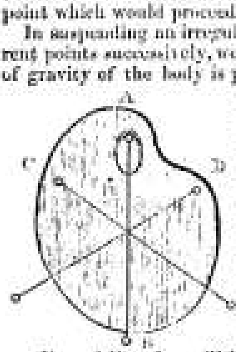
When a circular object (*a*) is placed on level ground, or a horizontal plane, it remains at rest on a point of its surface, because the line of direction from its centre, which is its centre of gravity, falls perpendicularly to the point on which it is in contact with the earth and at rest; and because it could not possibly get its centre of gravity nearer the earth by changing its position. When a similar circular object (*b*) is placed on an inclined plane, it will not remain at rest, but roll over, because the line of direction from its centre of gravity falls perpendicularly downwards in front of the point on its surface which touches the plane. On this account it rolls over, as if it were seeking a spot on which it might have the line of direction from its centre of gravity passing through its point of contact with the earth. Hence a circular body continues rolling down an inclined plane till it find a level spot on which the line of direction passes through its point of rest.



In a bar of iron six feet long, and of equal breadth and thickness, the centre of gravity is just three feet from each end, or exactly in the middle. If the bar be supported at this point, it will balance itself, because there are equal weights on both ends. This point, therefore, is the centre of gravity. If a bar of iron be loaded at one end with a ball of a certain weight, then the centre of gravity will not be at the middle, but situated near the heavy end of the bar. But if we attach a ball of the same weight to both ends, the centre of gravity is again in the middle of the bar.

A remarkable illustration of the principles now detailed is exhibited in the case of the earth and moon. The earth revolves round the sun in consequence of a cause already explained—namely, the sun's attraction; but instead of the centre of the earth describing the oval or elliptic orbit round the sun, it is the centre of gravity of the earth and moon that describes it. We shall briefly explain the reason for this. The earth, in its course, is encumbered with the moon, a body of about the seventieth of its mass; in other words, the moon is like a small ball stuck at one end of a bar, having the earth or a larger ball at the other end—the bar between being the mutual attraction of the earth and moon. On this account, the centre of gravity of the earth and moon is at a point somewhere between the centres of the earth and moon. This point lies not far below the earth's surface. Therefore, if the earth were to fall towards the sun, it would be this point which would proceed most directly towards it.

In suspending an irregularly-shaped body from different points successively, we may learn where the centre of gravity of the body is placed, by observing that the line of direction in each case passes through the same point, which point is the centre of gravity. For example, let a painter's palette, which is an irregularly-shaped body, be suspended from the thumb-hole, as in the annexed cut, and the line of direction will necessarily be from A to B. Next suspend it from a point at D, and a new line of direction will be obtained, crossing the line A B. The place where the two lines intersect is thus the centre of gravity. The point of suspension, on being removed to C, will give the same place of intersection in the original line of direction; and so on with every other point of suspension.

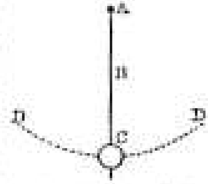


In the various natural structures displayed in the animal and vegetable kingdoms, the centre of gravity is always so situated, as to produce a just equilibrium and a harmony of parts. Every animal is properly balanced on its limbs, and every tree has a tendency to grow in a direction perpendicular to its base, whether it grow from a level or an inclined plane. Some animals are enabled to move in opposition to the law of gravity, as, for instance, flies creeping on the ceiling of a room; but in such cases, other powers in nature are exerted to preserve their secure footing.

THE PENDULUM.

Gravity, which causes bodies to fall, also causes them to swing backwards and forwards, when suspended freely by a string or rod from a point, and when once moved to a side, to give them an occasion of falling. A body suspended in this manner is called a *Pendulum*.

Pendulums usually consist of a rod or wire of metal, at the lower end of which a heavy piece or ball of brass or other metal is attached. When a pendulum swings, it is said to oscillate or vibrate; and the path which its ball pursues in swinging, from its resemblance in figure to an inverted arch or bow, is called its arc. In the accompanying cut, a pendulum of the most common construction is represented. A is the axis or point of suspension. B is the rod. C is the ball, or a round flattish piece of metal, which is fastened to the rod by a screw behind, and by which screw it can be raised or lowered on the rod. D D is the path or arc which the ball traverses in swinging. When the pendulum is at rest, it hangs perpendicularly, as here represented, and the place which the ball is seen to occupy is called the point of rest.



The pendulum remains at rest till its ball is drawn aside to allow it an opportunity of swinging on its axis. Being raised to any height on one side, and set at liberty, the ball, by the force of gravity, has a tendency to fall to the ground; but being confined by the suspending rod, it is compelled to make a sweep to that point where it was formerly hanging at rest, immediately beneath the point of suspension. But it does not stop here; it has acquired a velocity sufficient to carry it onward in an ascending course to nearly as high a point on the opposite side as that from which it was let fall. Of its own accord, it again falls downwards in the same arc, and rises to near the point where it set off; and thus, of itself, continues to vibrate for a certain length of time, till its force is expended, and it finally comes to a state of rest in its original situation under the point of suspension.

At every sweep of the pendulum (when not meddled with, or assisted by any external force), the length of the path or arc traversed by the ball is in a small degree diminished. This arises from two causes—the obstruction offered by the atmosphere, and the friction on its axis or point of suspension. These causes, therefore, sooner or later, bring the pendulum to a state of rest, unless external force of some kind continues to be applied to urge it to sustain its action.

The ball of a pendulum in swinging, as has been mentioned, describes the figure of an arc. This arc is a certain portion of a circle. The extent of this portion depends on the force exerted in setting the pendulum in motion, or in drawing it aside to let it fall. A circle being divided by mathematicians into 360 degrees or parts, the ball may be made to swing over five, ten, twenty, or any other number of degrees under 180, which is half a circle. The extent of the arc traversed is usually from ten to twenty degrees.

A pendulum with a long rod vibrates slower than one with a short rod. The time does not become longer, however, in exact proportion as we extend the rod. The vibration, it must always be recollected, is analogous to the falling of bodies. The spaces fallen through by a body in 1, 2, 3, or 4 seconds, are not in proportion to 1, 2, 3, 4, and so on, but in the proportion of 1, 4, 9, 16, 25, and so on, or the squares of the time occupied in falling. In the case of pendulums, it is found that their lengths are as the squares of the times of vibration. Thus if the times occupied by one vibration of two pendulums be 1 and 2 seconds respectively, the lengths of the pendulums will be as 1 and 4; so if the time of one vibration of several pendulums be as 1, 2, 3, 4, their lengths are as 1, 4, 9, and 16.

The vibrations of the pendulum being produced by terrestrial gravitation, it follows, as a natural result, that if the force of gravitation be weakened, so will the tendency of the ball of the pendulum to fall or swing be weakened. This result is distinctly observable in different parts of the earth. At the equator, the earth, as formerly mentioned, bulges out to a thickness of about 26 miles on the diameter, or 13 miles from the surface to the centre; and as the attraction of gravitation proceeds from the centre, the force of this attraction is consequently weaker at the surface at the equator than it is at the surface at the poles. At every part of the surface between the equator and poles, there is a proportionate increase of gravity. Besides the effect produced by the greater distance of the surface from the centre at the equator, centrifugal force, which is strongest at the equator, assists in weakening the attractive force at that place. In consequence of these combined causes, a pendulum of a given length vibrates more slowly at the equator than at the poles. In proportion as we advance on the surface of the earth from the equator towards the poles, so does the pendulum swing or vibrate more quickly. To preserve uniformity of speed, therefore, in pendulums at different parts of the globe—that is, to make them all vibrate in one second—their length must be regulated according to the distance of the places from the equator. Thus each degree of latitude has its own length of pendulum.

From a knowledge of these laws, we are enabled, by this instrument, not only to detect certain variations in that attraction in various parts of the earth, but also to discover the actual amount of the attraction at any given place. To compare the force of gravity in different parts of the earth, it is only necessary to swing the same pendulum in the places under consideration, and to observe the rapidity of its vibrations. The proportion of the force of gravity in the several places will be that of the squares of the velocity of the vibration. Observations to this effect have been made at several places by Biot, Kater, Sabine, and others.

The uniform vibration of the pendulum has rendered it useful in regulating the motion of clocks for measuring time. In the common clock, a pendulum, connected with the wheelwork, and impelled by weights, or a spring, regulates the motions of the minute and hour hands on the dial-plate, by which the time of day is pointed out. If no pendulum were employed, the wheels would go very irregularly. The pendulum is regulated in length, so as to vibrate sixty times, each time being a second, in the space of a minute. At each vibration, it acts upon the tooth of a wheel, which turns the rest of the machinery. In order that the pendulum may vibrate neither quicker nor slower than sixty times in a minute, in the latitude of London it must measure 39 inches and about the 7th of an inch from the point of suspension to the centre of oscillation. A pendulum at Edinburgh would require to be a small degree longer. The greatest nicety is required in the adjustment of the length, for a difference amounting to the 1000th part of an inch, would cause an error of about one second in a day. Therefore, to make a pendulum go slower by one second a day, it must be lengthened by the 1000th part of an inch; and to make it go quicker, it must be shortened in the same proportion. It is possible to cause short pendulums to regulate the movement of clocks the same as long pendulums; and this is done in cases where long pendulums would be inconvenient, or inelegant in appearance. This is accomplished by shortening the pendulum to a fourth of its ordinary length, by which it beats or vibrates twice instead of once in a second.

The pendulums of clocks being made of a rod of metal, they are liable to be extended by the heat of summer, and shortened by the cold of winter; and by this means the uniformity of their motion is destroyed. Various contrivances have been adopted in order to compensate this effect on the motion of the clock, and pendulums constructed for this purpose are called *compensation* pendulums. The parts of the rods of these pendulums are so constructed and arranged, that when one of them expands downwards, another at the same time expands upwards, by which any variation from temperature is counteracted on the whole. See No. 16.

LAWS OF MOTION.

Motion, as already mentioned, is the changing of place, or the opposite of rest. According to the general explanations which have been given, it appears that motion in bodies is as natural as rest, and that matter passively submits to remain in either of these states in which it may be placed, provided no external force or obstacle interfere to cause an alteration of condition. These and other fundamental laws of nature, in relation to rest and motion of matter, are laid down by Sir Isaac Newton in the following three propositions:—

1*st*, Every body must persevere in its state of rest, or of uniform motion in a straight line, unless it be compelled to change that state by forces impressed upon it.

2*d*, Every change of motion must be proportional to the impressed force, and must be in the direction of that straight line in which the force is impressed.

3*d*, Action must always be equal and contrary to reaction; or the actions of two bodies upon each other must be equal, and their directions must be opposite.

In the first of these laws, there are three points requiring consideration—namely, the permanency, the uniformity, and the straight line of direction of motion in bodies.

As was formerly observed, it is impossible to show either permanency or uniformity of motion in bodies upon or near the earth; for all moving bodies are sooner or later brought to a state of rest by the force of attraction, friction, and the opposition of the atmosphere. It is only, therefore, in the case of the great works of nature, or planetary bodies, that the laws of motion are most clearly and fully illustrated.

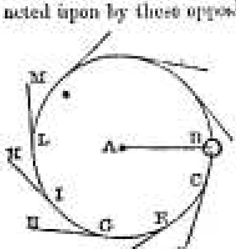
The tendency of a body to move in a straight line from the point whence it set out, is as much a property of matter as the uniformity of motion. If we conceive the idea of a body impelled into a state of motion by any given force, and at the same time conceive the idea that there is no obstacle to interrupt it, no attractive force to bend it aside, we shall then fully understand that a moving body must, as a matter of necessity, from its property of inertia, proceed in a straight line of direction—it must go on in an even path for ever.

CENTRIFUGAL FORCE AND CIRCULAR MOTION.

Bodies, in flying round a centre, have a tendency to proceed in a straight line, and this principle of motion, as already mentioned, is termed *centrifugal force*. Examples of this tendency are very familiar to our observation. When we whirl rapidly a sling with a stone in it, and suddenly allow the stone to fly off, it proceeds at first sensibly in a straight line, but is gradually drawn to the earth by attraction. In turning a circular grinding-stone rapidly with water in contact with it, we perceive a rim of water first rising on the stone, and next flying off; and the more rapidly we turn the stone, so does the water fly off with the greater force. In grinding corn by two rapidly-turning stones playing on each other, the grain poured in at an opening at the centre is quickly shuffled towards the edges of the stones, and expelled in the condition of meal or flour. If we put some water in a vessel, and rapidly turn it in one direction, we shall find that the water endeavours to escape, and rises up to the edges of the vessel, leaving a deep hollow in the middle. The tendency to fly off from a centre is made use of in the manufacture of pottery. Soft clay being placed on a revolving wheel, it quickly spreads towards the circumference of the machine, and is guided or moulded by the hand of the potter into the required form. In forming common crown or window glass, advantage is also taken of the principle of centrifugal force. A mass of glass, softened by heat, and fixed at the middle on an iron rod, being made to turn rapidly round, first in one direction, and then in the opposite, and continuing this alternating rotatory motion till the glass becomes cool, is found to spread out into a large, thin, circular plate, from which square panes of glass are afterwards cut.

In the same manner as solid bodies laid on a whirling table are thrown off, so water in a vessel which is caused to spin round in any way, as on the centre of a horizontal wheel, instead of lying at the bottom, is raised all round against the sides of the vessel. Equestrians, in performing their feats of horsemanship, always incline their bodies inwards when standing on a horse which is running round a circle. Centrifugal force having a tendency to impel them outwards, is thus counteracted by the inward leaning, and forms a species of support to their overhanging bodies. A horse running in a circle, or quickly turning a corner, naturally adopts the same counteracting posture, and leans inwards. A skater, in moving in a circular or curvilinear path on smooth ice, also leans inwards, so much so, that if he were to stand still in this posture, he would inevitably fall on his side; but centrifugal force, which has a tendency to impel his body outwards from the curve, or in a straight line of motion, sustains him, as it does the equestrian, and he therefore moves gracefully and safely in the circular path which his fancy directs. In this and other instances, we find the force of gravity overcome by centrifugal force. It is in obedience to this principle that the earth bulges out to the thickness of 26 miles upon the circumference at the equator, where the whirling motion is most rapid.

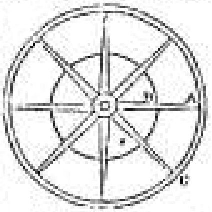
Thus centrifugal force is the tendency to fly off in a straight line, or at a tangent, from motion round a centre; and the power which prevents bodies from flying off, and draws them towards a centre, is, as already mentioned, called *centripetal, or centre-seeking* force. All bodies moving in circles are constantly acted upon by these opposite forces, as may be exemplified by the annexed cut.



A is a point to which a string with a ball at the end of it (B) is attached. On forcing the ball B into motion, it will describe a circle round the point A, in which case the string is the centripetal force. The ball, in whirling, however, having a continual tendency to fly off, if it be disengaged from the string at C, will go in a straight line C D; if at E, it will go in the line E F; if at G, in the line G H; and so on at every point in the circle.

The mutual action of centrifugal and centripetal forces, in the case of circular motion, proceeds according to a certain ratio. If the mass of the revolving body be increased, its distance from the centre and velocity remaining the same, its centrifugal force will be increased in the same proportion. If the distance from the centre be increased, while the mass and the time of revolution remain the same, the centrifugal force will also be increased in the same proportion. If the number of revolutions performed in a given time be twice as many, the distance and mass being unchanged, the centrifugal force will be four times as great; if three times as many, the force will be nine times as great; if four times as many, it will be sixteen times as great; and so on in the same proportion. The masses of the planets, and their distances from the sun, being various, the forces which affect them are also similarly varied.

The line round which a body performs a motion of rotation is called an *axis*. This axis may be only imaginary, like that of the earth; or real, as the axle of a wheel. The body may revolve about two projecting pins or pivots resting in sockets, in which case its axis is a straight line joining the pivots; or it may turn on a cylindrical rod of small diameter, passing through the body, like a wheel on its axle. It is evident that every point of the body, during its revolution, will describe a circle, the centre of which is a point in the axis of the body. In the turning of a wheel on its axis, that part which is at the greatest distance from the centre has the greatest velocity; and at this extremity of the circumference the centrifugal force is greatest. For example, in the annexed representation of a wheel with arms radiating from a centre, the velocity is greater at the extremity of the arm, at A, than it is at B, half the distance from the centre. But the point B goes round as often as the point A, having a smaller circle to traverse. In this manner, the velocity of revolving bodies must always, as a matter of necessity, increase in proportion to the distance from the centre of motion; hence a comparatively small centrifugal force near the centre is prodigiously increased towards the circumference. By increasing the force, and adding to the velocity of a revolving body, the centrifugal force becomes so great, that it will in some cases overcome the cohesiveness in the material of the body, and cause it to break and fly off in pieces. When large grinding-stones are thus whirled with great rapidity, they are apt to fly in pieces, to the extreme danger of those using them.



Bodies movable on an axis of rotation are submitted to different kinds of forces. They are generally distinguished by the duration of their action into instantaneous and continued forces. If the body which sustains an action of the former kind be quiescent and free, it will move in the direction in which the impulse is given with a uniform motion. If, however, the force impressed upon it be incapable of setting it in motion, then it receives a shock, the effect of which is called *percussion*. A continued force produces a continued effect. If the body be free, and previously quiescent, this effect is a continual increase of velocity. If the body be so restrained that the applied force cannot put it in motion, the effort is a continued pressure on the points or lines which sustain it.

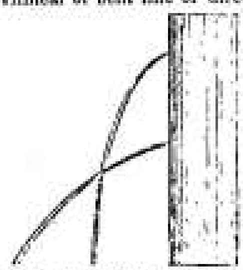
A solid body which is movable upon a fixed axis, is susceptible of no motion, except one of rotation upon the axis. If it be submitted to the action of instantaneous forces, one or other of the following effects must ensue:- 1*st*, The axis may resist the forces, and prevent any motion. 2*d*, The axis may modify the effect of the forces, sustaining a corresponding percussion, and the body receiving a motion of rotation. 3*d*, The forces applied may be such as would cause the body to spin round the axis, even were it not fixed, in which case the body will receive a motion of rotation, but the axis will suffer no percussion.

What has been just observed of the effect of instantaneous forces, is likewise applicable to continued ones. 1*st*, The axis may entirely resist the effect of such forces, in which case it will suffer a pressure which may be estimated by the rules for the composition of force. 2*d*, It may modify the effect of the applied forces, in which case it must also sustain a pressure, and the body must receive a motion of rotation which is subject to constant variation, owing to the incessant action of the forces. 3*d*, The forces may be such as would communicate to the body the same rotatory motion if the axis were not fixed. In this case the forces will produce no pressure on the axis.

The power of centrifugal force in rapidly-whirling bodies may be rendered so great, as to overcome the force of gravity. In whirling a sling with a stone in it, the stone does not fall out of its place in the sling. The following is a more striking example:—Place a jug of water on the inside of the rim of a wheel a few feet in diameter; then, beginning gradually, set the wheel in rapid motion, and it will be observed that the jug retains its place, whirling round in a perfectly stable manner, and that even the water in it is not spilled. Thus gravity, or the tendency to fall downwards, is overcome by centrifugal force. If the jug were placed in a situation in the wheel near the centre of motion, where the centrifugal force is weak, it would at once fall to the ground.

LAWS OF PROJECTILES.

Bodies, on being projected by any impulsive forces, are called *projectiles*, and are observed to pursue a curvilinear or bent line of direction in their motion. The bending from the straight line is produced by the force of gravity, and 'the change is proportional to the impressed force.' A ball projected from a cannon, a stone thrown by the hand, and water spouted from a vessel (see fig.), furnish familiar examples of curvilinear motion.



It is a remarkable law of motion, that whether the force which projects a body be great or small, the body, if thrown horizontally, will reach the surface of the earth from the same height, in the same space of time, not calculating resistance of the air. For example, if two guns are fired from the same spot, at the same instant, and in a horizontal direction, one of the balls falling half a mile, and the other a mile distant, it will be found that the ball which proceeds the greatest distance, takes precisely the same time to reach the ground which the other does. The time of flight, as it is called, of two balls will be the same in whatever directions, and with whatever velocities, they are fired, provided they reach the same height. The reason for the same length of time being occupied in falling by both balls is, that they are both carried downward at the same rate by gravity. Hence a ball dropped perpendicularly from the top of a high tower, does not reach the ground sooner than a ball shot from the same height to the distance of one or more miles in a horizontal direction.

In projecting bodies through the atmosphere, great advantage, in point of distance, is gained by impelling them from heights, because a ball thrown from a high situation to a lower, reckoning its whole course, is more aided than retarded by gravity. When the ball is projected from a lower situation to a higher, it is in the first place retarded by gravity in its ascent, and the acceleration afterwards by gravity being less than this previous retardation, it consequently does not go so far as if projected from a height.

We are now prepared for the consideration of one of the most important principles in dynamics—namely, the law of motion which governs a body after receiving a projectile impulse. A projectile exhibits a composition of motion—namely, a horizontal motion forward, when thrown in that direction, produced by the impressed force; and a descending motion, produced by gravity, or the earth's attraction. These two motions are unequal; they are not at the same velocity. The horizontal motion is uniform, while the descending motion, according to the law of gravitation in relation to falling bodies, is accelerated. The consequence is, that the projectile, as already mentioned, pursues a curved line of direction, the convex side of the curve being uppermost. The degree of curvature of the line of motion depends on the amount of the original projectile force. The law is, the greater the projectile force, or the greater the original velocity of the object, so is the sweep of the curve proportionally greater.

Let us suppose that the projectile force is sufficient to carry a cannon ball ten miles; this will give a very wide curve, allowing that the ball is shot from a lofty situation. But let us add to the projectile force, and send the ball double the distance, and the curve is now exceedingly wide. If we in this manner go on adding to the projectile force, we at length give the ball such a motal force, that it will go quite round the world; instead of describing portions of curves, it will describe a whole circle.

This conducts us to a most extensive result. We have at once placed before us a reason why the planetary bodies should have assumed curvilinear paths in relation to the sun. The original projectile force which they received in connection with the force of gravitation, has obliged them to pursue curved lines in their motion; and once being disengaged, they have, by a balance of centrifugal and centripetal forces, continued to travel in circular, or, properly speaking, elliptical orbits—the ellipticity being caused by a want of exact uniformity between the forces which affect them.

ACTION AND REACTION.

According to the third proposition of Newton—'Action must always be equal and contrary to reaction.' Action is the impression of force. A blow is action; pressure is action. Reaction is resistance; but the word resistance does not fully convey the meaning of reaction, which properly signifies the action of striking or pressing back, even although the body struck or pressed upon do not move. When a man strikes a hammer upon a fixed stone, the stone strikes the hammer at the moment of contact as much as the hammer strikes it. But if the stone be not fixed, and be liable to be easily upset, then its reaction is less, and it acquires a momentum. When a boy throws his ball against the wall of a house, the wall reacts on the ball, and causes it to rebound; but if the boy throw his ball at a pane of glass with the same force, the glass, having the power to resist only a portion of the force, gives way before it. In this case, if we suppose the ball to possess the action or force of 4, and the glass to possess the reaction of 2, the ball, in passing through the glass, loses 2 in its force, and retains the remaining 2. If it then came against another pane possessing a reactive power of 2, it would not break the glass, and, its force being now spent, it would fall to the ground. Thus 'action and reaction are equal.'

A story is told of a person who, from his knowledge of the law of action and reaction, betted that he would lie down on the ground and allow an anvil to be placed upon his breast, and that any one might strike the anvil with as much force as he was pleased to exert. In this case the person who made the offer was quite safe, provided he could support the weight of the anvil; for if a blow were given with the utmost force by a comparatively light body, as a hammer, though it would communicate nearly double its momentum to the anvil, yet the anvil, being so heavy, would acquire so small a velocity, that the shock given to the person would be insensible. Were a freestone of the same weight as the anvil used, it would give a still less shock, for the action and reaction of perfectly elastic bodies are twice as great as that of inelastic bodies. Iron has more elasticity than freestone.

It is by reaction acting contrary, or in opposition to action, that the movements of living objects are rendered effectual. When we walk on the ground, the ground resists the pressure, and we feel ourselves steadied. A bird in flying, pushes itself onward by the flapping of its wings against the partially-resisting medium of the atmosphere. A sailor in rowing a boat causes the oars to push against the water; and the water partially resisting the force, motion is communicated to the boat. In pushing a boat from the shore, the firm ground has such a power of reaction, that we are able to give the boat much greater momentum than if we pushed only against water. If we go into the boat, and try to move it by merely pressing against some part of its fabric, no motion whatever is produced, for the action and reaction are equal. The whole force employed must be rendered greater than the reaction, otherwise no motion can be communicated to the body.

When two bodies come into collision with each other, as in the case of two bodies moving in a straight line, but opposite course, to each other, the law of action and reaction being equal, will not be clearly illustrated, unless the collision be in the direction of the centre of gravity or inertia of the two—in common language, unless the blow be *fair*. The centre of gravity, in cases of this kind, is called the *centre of action*, or *percussion*. For example, when we strike a ball with a club, fairly against its side opposite to its centre of gravity, it is impelled to a considerable distance; but if we strike it above this central point, a part of the force is expended in vain, or lost, and the ball moves but a comparatively short distance. Experience has demonstrated that the centre of action in hammers should be in the head or striking part; and therefore, in striking with these instruments, the blow may be given with every advantage. But when an attempt is made to strike with an object in which the centre of action is at a place short of its extreme point, for instance, a common iron poker, a part of the action is expended towards the hand of the person who strikes, and he feels a disagreeable jarring sensation in his arm.

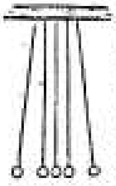
This definition of the centre of action applies only to the motion of bodies in a straight line. In the case of revolving bodies, the centre of action or percussion is a point in it, to which, if an immovable obstacle be applied, the body will remain at rest without any tendency to move in any direction, and the axis will receive no shock. In straight rods or bodies of any form, suspended as pendulums, the centre of oscillation is the same as the centre of action in revolving bodies.

MOTION IN ELASTIC BODIES.

In reference to the effects of collision, bodies are divided into three classes—hard, soft, and elastic. A hard body is one that suffers no change of form by the action of any force. A soft body is one that undergoes a change of form by this means. An elastic body suffers a momentary change of form by the action of any force impressed upon it, and immediately springs back, or recovers its original form. The first two classes are styled *inelastic* bodies.

If two equal inelastic bodies be moving with equal velocities in opposite directions, and come in collision, each will destroy the onward motion of the other, and consequently both will be reduced to a state of rest. If there be any elasticity in the bodies, they will, according to their degree of elasticity, rebound from each other, and a positive process of reaction will be exhibited. By this means there will be at once a counteraction and transmission of force. As above stated, when the bodies are perfectly elastic, the action and reaction are double that of inelastic bodies.

An example of the transmission of force or motion from one body to another, while the transmitting bodies remain at rest from their mutual counteraction of the force communicated, may be seen in the case of a row of billiard balls, which possess a certain elasticity. Place six billiard balls in a row on a smooth plane, and let them be all pretty close to each other, or even in contact. Then give a smart blow to the first ball, or, as we may call it, No. 1; it will instantly strike against No. 2, which will communicate the force to No. 3, and from 3 it will be given to 4, and from 4 to 5, and from 5 to 6. None of the balls, however, will sensibly move from the spot in which it rests, except the last of the row, which, having no ball to impinge upon, will roll away, and thus expend the force communicated by the blow upon No. 1.



An experiment of this kind is generally performed upon a number of elastic balls of a small size, suspended in a row by threads, as in the preceding fig., in which case there is no friction to interrupt the process of action and reaction.

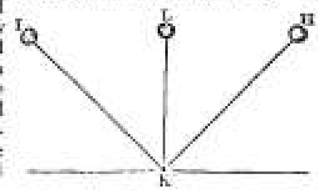
REFLECTED MOTION.

A body projected by a single force proceeds in a straight line till a new force act upon it, and send it on a new line of direction. When a moving body is thus impelled into a new line by striking against some body, its motion is said to be *reflected*.

Examples of reflected motion are very common—as, for instance, when a rolling ball encounters an opposing stone in its path, in which case it flies off obliquely in a new direction; when we throw a thin piece of slate along the surface of a river, and make it skip from point to point; or when an apple, in falling from a tree, touches a lower branch in its descent, and rebounds in a slanting direction to the ground.

It is found by experiments that moving bodies observe certain laws in respect to the line of direction they pursue in rebounding, or being reflected from any impediment with which they happen to come in contact. In the accompanying cut, the line A B is a level marble slab, C is an ivory ball, which being thrown towards the slab in the direction of C E, is reflected in the direction E D. Thus the two angles F and G are exactly equal; and it is demonstrated that a perfectly elastic ball striking a smooth wall or floor, makes the same angle in leaving the point where it strikes that it does in approaching it.

Whatever be the angle at which the ball strikes the smooth fixed surface, the same rule will be observed to be followed. This is exemplified in the next fig. If the ball be dropped perpendicularly from L to K, it will rebound and return to L. If sent in the line H K, it will rebound or be reflected to I. The angle which a ball makes with the perpendicular line in going from H to K, is called the *angle of incidence*; and the angle which it makes in rebounding from the point at K to I, is called the *angle of reflection*. These angles are always equal.



A calculation of the angles of reflected motion is necessary in the case of presenting a shield or other object to ward off a missile or blow from the person. If the angle be too acute—that is, if the blow be too point-blank—the shielding object may be damaged, or perhaps destroyed; while if the angle be obtuse, the object which gives the blow will slide off harmlessly.

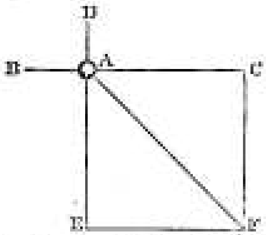
If a billiard player strike a ball perpendicularly against the cushion, it will return in the same direction. If, however, he strike the ball at an angle against the side of the table, it will rebound or fly off at an opposite angle. Suppose a ball to be placed half way up the side of an oblong table, and to receive sufficient force in such a direction as would make it strike the centre of the end of the table, the ball will fly off at an angle, and approach the side of the table opposite to that from which it was put in motion. By a knowledge of these laws, the billiard player often makes a ball fly from one corner, strike the centre of the table, and reach the corner parallel to that from which it was originally struck.

COMPOSITION OF MOTION AND FORCES.

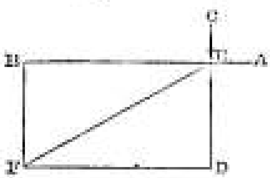
Hitherto we have spoken only of the motion of a body as produced by a single impulsive force, and turned aside or reflected by another force acting upon it; we have now to consider the subject of *compound motion* *and force*, or motion and force produced by two or more forces acting on a body in different directions at the same time.

If two or more forces act on a given point of a body, at certain angles, a single force may be found which would produce the same effect. This single force is technically called the *resultant*, or *equivalent*. For instance, a wind blowing from the north-west, and a current setting from the north-east, both acting on a ship, and tending to carry it with equal velocities in their own directions, the ship will be found to move in an intermediate direction, as if it were acted on by a single force, like a breeze, from due north.

In treating of combinations of mechanical forces, it is usual to represent them by diagrams, the various lines of which are significant of the quantity or intensity of the forces, of the directions in which they act, and of the effects produced by them. Thus, in the annexed diagram, we have an example of motion produced by two forces acting on a body from different directions. A is a ball, which, having received a blow at B, is proceeding onward to C. At the point A, while on its course, it receives a blow equal to the former, which second blow would have been alone capable of carrying it to E in the same time that the first blow would have carried it to C. This new force, by changing the direction of the original motion, causes the ball to move in a line towards F, and the effect is the same as if the ball had been at first sent in the direction of A F by a single force. Practically, it would be difficult to regulate blows with such nicety as to produce this line of motion, but in the theory of forces, the law is as it has been stated. The line A F in the figure is termed the *diagonal*.

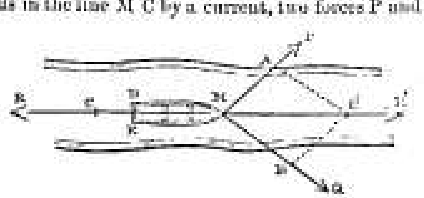


Should the constituent forces be of different magnitudes, then the figure described may be a parallelogram, or oblong, as in the following cut. The force here, in the direction A B, is double that of the cross force C D, by which means the ball describes a diagonal line to F, and so forms a parallelogram, when we draw all the lines connected with the experiment. The parallelogram thus formed is called the *parallelogram of forces*. The two given forces acting in the directions E B, E D, are called *components*, and the single force in the direction E F is the *resultant*. The process of finding a single force equivalent to two or more forces, is called the *composition of forces*.



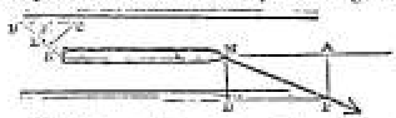
The process of finding forces which will produce a motion equal to that of a single force, is called the *resolution of forces*. The following are examples :—

If a boat D E M floating on a river be pressed downwards in the line M C by a current, two forces P and Q,



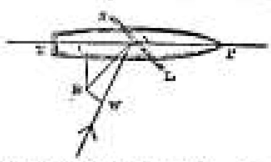
acting in the directions M P, M Q, may be found that will counteract the influence of the current, and keep the boat stationary. For make M C to represent R, the force of the current, and make M C' equal to M C, and find M A and M B as before, they will respectively represent P and Q. If two men, therefore, pull two ropes in the directions M P, M Q, with forces denoted by M A, M B, they would keep the boat at rest. If the ropes be tied to two posts at P and Q, the forces M A, M B, will represent their reactions.

Let H M be a canal boat, M P the rope by which it is drawn by a horse attached to it at P. The force of the draught being denoted by M P, it may be resolved into M A and M B, of which only M A is effective in drawing the boat forward; the other force M B tends to turn the head of the boat in the direction M B. This last force must therefore be counteracted, which is effected by means of the helm H E turned to an oblique position. When the boat is in motion, the water, being at rest, produces a resistance or pressure against the



helm. If C D denote the resistance, it may be resolved into H D and H C, of which H D produces no effect on the helm; therefore C H is the only effective pressure. Again, C H may be resolved into C F and F H, the latter of which tends to turn the stern of the boat in the direction F H, and thus counteracts the force M B, by tending to turn the boat round in an opposite direction; and the part C F tends to move the boat backwards, and thus, counteracting a part of the force M A, it retards the progress of the vessel. The two forces F H, M B, would move the boat sideways, or laterally, to the side of the canal; but this can be prevented by giving the helm a little more obliquity, for, from the length and shape of the vessel, it is much more easily moved in the direction of its length than of its breadth.

Let T P be a ship, S L its sail, W A the direction of the wind and its pressure on the sail. W A can be resolved into A B perpendicular to the sail, and B W parallel to it, the latter of which has no effect in pressing on the sail; therefore A B is the effective pressure on the sail. Were the vessel round, it would move in the direction B A. Let B A be resolved into C A and B C, the former C A acting in the direction of the keel, or length of the vessel, or in the direction C A, and the latter perpendicular to it, or in the direction of the breadth. The former pressure C A is the only pressure that moves the vessel forward, the other B C makes it move sideways. From the form of the vessel, however, this latter force B C produces comparatively little lateral motion; any that it does occasion is called *lee-way*. By turning the helm, the vessel may be made to turn round in any direction by the pressure of the water upon it, if the vessel has also at the same time progressive motion.



The suspension of a kite in the air is another illustration of the effect of the pressure of an aërial current, the explanation of which belongs to PNEUMATICS.

COMMON MOTION.

Motion, as has been stated, is called *common*, when participated in by two or more bodies. Thus all things on the earth, including the atmosphere, have a motion in common with the earth; a person riding in a chaise has a motion in common with the chaise; a person in a moving vessel at sea has a motion in common with the vessel. For convenience, we shall, in treating of this branch, use the terms larger and smaller body—the larger being understood to be the body on which the force to produce motion is immediately impressed, and the smaller that which is carried along by the body impressed.

A large body is in motion; it is moving in a certain direction, at a certain velocity; everything on it, or small body connected with it, partakes in its motion, and has a tendency to proceed in the same direction, and at the same velocity.

It appears strange that there should be a communication of motion from the larger body to the smaller, without the immediate intervention of impressed force on the smaller; but a little examination shows that such must necessarily be the case. The larger body has received the impulse to move, and this impulse is transmitted through the whole mass of the body, including all the small objects on its surface, and those which are anyway connected with it in its propulsion. When a man is walking on the deck of a ship, which is moving at the rate of ten miles an hour, he perhaps imagines that he has no more motion than if he were walking on the solid ground. But it would be incorrect for him to think so. His body, and everything about his person, have received an impulse from the vessel; he possesses a velocity of ten miles an hour as much as the planks of the vessel do; and this onward motion he cannot divest himself of, as long as the ship continues to move at this rate of speed, or as long as he continues in connection with it.

On account of this participation of motion in all bodies moving in connected masses, it is observed that all objects whatever keep their proper places in or about the large moving bodies with which they are in contact, and hence no confusion takes place in the relative situation of objects on the earth by its motion. For example, when we leap from the ground, the earth does not slip away from below us; if we ascend in a straight line of direction, we fall down exactly upon the same spot whence we rose. When a man falls from the top of a mast of a moving vessel, he falls upon the deck upon a spot directly under the point whence he fell: the vessel does not leave him. When we are sitting in the cabin of a moving vessel, and let a small object drop from our hand to the floor, it falls on a point on the floor immediately below, the same as if it had been dropped in a house on solid ground: the floor does not leave it behind. When we are sitting in a rapidly-moving coach, and in a similar manner let an object fall, it descends in the same manner to the bottom of the coach. The reason for these phenomena is that already mentioned—the small objects possess a motion derived from the larger; this common motion, or *motal inertia*, as some authors call it, is retained by the small objects during their descent, so that, while descending, they are also going forward.

One of the most beautiful examples of common motion is that which is exhibited by an equestrian standing on a horse which is running round a circle, while he at the same time throws oranges from his hand and catches them in their descent. Notwithstanding his rapid motion, the oranges which are thrown into the air do not fall behind; they return regularly to his hand. To counteract centrifugal force, he leans greatly inward; but this does not alter the law of motal inertia, which causes the oranges to return. He throws them almost sidewise in an inward slanting direction, and yet they come readily back to him. The reason for these phenomena is, that the oranges participate in the forces by which he himself is impelled and sustained.

Small bodies which have derived a motal inertia from a larger, continue to possess this motal inertia after leaving the larger, until they meet with some new impression of force sufficient to alter their condition. If they were not drawn to the earth by attraction, and were not opposed by the atmosphere, they would go on moving in a straight line for ever. When we drop a ball from the window of a moving coach, it continues to go forward, as if it were still in the coach, till it meet the ground, when it is stopped; thus its motal inertia is destroyed. If we attempt to leap from a moving body, such as a coach or a boat, we continue to possess the motion which we previously had, until we touch the earth, when we receive a shock by the destruction of our motal inertia. But if we leap from one moving body to another moving body which is going near it, on the same level, in the same direction, and at the same velocity, we sustain no shock, because the body upon which we leap possesses the same condition of motion as that which we possess.

When a man, standing on the ground, shoots at a bird on the wing, he requires to follow its motion by keeping his gun moving when presented at it; but if he be standing on the deck of a ship sailing at the rate of ten miles an hour, and point his gun at a bird flying in the same direction and at the same velocity as the ship, then he is placed in the same condition as the bird: he does not require to move his gun, as if following the bird. In taking aim at a bird on the wing from the solid ground, it requires considerable skill to prevent the shot from proceeding to a point behind the bird, because the shot is entirely destitute of motal inertia on being fired, unless it be previously put in motion. But a bullet on leaving a gun which is moving at the same rate as the bird, and in the same direction, keeps going on in the direction of the bird, because it retains the motion it had in common with the gun. The bullet in this case does not go in the direction of the gun, but obliquely, so as to keep up with the motion of the bird, so that the same effect is produced as if the shot had been fired from a fixed gun on land to a fixed point in the air in advance of the bird. Should the bullet be fired from a gun in a moving vessel, for instance a ship sailing westward to a fixed point on land, then a certain allowance must be made for the motal inertia of the bullet: it must be fired a little eastward, and the motal inertia will carry it westward to the object.

Objects falling from bodies moving in an onward direction to those which are at rest, are regulated by the same law that governs projectiles. The falling objects, as formerly mentioned, are affected by two motions—one in a horizontal, and the other in a descending direction. When these motions are unequal, the falling body describes a curve in its descent, the convex side of the curve being uppermost. Thus motal inertia, and the motion produced by projectile impulse, are the same thing; hence powerful centrifugal force in the sun, sufficient to disengage a portion of its mass, would be equivalent to a projectile impulse from it as a fixed body.

In consequence of the general participation of common motion in all things connected with a moving body, there can be no consciousness of motion in the living beings carried about by it, provided the motion be perfectly smooth, and there be no means of observing bodies which are at rest. Thus, on account of our possessing a motion in common with the earth, which moves with perfect smoothness, we can neither see nor feel the earth moving. And here we may remark, that although Astronomy assures us we are thus carried through space with the earth, as it revolves round the sun, we cannot say anything definite respecting our *absolute motion*, as we know not whether the sun is an immovable centre of the world. Everything, however, seems to imply that the sun itself is only a planet revolving around another sun, which, in its turn, is not fixed; and therefore we are as yet unable to conjecture what the centre of all motion is. Again, a person sitting in the cabin of a smooth-sailing ship, and not looking out at the windows, cannot, by his mere sensations, tell that the vessel is moving; but if he look at the shore, which he knows to be at rest, he is immediately sensible of the progressive motion of the vessel.

In looking from a moving body, as from a ship to the shore, or from a coach to objects on the wayside, a delusive feeling prevails that it is not the body we are upon, but the body which is at rest, that is really moving—going in a direction contrary to that of the body we are connected with. This is in consequence of our possession of motion in common with the moving body. We are under an influence, or in a condition, that renders us incapable of seeing our own motion; hence the error which the sense of vision leads us to commit, is left to be rectified by the understanding.

MECHANICS—MACHINERY.

THE application of the laws of motion and forces to objects in nature or contrivances in the arts, constitutes the branch of Natural Philosophy usually treated under the head MECHANICS, MECHANICAL POWERS, or ELEMENTS OF MACHINERY.

GENERAL DEFINITIONS.

The original signification of the word *machine*—which is the root of the various terms *mechanic, mechanical*, and so forth—was art, contrivance, ingenuity, or, in general, the means of bringing about an effect; hence a machine, in its widest acceptation, is an engine or instrument devised to produce an effect. When the term 'mechanics,' or 'mechanical,' is applied to the action of forces—as mechanical powers—it is meant that certain powers are exerted, or motion produced, by the action of particles or masses of matter, solid or fluid, one upon another. Thus *mechanical action* is applied to the action of forces that produce no change in the constitution of bodies, and is therefore distinguished from *chemical, vital*, or any other species of action. For example, the pounding of a piece of limestone to powder is strictly mechanical, whether it be effected by the blows of a hammer, or by the silent agency of running water; but the reduction of limestone to a similar state by sulphuric acid is chemical. In the former case, all the elements of the original limestone remain in the powder; whereas in the latter, it is converted by the action of the acid into a very different compound.

In natural philosophy, machines are usually distinguished as *simple* or *complex*. A simple machine is equivalent to a tool or instrument, as a spade or lever; a complex machine is an engine in which different parts, or various tools, combine to produce the required effect. In ordinary language, these distinctions are not very minutely attended to, though indispensable to the precision of science. *Mechanics* is the term commonly employed to comprehend the science which treats of machines, whether theoretically of their powers, or practically of their application and construction.

Machines are, under all denominations or circumstances, only instruments through which power may be made to act. They only convey, regulate, or distribute the force or power which is communicated to them from some source of motion, and never create or generate power. But although a machine does not create power, or give more power than it has received, it practically applies the power which has been communicated to it in so convenient and easy a manner, that a result ensues almost as surprising as if it had actually generated the whole or a portion of the power it exhibits.

The main purpose required in mechanical operations is to overcome, oppose, or sustain a certain resistance or force. This purpose is obtained by applying another species of force. According to the usual phraseology, the resistance or force to be overcome is termed the *weight*, and the force which is applied the *power*.

The ability of applying force by the human hands, without the aid of instruments or machines, is very limited. In almost all our operations of art, it is found necessary to call in the aid of instruments or machines of some kind. All the instruments which mankind have adopted for their use—from the piece of stick with which the savage scratches the ground as a plough, to the most elegantly-finished piece of mechanism—act upon certain fixed principles in nature, which a long course of experience and scientific investigation has developed.

The mechanical powers which exhibit the working of these principles are strictly only three in number—namely, 1, The *Lever*; 2, The *Pulley*; and 3, The *Inclined Plane*. These may be called the Primary Mechanical Powers; and from two of them, the Lever and Inclined Plane, other three are formed, as follow:—1, *Wheel* and *Axle*, from the *Lever*; 2, *Wedge*, from the *Inclined Plane*; 3, *Screw*, from the *Inclined Plane*. These may be called the Secondary Mechanical Powers. The six altogether form the most usually-occurring elements of complex machinery.

THE LEVER.

The lever is one of the most important and extensively-used of all the mechanical powers, and its operation exhibits some of the leading principles in mechanics. A lever is a rod, or bar of iron, wood, or any other material, which is movable upon or about a prop or fulcrum, or about a fixed axis. It is called a *lever*, from a French word signifying to raise, and has been applied to instruments for raising or lifting weights.

Three elements contribute to the operation of the lever—the *power*, the *fulcrum*, and the *weight*. The power is the force applied, the fulcrum is the prop or support, and the weight is the resistance or burden to be lifted. The terms *power* and *weight* have merely a reference to the manner in which the machine is used; strictly, both the power and weight are *forces* the same in character and action. The distance of the point of application of a force from the fulcrum is called the *arm* of the lever.

There are three kinds of levers, differing according to the relative situation of the power, fulcrum, and weight. Each of these consists of a straight bar, and, in theoretical calculations, is supposed to be in itself destitute of any gravity or degree of heaviness. In theory, also, the forces which are applied are supposed to act at *right angles* to the fulcrum. In the *first*, or most simple kind of lever, 'the fulcrum is disposed between the power and the weight;' in the second, 'the weight is disposed between the power and the fulcrum;' and in the third, 'the power is disposed between the weight and the fulcrum:'—

In the first kind of lever, 'the fulcrum is disposed between the power and the weight.' Fig. 1 is an example. A to B is a straight bar, resting on a prop or fulcrum F. From A to F is the long arm of the lever, and from F to B is the short arm. P is the power, or a certain force drawing down the extremity of the long arm at A. W is the weight suspended from the extremity of the short arm at B. The object is to cause P, which is supposed to be a small weight, to balance or overcome W, which is supposed to be a much heavier. Practically, the force of a man pressing upon the extremity of the handle of the lever at A, will effect with ease, in lifting the heavy weight W, what it would require a much greater force to accomplish by pressing upon the long arm at a point nearer the fulcrum.

Fig. 1.

This is more clearly exemplified in fig. 2, which represents a lever placed conveniently for raising a square block W, which is the weight. On pressing down the extremity of the long arm of the lever at A, the point of the short arm B raises the block. F is an object lying on the ground to press against as the fulcrum. As in the case of fig. 1, 'the

Fig. 2.

force of a man pressing upon the extremity of the handle at A, will effect with ease, in lifting the weight W, what it would require a much greater force to accomplish by pressing upon the long arm at a point nearer the fulcrum.'

The principle in mechanics which produces this phenomenon is very simple, and is explained by what is called the Law of Virtual Velocities, or, from its general application, the Golden Rule of Mechanics.

This fundamental law or rule is—*That a small weight, descending a long way in any given length of time, is equal in effect to a great weight descending a proportionally shorter way in the same space of time.* In other words, what is gained in velocity or time is lost in expenditure of power.

Another way of stating this important law is as follows:—*In the case of equilibrium, if a motion be given to the mechanical power, then the power multiplied by the space through which it moves in a vertical direction, will be equal to the weight multiplied by the space through which it moves in a vertical direction.*

This principle, which applies to every mechanical movement in the case of equilibrium, has been illustrated by a reference to the property of attraction of gravitation. What is called weight, is only an effect of gravity on the atoms of matter. In figurative language, every atom is drawn towards the earth by an invisible line or cord of attraction; and when one atom rises or falls ten inches, the same quantity of attraction is drawn out from, or sent back to the earth, as if ten atoms were to rise or fall only one inch.

Thus, by a proper mode of applying the power, we may cause a weight of one pound, by moving through a space of ten feet, to raise another weight of ten pounds, moving through a space of one foot; or (the reverse) by a weight of ten pounds, moving through the space of one foot, we may make a single pound move through the space of ten feet. But by none of the mechanical powers shall we be able, by moving a weight of ten pounds through one foot, to move a single pound through eleven feet; nor, by a single pound moving through a space of nine feet, shall we be able to raise a weight of ten pounds through one foot.

Neither by the power of the lever, therefore, nor by any other of the mechanical powers, can we make any absolute increase of the power which is applied. In other words, the quantity of power expended in any great and instantaneous effort, is exactly the amount of the power which has been previously accumulated. All that we can do to procure mechanical advantage, is to accommodate the velocity, force, or direction of the applied power to the purposes we have in view.

To apply this principle to the lever: in fig. 1 or 2, a small force at A is equal to double the force exerted at a point half way betwixt A and the fulcrum; yet in both cases the same amount of mechanical power is expended. A slight push downwards at A, by being continued for one minute, is equal to a push of double the force at a point half way towards the fulcrum, continued for the same time. Any amount of force, therefore, can be exerted with ease at the extremity of the long arm of the lever, provided we choose to make the arm long enough and strong enough.

It may possibly be said that it would be as expeditious to push down the extremity of the long arm of the lever, as to push down the arm at a point nearer the fulcrum. Practically, in small levers this may be the case; but when levers of considerable length have to be used, and a succession of depressions and raisings are necessary, it will be found that more time is spent in working with a long than a short lever. For when the sweep of the lever is inconveniently long, the person using it has to move his body quickly up and down over a larger space, and is sooner fatigued. For this reason, although a boy with a long lever may balance as great a weight as a man with a shorter one, yet, in raising weights successively by it, the boy would be sooner fatigued.

It is a general rule that 'the force of the lever increases in proportion as the distance of the power from the fulcrum increases, and diminishes in proportion as the distance of the weight from the fulcrum increases.' In making calculations to ascertain the proportions to be observed betwixt the power and the weight, regard must be paid to the respective lengths of the long and short arms of the lever. We must also fix what are to be the units of weight and distance, and let them be the same on both ends. If we state inches to be the unit of length of the short arm, inches must be the unit of length of the long arm; and if ounces be made the unit of weight of the short arm, ounces must be made the unit of power of the long arm.

Rule.—Multiply the weight by its distance from the fulcrum; then multiply the power by its distance from the same point; and if the products are equal, the weight and the power will balance each other.

Example 1.—Suppose a weight of 100 pounds on the short arm of a lever, at the distance of 8 inches from the fulcrum, then another weight or power of 8 pounds would be equal to this, at the distance of 100 inches from the fulcrum. Because 8 multiplied by 100 produces 800, and 100 multiplied by 8 produces 800—and thus the weight and the power would mutually counteract each other.

Example 2.—Suppose we wish to calculate what power should be employed at the end of the long arm of a lever to balance a given weight at the end of the short arm. We multiply the weight by the length of its arm: this gives us a product; then divide that product by the number of inches in the long arm, and the result or quotient is the power. Thus a weight of 10 pounds, multiplied by 10 inches, as the length of the short arm, gives a product of 100. If the length of the long arm be 20, we find how many twenties are in 100; and there being 5, consequently 5 pounds is the power. In this instance the mechanical advantage is two to one—that is, the power is twice as small as the weight.

The common spade used in delving offers a similar example of simple lever power, when employed in raising the earth from its place to turn it over. Fig. 3 represents an equally familiar example—namely, a

Fig. 3.

wood-sawyer or carpenter moving a log of timber from its place, by means of a long pole or beam of wood. Stone masons use a lever of iron of this description, called a crow-bar.

The power of the first kind of lever is frequently seen to operate in machines or instruments having two arms. The most common examples of this nature are pincers, scissors, and similar instruments. In the pair of scissors here represented, the two limbs are seen to be joined together by a rivet at the centre, which becomes the fulcrum of both.

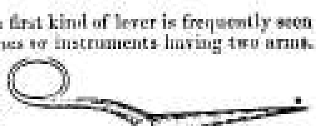


Fig. 4.

A common scale-beam for weighing, used by shopkeepers, is an example of the first kind of lever, formed with two arms of equal length, and suspended over the centre of gravity, so that the two extremities balance each other. (See fig. 5.) S is a string or line suspending the beam A B at a central point F, which is the fulcrum. The point of suspension, or pivot, is sharpened to a thin edge, so as to allow the arms to rise or fall with as little friction as possible when any weight is put in the scales.

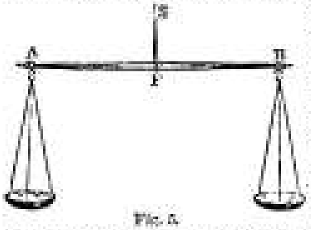


Fig. 5.

There is another kind of balance, called a *steelyard*, which consists of a lever with arms of unequal length, and acts upon the principle of distance from the fulcrum on the long arm compensating for weight on the short arm, as already defined. Fig. 6 is a representation of the steelyard balance:—C is the fulcrum or pivot by which the beam is suspended, and freely plays as on an axis. A is the short arm, and the opposite end is the long arm. W is the scale for the reception of the article to be weighed. The long arm is graduated into divisions by marks, each mark denoting by a figure a certain number of pounds or ounces. P is a weight of a certain heaviness, and being movable

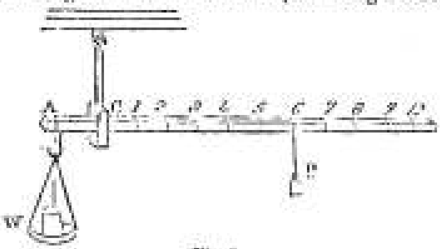


Fig. 6.

by a ring, it can be slipped along the bar to any required point. The same weight is always used, and thus constitutes one of the principal conveniences of this kind of balance. In proportion as the article to be weighed in the scale W is heavy, so is the weight P slipped along to a greater distance from the fulcrum; and when it is brought to a point where it balances the article, the figure on the bar at that point indicates the amount of the weight. If P be one pound, and if, when suspended from the division at 6, it balance the weight at W, it is evident that the weight will be six times P, or 6 pounds. And so on with all the other divisions.

The steelyard, though not so ancient as the common balance, is of considerable antiquity. It was used by the Romans, and has long been in use among the Chinese. Neither the common balance nor the steelyard is suitable for showing the varying weight or heaviness of an article at different latitudes of the earth's surface, because the weights employed are equally affected with the attraction of gravitation and centrifugal force, as the article to be weighed. For this reason, the difference of weight resulting from the causes mentioned, can only be demonstrated by a balance formed of a spring of elastic metal. By suspending the article from the spring, it pulls it out to a certain extent, and so indicates the weight on a graduated scale on the instrument. As the spring acts the same in all latitudes, it serves as a fixed or unalterable power, while the article to be weighed is liable to an alteration in its weight or heaviness according as it is brought near, or carried from, the equator. [See Laws of Matter.]

In the lever of the second kind, the weight is placed between the power and the fulcrum, as in fig. 7. The line from A to F is the long arm, B to F is the short arm. W is the weight, and P is the power. The object required by this lever is to lift the weight W by raising

Fig. 7.

the extremity of the lever at A. In this, as in the case of the first kind of lever, the power is increased in proportion to its distance from the fulcrum.

Examples of this kind of lever-power are common. One of the most familiar is that of a man pushing or lifting forward a bale of goods, as represented in fig. 8, in which the bale or weight W presses against the lever between the power P and the fulcrum F.

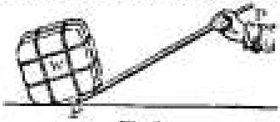


Fig. 8.

Another example of this lever is that of a man using a wheelbarrow, as represented in fig. 9. A point in the wheel of the barrow, where it presses on the ground, is the fulcrum. The body of the barrow, with its load, is the weight. And the two handles, lifted or held up by the man, form the power. In proportion as the man shortens or lengthens the handles in holding them, so does he increase or diminish the weight he has to sustain; increasing, however, by another law, the difficulty of pushing forward the barrow, according to the weight on the fulcrum.


Fig. 9.

Two men carrying a load between them on a pole is also an example of the second kind of lever. The load may either rest upon, or be dependent from, the pole. In the case of two porters carrying a sedan chair by means of two poles, the load or weight is partly above and partly below the line of the lever. In the case of porters carrying a barrel slung from a pole, as in fig. 10, the weight is altogether below the lever. In both instances the principle is the same. Each man acts as the power in moving the weight, and at the same time each man becomes a fulcrum in respect to the other. If the weight hang fairly from the centre of the pole, each man will bear just a half of the burden; but if the weight be slipped along to be nearer one end of the lever than the other, then the man who bears the shorter end of the pole supports a greater load than the man who is at the long end. The weight increases precisely in proportion as it advances towards him. Sometimes, when a man and a boy are carrying a hand-barrow between them, the man, in order to ease the weight as much as possible to the boy, holds by the arms of the barrow near to where they join the loaded part. In yoking horses to the extremities of cross bars in ploughs, coaches, or other vehicles, care should be taken to hook the cross bar to the load at its centre, otherwise one horse will have to pull more than the other.

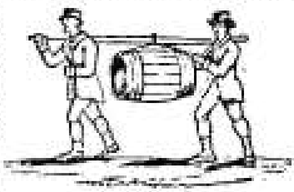


Fig. 10.

An inflexible beam, resting on supports or fulcra at its two extremities, acts similarly as a lever of the second kind. Should no weight be appended to its centre, the weight of the material itself, when the extension is considerable, will be enough to bend it down, and even to break it. Extended flexible cords or chains are from this cause always bent down in the middle, no power of extension being able to overcome the gravity of the materials, which will give way before they can be rendered perfectly straight. The bent string of a boy's paper kite is an example of this powerful influence of gravity of materials.

The instrument used for cracking nuts (fig. 11) is an example of the second kind of lever with two arms or limbs. The fulcrum is the joint which connects the two limbs; the nut between them is the weight or resistance; and the hand which presses the limbs together, in order to break the nut, is the power. As each limb is a lever, a double lever action takes place in the operation. The oar of a boat in rowing is also a lever of this kind. The hands of the sailor who pulls constitute the power; the boat is the weight to be moved; and the water against which the blade of the oar pushes, the fulcrum.

Fig. 11.

The second kind of lever is sometimes employed as an instrument of pressure. The point of the short arm is, for example, pushed into a crevice or hole in a wall, the fulcrum is the object to be pressed, and at the extremity of the long arm a heavy weight is applied. In this rude but efficacious manner are cheeses pressed in some parts of the country.

In the lever of the third kind, the power is placed between the weight and the fulcrum (fig. 12). The fulcrum is at the extremity of the short arm at F; the weight W is dependent from the extremity of the long arm at A; and P is the power. In this lever, the power acts with considerable disadvantage, or with small effort; but this disadvantage is compensated by an opposite advantage, which is frequently of great importance in the operations of both nature and art. The advantage consists in the velocity with which a small power will cause the extreme point of the long arm of the lever to move over a great space. This lever, therefore, whether in nature or art, is used only when a great space has to be traversed quickly by the long arm; but in this case the power must always be greater than the weight.

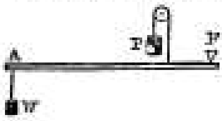


Fig. 12.

An example of this kind of lever is found in the foot-board of the turning-lathe (fig. 13). The foot of the workman presses lightly on the board or plank near the end which rests on the ground, or fulcrum, and causes the opposite extremity of the board to move in a downward direction over a considerable space. A spring overhead, or a crank, pulls the board up again by means of a string S; the workman again presses it downward, and so a constant action of the string or cord which works the lathe is easily produced.

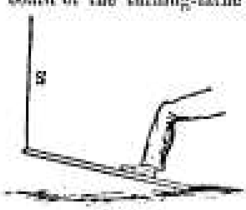


Fig. 13.

A man wielding a flail with two hands, and similar instances of using weapons, are also examples of the third kind of lever action. A similar action is observable when we use fire-tongs; a small motion of the fingers near the joint of the instrument causes the legs, which are two levers, to open or shut over a considerable space.

Before the peculiar advantages of this species of lever became known, or were appreciated, it was called the *losing lever*.

The movements in the limbs of animals are generally produced by the action of this kind of power.

Compound Levers.

When several levers of the simple kinds are connected together, and are made to operate one upon the other, the machine so formed is called a *compound lever*. In this machine, as each lever acts with a power equal to the pressure on it of the next lever between it and the power, the force is increased or diminished, according to the number or kind of levers employed. Fig. 14 represents a compound lever, consisting of three simple levers of the first kind, placed in a line, and each working on its own fulcrum. The desired object of the machine is for a small force or power at P to move or balance a large weight at W. The same rule applies, in calculating the action of this combined lever, which has already been given for the simple lever—namely, 'Multiply the weight on any lever by its distance from the fulcrum; then multiply the power

Fig. 14.

by its distance from the same point; and if the products are equal, the weight and the power will balance each other.' Or, for the form of lever in the figure, 'Multiply the length of the long arm by the moving power, and multiply that of the short one by the weight or resistance.'

It is supposed that the three levers in the figure are of the same length, the long arms being six inches each, and the short ones two inches each; required—the weight which a moving power of 1 pound at P will balance at W. In the first place, 1 pound at P would balance 3 pounds at E; we say 3, because the long arm being 6 inches, and the power 1 pound, 6 multiplied by 1 is 6; and the short one being 2 inches, we find that there are 3 twos in 6, therefore 3 is the weight. The long arm of the second lever being also 6 inches, and moved with a power of 3 pounds, multiply the 3 by 6, which gives 18; and multiply the short arm, being 2 inches, by a number which will give 18; we find that 9 will do so (9 twos are 18); therefore 9 is the weight borne at the extremity of the short arm of the second lever at D. The long arm of the third lever being also 6 inches, and moved with a power of 9 pounds, multiply the 9 by 6, and we have 54; and multiply the short arm, being 2 inches, by a number which will give 54; we find that 27 will do so (twice 27 is 54); therefore 27 is the weight borne at the extremity of the short arm of the third lever. Thus 1 pound at P will balance 27 pounds at W; or 1 ounce at P will balance 27 ounces at W—the proportions being always alike, whatever denomination of weight we employ.

In this instance, the increase of power is comparatively small, because the proportion between the long and short arms is only as 2 to 6, or 1 to 3. If we make the proportions more dissimilar, as 1 to 10, or 1 to 20, the increase of force becomes very great. For example, let the long arms be 18 inches each, and the short ones 1 inch each, and 1 pound at P will balance 18 pounds at A, and the second lever would be pushed up with a power of 18 pounds. This 18 being multiplied by the length of the lever 18, gives 324 pounds as the power which would press down the third lever. Lastly, multiply this 324 by the length of the lever 18, and the product is 5832 pounds, which would be the final weight at W which 1 pound at P would raise.

The following is a general rule for calculating the advantages of a compound lever consisting of any number of levers, whether equal or not:—Call the arms of the different levers next the power the *arms of power*, and the other arms the *arms of weight*; then, if the lengths of the arms of power and the power itself be multiplied together, the product will be equal to the continued product of the arms of weight and the weight, when the power and weight are in equilibrium.

A similar result to that of a combination of levers might be produced by only one lever, provided it were long enough; but the operation would be both clumsy and inconvenient. By combining levers, and making them act one upon another, great weights may be balanced within a small compass, and with an exceedingly small power. On this account, machines are constructed with combinations of levers for weighing loaded carts and other heavy burdens. The cart is wheeled upon a sort of table placed level with the ground, beneath which the levers are arranged; and a small weight placed on a scale attached to the extreme point of the first lever balances the load, which rests on the table above the last lever. This species of weighing-machine is often to be seen at toll-bars.

Bent Levers.

In the foregoing examples of lever powers, the levers or bars are supposed to be straight, and the powers and weights, or forces, are supposed to act at right angles with them. Levers, however, are frequently *bent* in their form, for purposes of convenience, and the powers and weights often act *obliquely*, or not at right angles.

In calculating the mechanical advantage of bent levers, the chief matter for consideration is *obliquity* in the direction of the applied power and weight. Obliquity in the action of the forces generally diminishes the mechanical advantage. Whatever be the form of the lever, or the direction of the power and the weight, the mechanical advantage of the power or the weight is always represented by *a line drawn from the fulcrum, at right angles to the direction in which the forces are respectively exerted.*

Fig. 15 is a bent lever, with the power P hanging from A, and the weight W hanging from B. In this case, both the power and the weight act at right angles to an ideal line, drawn as from E to G across the fulcrum, which strikes the lines of direction of the forces at right angles.

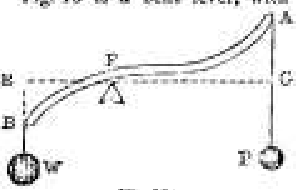


Fig. 15.

The adjoining fig. (16), representing a pronged hammer in the act of being employed to extract a nail, is another example of a bent lever. The hand of the workman is the power exerted on the long arm of the lever; the head of the hammer, where it presses on the flat surface beneath it, is the fulcrum; the prongs are the short arm of the lever, and the resistance of the nail is the weight.


Fig. 16.

THE WHEEL AND AXLE.

A lever has been defined to be 'a rod or bar of iron, wood, or any other material which is movable upon or about a prop or fulcrum, or about a fixed axis.' The illustrations which have been given show the lever only in its character of a simple bar, which is movable in some part 'upon or about a prop or fulcrum.' It is now to be shown how it acts when movable upon or about a fixed axis. When a lever is movable upon an axis, and is susceptible of being turned completely round, it assumes the character of the diameter of a wheel. In fig. 17, the simple rudiments of a wheel are represented. A and B are the two arms of a bar or lever playing upon a fixed axis at F, and which axis is the fulcrum. If we push down A, we raise B, or if we push down B, we raise A. In this manner the situation of the power and the weight is transferable from one end to the other, as in the beam of a common balance, without altering the equilibrium.

Fig. 17.

Fig. 18 is a representation of a wheel in a state more advanced to completion. Here the arms A B are connected with the arms D C, both at the centre F, and by means of the circumference or rim of the wheel. By reason of this union of parts, the central axis at F becomes the common fulcrum for every portion of the wheel; therefore, from the centre to any point of the circumference is an arm of a lever, although the line of that lever be not marked or seen, as in the case of a distinct spoke. Besides wheels with axes in the centre, there are others with axes not in the centre, called eccentric wheels. At present, however, we are treating only of those having their axes in the centre.

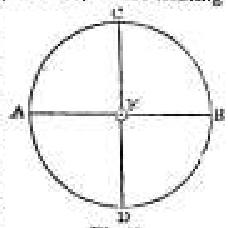


Fig. 18.

Wheels with a central axis may be rendered available as levers in various ways, according to the placing of the weight or resistance. The plan commonly pursued consists in giving to the wheel an axle, which is fixed to its arms, and placing a weight near the axle or fulcrum, to work against another weight at the circumference. Thus a machine is formed called the Wheel and Axle, which constitutes one of the simple mechanical powers founded on the lever.

The machine termed the Wheel and Axle consists of a wheel fixed upon an axle or spindle, which axle turns horizontally on its two ends in upright supports. See fig. 19. The fulcrum of the machine is common to both the wheel and the axle, and is the centre of the axle. A is the wheel, B is the axle, and H is a handle with which the machine may be turned. By turning the wheel, the axle is also turned, and a rope being fixed to the axle, with the weight W hanging at its extremity, the turning of the wheel causes the axle to wind up the rope, and so lift the weight. If, instead of turning the wheel with the hand, we wind a rope round the circumference of the wheel, in a contrary direction from that in which the axle-rope is wound, and also hang a weight of a certain heaviness, P, to its extremity, then the draught, or pulling of the wheel-rope in unwinding, will turn the axle, and so wind up the axle-rope with its weight. In this manner one power works against another, exactly as in the case of the lever. By properly apportioning the two powers in correspondence with the diameters of the wheel and the axle, the one power or weight may be made to balance the other power or weight, so as to produce an equilibrium of the machine.

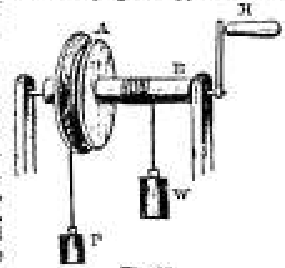


Fig. 19.

The wheel and axle form what is called a *perpetual lever*. Common simple levers act only for a short space, or by reiterated efforts, so as to be adapted for lifting an object from one place to another on the ground. The perpetual lever, formed by the wheel and axle, turns round without intermission, and is therefore suitable for lifting weights attached to a rope through any space upward from the ground without stopping.

Fig. 20 is a representation of the machine endwise, and shows how the lever operates. The line going across the machine from A to B represents the line of the lever. A is the situation of the power, F is the centre or fulcrum, and B is the situation of the weight; therefore from A to F is the long arm, and from F to B is the short arm of the lever. In other words, the long arm is half the diameter of the wheel, and the short arm is half the thickness or diameter of the axle. By widening the wheel, and so lengthening the long arm of the lever, the smaller will be the power necessary to overcome the weight on the axle or short arm; but what is gained by this mechanical advantage, is lost by the circumstance, that the power must descend

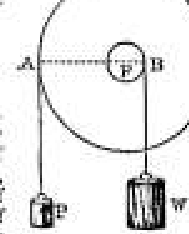


Fig. 20.

through a proportionally greater space, in order to raise the same weight through the same space in the same time.

To find what forces will balance each other, let the same rules be followed as those formerly given for the simple lever. Multiply the weight by its distance from the fulcrum (that distance is half the diameter of the axle), then multiply the power by its distance from the same point (that is, half the diameter of the wheel), and if the products be equal, the weight and the power will balance each other. Thus a power of one pound at or depending from the circumference of a wheel of twelve inches in diameter, will balance a weight of twelve pounds at or depending from the circumference of an axle one inch in diameter.

Note.—No allowance is made in these calculations for the overlaying of the rope in winding, which affects the length of both the long and short arm; but this is a matter of practical, not of theoretic import.

The principle of the wheel and axle, or perpetual lever, is introduced into various mechanical contrivances which are of great use in many of the ordinary occupations of life. One of the simplest machines constructed on this principle is the common windlass for drawing water by a rope and bucket from wells. Coal is lifted from the pits in which it is dug by a similar contrivance, wrought by horse or steam power.

The capstan in general use on board of ships for hauling or drawing up anchors, and for other operations, is an example of the wheel and axle constructed in an upright or vertical, instead of a horizontal position. In fig. 21, one of these capstans is represented. The axle is placed upright, with the rope winding about it, and having a head pierced with holes for spokes or levers, which the men push against to cause the axle to turn. This is a powerful and convenient machine on shipboard: when not in use, the spokes are taken out and laid aside.

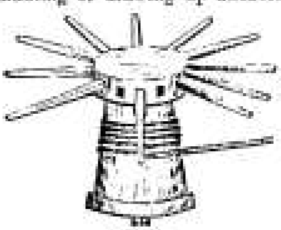


Fig. 21.

The common crane affords an excellent illustration of the wheel and axle in a combined form.

PULLEYS.

The pulley and cord is one of the primary mechanical powers. A pulley is a wheel, with a groove in its circumference, and is suspended by a central axis. In fixed pulleys, a flexible cord, which is made to pass over and hang from the upper part of the groove, has at one extremity a certain weight to be raised, and at the other extremity a power is attached for the purpose of pulling. There are two kinds of pulleys—the *fixed* and *movable*.

The annexed cut, fig. 22, represents a fixed pulley. A is the wheel, B is a beam or roof from which the wheel is suspended. P is the power hanging at one end of the rope, and W is the weight at the other end. This kind of pulley is called a fixed pulley, because it does not shift from its position. It possesses no mechanical advantage. The wheel is merely a lever with equal arms, and therefore the cord which passes over these arms gains no advantage. To raise a pound weight from the ground at the one end of the cord, the power of one pound must be exerted at the other. The object of the single fixed pulley is not to save power, but to give convenience in pulling. For instance, by pulling downwards, a weight may be raised upwards; or by pulling in one direction, a load may be made to proceed in another. The same object might be gained by drawing a cord over a fixed post or pivot, but in this case the friction of the cord would chafe or injure it; the wheel or pulley is therefore a simple contrivance to prevent friction, for it turns round along with the cord.

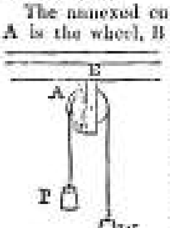


Fig. 22.

The movable pulley is in form the same as the fixed pulley, but instead of being placed in a fixed position from a beam or roof, it hangs in the cord which passes under it, and from it the weight is suspended. In fig. 23, a movable pulley is represented. A is a hook in a beam to which one end of a cord is fixed. B is the movable pulley, under which the cord passes, and proceeds upwards to C, a fixed pulley, from which it depends to P, the power or the hand pulling. The fixed pulley C is of no further use than to change the direction of the power. W is the weight hanging from B. The movable pulley possesses a mechanical advantage. The first point to be observed is, that the weight hangs in the cord; second, that the weight presses down each side of the cord equally—that is, it draws as hard at A as at C or P; third, that the consequence of this equal pressure is the halving of the weight between the two ends of the cord. The *halving of the weight* is therefore the mechanical advantage given by the movable pulley.

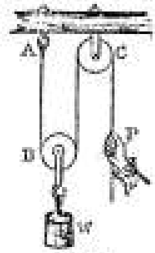


Fig. 23.

Example.—If the weight W be ten pounds, five pounds is borne by A, and five pounds by P. The case is precisely the same as that of two boys carrying a basket between them. The basket is the weight, and each boy, with his hand upholding the handle, bears only half the load, whatever it may be. If, instead of holding by the handle, the boys slip a cord beneath it, and each take an end of the cord, the case is the same.

In order to save expenditure of power in lifting weights by pulleys, it is always contrived to cause some inanimate object, as, for instance, a beam or roof, to take a share of the weight, leaving only a portion to be borne by the person who pulls. But in this, as in all cases of mechanical advantage, the saving of power is effected only by a certain loss of time, or a longer continuation of labour. To lift a weight one foot from the ground by the movable pulley, a man must pull up the cord two feet; therefore, to lift a weight, it will take double the exertion to draw it up a given height in a given time without the pulley, that it would require with the intervention of the pulley.

As the power which a man can exert by his hands is able to overcome a weight greater than the weight of his own person, this circumstance may be taken advantage of in a very peculiar manner, through the agency of the fixed pulley. As represented in fig. 24, a man may seat himself in a loop or seat attached to one end of a cord, and passing the cord over a fixed pulley above, may pull himself upwards by drawing at the other end of the cord. By adding a movable pulley and another fixed pulley to the apparatus, the exertion of pulling would be diminished one half. An apparatus of this nature, having two fixed pulleys and one movable pulley, is used by masons and other artisans in making repairs on the fronts of buildings.

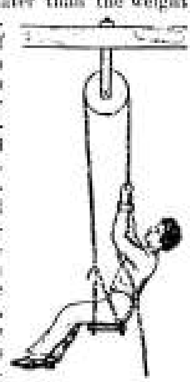


Fig. 24.

The principle upon which pulleys act is the distribution of weight throughout the different portions of the cord, so as to lessen the power necessary to be exerted by the operator. And along with this principle is the changing of the direction of the power for the sake of convenience in pulling.

According to ordinary language, the mechanical power of which we are treating is called the power of the pulley; but, in reality, as has been just shown, the pulley has no power in itself. The power of the machine is in the cord. *It is in the equal tension of the cord through its whole length, by which the weight is distributed upon intervening points, that the machine offers any mechanical advantage.*

In all cases in which cords are drawn tightly, so as to hold objects in close contact, the same species of power or mechanical advantage is exemplified. For instance, in drawing a cord in lacing, or a thread in sewing, this distribution of power is observable. If all the power which is distributed throughout the sewing of a single pair of strong shoes were released and concentrated in one main draught, it would in all likelihood be a power sufficient to lift one or two tons in weight.

Technically, the wheel of a pulley is called a *sheave;* for protection and convenience, this sheave is ordinarily fixed with pivots in a mass of wood called a *block;* and the ropes or cords are called a *tackle*. The whole machine, fully mounted for working, is termed a *block and tackle*. By causing a wheel and axle to wind up the cord of a block and tackle, the power of the lever is combined with that of the pulley in the operation.

There is no assignable limit to the power which may be exerted by means of pulleys. The machine may be constructed to raise with ease any weight which the strength of materials will bear, provided the combination is not so complex as to exhaust the power by the friction produced.

The power of pulleys is increased by a combination of wheels or sheaves in one tackle. There are different kinds of combinations or systems of pulleys. In some there is only one fixed pulley, and in others there are several. The following are examples of different combinations of pulleys:—

Fig. 25 represents a compound system of pulleys, by which the weight is distributed through four folds of the same cord, so as to leave only a fourth of the weight, whatever it may be, to be raised by the operator. In this illustration, the cord number 1 bears one fourth of the weight; the cord number 2 bears a second fourth; the cord number 3 bears a third fourth; and the cord number 4 bears a fourth fourth. Here the mechanical advantage ceases. For although the cord number 4 passes over the topmost fixed pulley down to the hand of the operator, no more distribution of power takes place; this topmost pulley being of use only to change the direction of the power. The person who pulls has thus only a quarter of the weight to draw. If the weight be one hundred pounds, he has the labour of pulling only twenty-five pounds.

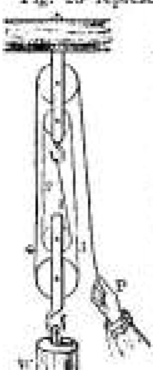


Fig. 25.

Thus it is observable that the diminution of weight is in proportion to the number of movable pulleys. To calculate the expenditure of power or diminution of weight, therefore, we have only to multiply the number of movable pulleys by two, and the product shows the power to be exerted. Two movable pulleys multiplied by two, gives 4; therefore a fourth of the weight is the power required; and so on. The addition of a single movable pulley to any system of pulleys, at once lessens the apparent weight one-half, or, in other words, doubles the effect of the power; but every such addition causes more time to be spent in the operation, there being at every additional fold of the cord more cord to draw out, and also more friction to overcome.

In the annexed system of pulleys (fig. 26), a series of movable pulleys, with different cords, are made to act successively on one another, and the effect is doubled by each pulley. At the extremity of the first cord, a power of one pound depends. This cord, marked 1, by being drawn below a movable pulley, supports two pounds—that is, 1 pound on each side. The next cord, marked 2, in the same manner supports four pounds, or 2 pounds on each side. The next cord, marked 4, supports eight pounds, or 4 pounds on each side. Thus 1 pound at P supports 8 pounds at W. If another movable pulley were added, the 1 pound at P would support 16 pounds; and so on.

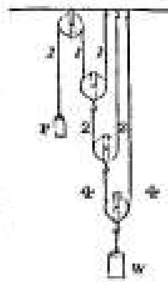


Fig. 26.

In working pulleys, the power must be applied in a line perpendicular to, or parallel with, the weight—that is, straight above the weight—in order to produce the full efficacy of direct force. If the power be applied obliquely—do not draw fair up—there will be a loss of power in proportion as the line of draught departs from the perpendicular.

Pulleys are used chiefly on board of ships, where blocks and tackle are in constant requisition for raising and lowering the sails, masts, and yards. They are likewise in considerable use by house-builders and others, in connection with the wheel and axle, for raising or lowering heavy masses of stone and other articles.

Fig. 27 is a representation of a system of pulleys commonly used in practical operations. Three movable pulleys are enclosed in the block A, and three fixed pulleys are enclosed in the block B. Suppose, therefore, that the weight W, in this case, is six hundred pounds, the hand P pulls it upwards by exerting a force of one hundred pounds. A combination of pulleys resembling this is used in turning kitchen jacks. The weight in sinking draws off the cord from a spindle, by which motion the jack is turned. In order that a considerable weight falling slowly through a comparatively small height may keep the jack in motion for a long time, as many as ten or twelve movable and fixed pulleys are used.

Fig. 27.

THE INCLINED PLANE.

A horizontal plane is a plane coinciding with that of the horizon, or parallel to it; when the plane is not level or horizontal, but lies in a sloping direction, with one end higher than the other, it is said to incline, or is called an *inclined plane*. In fig. 28, A B is the *horizontal*, and A C the *inclined* plane.

Fig. 28.

The inclined plane, as already stated, is a primary mechanical power. The object which is accomplished by it is the raising of weights to considerable elevations, or the overcoming of resistances by the application of lesser weights and resistances; or, making a small power overcome a greater.

To raise a load of a hundred pounds to an elevation of fifty feet by a direct perpendicular ascent, and without using any mechanical advantage, the power exerted must be a hundred pounds, or equal to the weight to be overcome. If, instead of raising the load directly upwards, we raise it by the gradual ascent of an inclined plane, the power required is less than a hundred pounds, and the diminution is in proportion to the smallness of rise in the inclined plane. But this saving of power, as in all other instances of mechanical advantage, is accomplished only by a corresponding loss of time.

In drawing a load, as, for instance, a loaded carriage, along a horizontal plane, the resistance to be overcome is chiefly the friction of the load upon the plane. If there were no friction or impediment from inequalities of surface, and if the load were once put in motion, it would go on moving with the smallest possible expenditure of power.

In drawing a load up an inclined plane, ordinary friction has to be overcome, and also the gravity of the body, which gravity gives it a tendency to roll down to the lowest level. In this constant impulse to descend, it is not at liberty to pursue the same line of descent as bodies falling freely from heights. It falls or rolls down as much less speedily than a free falling body (omitting the loss by friction), as the length of the inclined plane is greater than its height. A freely descending body falls about 16 feet in the first second; and a body rolling down an inclined plane, rolls just as many feet the first second as the number of feet of inclination is in sixteen feet. If the inclination be one foot in sixteen, the body rolls down one foot; and so on.

Any body, in being drawn up an inclined plane by a power parallel with the plane, presses at right angles with the plane. The common expression is, that the reaction of the plane upon the object is perpendicular to the plane. When an object, as a ball, rests upon a horizontal plane, its pressure is at right angles with the plane; or, what is the same thing, the reaction or resistance of the plane is at right angles with it. This is seen in fig. 29, in which a ball is represented lying on a level plane, with the line of pressure A passing down to B, which line is at right angles with the plane. Suppose, then, that the end of the plane at C is elevated to D, as in fig. 30, so as to form a slope; in this case the line of pressure of the ball on the plane is also moved, so as still to be at right angles with the inclination.

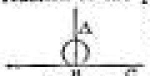


Fig. 29.

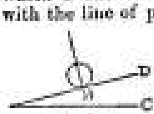


Fig. 30.

The power which is required to be sustained for the purpose of overcoming friction or inequalities of surface on level planes, is for the purpose of drawing the load up or over the inequalities.

The amount of power corresponding to different weights and inclinations of the plane has been correctly ascertained; hence the following rules:—

First.—The quantity of weight is great in proportion to the inclination of the plane; consequently, so is the difficulty of raising greater, and the rate of elevation or motion slower.

Second.—To overcome the weight or resistance, and the slowness of movement, a corresponding increase of power must be given.

Third.—The smaller the inclination, so is the pressure of the weight on the plane the greater.

Fourth, or Special Rule of Calculation.—Whatever is the unit of inclination in a given length, the same is the unit of weight that can be lifted, and the unit of power to be exerted.

If the inclination of a road be one foot in ten, *one-tenth* is called the unit of inclination; hence, *one-tenth* part of the nominal weight of the load has to be lifted; and a power to draw this one-tenth part of the load has to be exerted. Or, to put the case in other words:—If the road rise one foot in ten, there is in the ten only one foot of perpendicular height to be lifted through; and the weight at any point of the ten feet is only a tenth of what it would be if it were to be lifted through a perfect perpendicular ascent of ten feet.

The reason is now perceived why a small power overcomes a greater in the case of draughts upon inclined planes. The load is, as it were, lifted by instalments. Partly supported as it advances, and always supported more completely the smaller the inclination, the weight of the burden is apparently lessened by merely taking the rise gradually and slowly. If we suppose a case of two roads, the first rising one foot in twenty, and the second rising one foot in fifty, a loaded carriage will be found to go over the fifty feet of the one with precisely the same expenditure of power that would be required to make it go over the twenty feet of the other—that is, always providing that friction and other circumstances are alike.

Fig. 31 represents a supposed case of two inclined planes of the same height, but different slopes, meeting together at the top, with a weight resting on each, P and Q, hanging by a string, which passes over the pulley M. If the length of the longest plane from A to M be two feet, and that of the shorter from B to M be one foot, then two pounds at Q, on the short side, will balance four pounds at P, on the long side; and so on in this proportion, whether the planes be longer or shorter. In this manner, weights moving on two adjoining inclined planes may be adjusted so as to balance each other, although the inclinations be different; and they are so made to act on various sloping railways connected with public works, where one wagon descending on one plane is made to draw up another wagon on another plane.

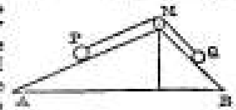


Fig. 31.

An inattention on the part of our forefathers to these exceedingly simple principles of mechanical science, led them to form roads over steep hills, pursuing, as it was imagined, the best routes, because they were the straightest in a forward direction. In modern times, this error has been avoided by enlightened engineers, and roads are now constructed with as few risings and fallings as possible. When roads have necessarily to be carried to the summits of heights, they are very properly made either to wind round the ascent, or to describe a zig-zag line of direction. The drivers of carts are aware of the saving of labour to their horses by causing them to wind or zig-zag up steep roads instead of leading them directly forward.

The inclined plane is resorted to for a saving of labour in many of the ordinary occupations of life. By it loaded wheelbarrows are with comparative ease wheeled to considerable elevations in house building and other works of art; hogsheads are rolled out of or into wagons, and ships are launched into or drawn from the water, the inclined plane being as useful in giving facilities for letting down loads as in drawing them up. It is also by inclined planes that we reach the higher floors of a house from the ground, or attain other elevations. For all such purposes, the inclined plane is formed with steps to insure our safe footing. All stairs or flights of steps are inclined planes. A ladder forms a steep inclined plane.

THE WEDGE.

The inclined plane has been described as being fixed or stationary—as, for instance, a common ascending road, or a sloping plank, upon which the weights are moved. It has now to be viewed as a *movable plane*, in which form it suits many useful purposes.

When an inclined plane is movable, and the load or weight which it affects is at rest, it is called a *wedge*. The wedge is therefore a mechanical power, founded on the principle of the inclined plane.

The wedge is an instrument or simple machine, consisting of a solid body of wood, iron, or some other hard material, and is triangular in form. (See fig. 32). Here the wedge is seen to taper from a thick end or head at B to a thin edge or point at A. This, however, is only the more common form of the wedge. It is made with sides of various angularities or degrees of slope; and in some cases it possesses a flat and a sloping side. When it slopes on both sides, it consists of two inclined planes joined together; and when one of its sides is flat, it acts as only one inclined plane. The wedge is employed as an instrument for cleaving solid masses asunder, to compress bodies more closely together, and to move great weights through small spaces. Fig. 33 is a front view of a wedge in the act of splitting asunder a piece of timber. The power employed to

Fig. 32.

force the wedge forward, is either repeated blows with a mallet or hammer, or the gradual pressure of a weight. In general, the power is applied by rapid strokes, or quick applications of some kind of external pressure.

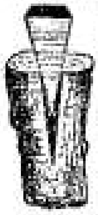


Fig. 33.

The rules for calculating the power of the wedge are similar to those for the inclined plane. In proportion as the inclination or angularity is great, so is the resistance greater, and the power must be greater to overcome it. Thus, if the wedge be of short dimensions, and thick at its head, it will require a greater power to move it than if it be long, and thin in its form. The resistance offered to the wedge of equal sides, when the pressure is equally applied, is, as in the case of the inclined plane, at right angles with the sides. See fig. 34, in which the oblique cross lines represent the direction of the pressure passing at right angles through the sides, and meeting at the centre.

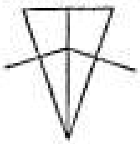


Fig. 34.

It is difficult to calculate the precise power of the wedge, for much depends on the force or the number of blows which may be given to it, together with the obliquity of the sides, and the power of resistance in the object to be split. In the splitting of timber, for instance, the divided parts act as levers, and assist in opening a passage for the wedge.

The wedge is the least used of the simple machines, but the principle upon which it acts is in extensive application. Needles, awls, bodkins, and driving nails are the most common examples. Knives, swords, razors, the axe, chisel, and other cutting instruments, also act on the principle of the wedge; so likewise does the saw, the teeth of which are small wedges, and act by being drawn along while pressed against the object operated upon.

The principle of the inclined plane, which is the basis of that of the wedge, is particularly observable in the action of the razor and the scythe, both of which cut best by being drawn along the materials against which they are applied. When the edge of a scythe or razor is examined with a microscope, it is seen to be a series of small sharp angularities of the nature of the teeth of a saw.

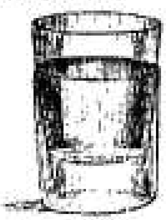


Fig. 35.

The principle of the wedge operates in the case of two glass tumblers, one placed within the other, as in fig. 35. A very gentle pressure applied to the uppermost tumbler would be sufficient to burst the lower. At every little advance of the uppermost tumbler, it acts more and more as a lever power on the rim of the lower, and at last overcomes the resistance, and fractures the vessel.

THE SCREW.

The screw is the fifth, and usually the last mentioned mechanical power. Like the wedge, it is founded on the principle of the inclined plane.

The screw consists of a projecting ridge winding in the form of an inclined plane, and in a spiral direction, round a central cylinder or spindle, similar to a spiral road winding round a precipitous mountain. Fig. 36 is a representation of a common strong screw used in various mechanical operations. The projecting ridge on the spindle is technically called the *thread*. The thread is not always made in this square projecting form; it is frequently sharpened to a single thin edge, as in fig. 39, but this does not affect the principle of the machine.

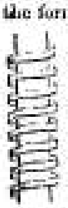


Fig. 36.

One circumvolution or turn of a thread of a screw is, in scientific language, termed a *helix* (plural *helices*), from a Greek word signifying winding or wreathing. The spiral winding of the thread is called the *helical line*.

The helices of a screw do not necessarily require to have a central spindle. They may form a screw of themselves, and do so in the case of the common cork-screw (fig. 37). A screw of this pointed or tapering form, in penetrating a substance, possesses the advantage of the inclined plane in three ways—first, by the gradual thickening of the substance of the thread from a sharp point; second, the gradual widening; and third, the gradual ascending of the thread.

Fig. 37.

The screw acts on the principle of the inclined plane, and this is obvious from the consideration of the nature of the threads. If we were to cut through the turns of the threads straight from top to bottom, and draw them out to their full extent, each separate and retaining its own inclination, we should find that they were so many inclined planes. In the annexed cut, fig. 38, one entire turn of the thread is thus drawn out, reaching from *b* to *a*, and is seen to form an inclined plane. If not drawn out, it would wind down to *c*; therefore, while a weight is raised by one turn of the screw over the limits of one thread, or from *c* to *b*, it has actually been carried up the inclined plane from *a* to *b*.

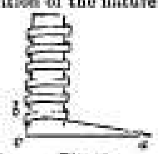


Fig. 38.

The screw has no power by itself. It can operate only by means of pressure against the threads of another screw which overlaps it and holds it. This exterior screw, which is technically called a *box* or a *nut*, consists of a block with a central tube cut out in spiral grooves so as to fit with perfect exactness to the screw which has to work in it. Fig. 39 represents both screws in combination. M is the box or nut through which the screw passes; L is a lever inserted into the head of the screw, for the purpose of turning it.

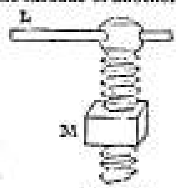


Fig. 39.

The object required by the use of the screw is to apply force or pressure. To produce the intended effect, either the outer or inner screw—that is, either the nut or the screw—must be fixed. If the screw be fixed at one extremity, say at the top, to a solid body, the nut may be turned round it so as to move from the bottom to the top; and if the nut be fixed, held fast by some solid body, the screw in the same manner may be turned round till it reach its extremity. Thus either the screw or the nut may be forced in such a way as to squeeze or press any object presented to it.

Practically, the screw is never used as a simple machine; the power being always applied by means of a lever, passing either through the head of the screw or through the nut. The screw therefore acts with the combined power of the lever and inclined plane; and in investigating the effects, we must take into account both these simple mechanical powers, so that the screw now becomes really a compound machine.

In the inclined plane, as has been seen, the less it is inclined, the more easy is the ascent, though the slower is the process of rising to a certain elevation. In applying the same principle to the screw, it is obvious that the greater the distance is betwixt the threads, the greater or more rapid is the inclination, and consequently the greater must be the power to turn it under a given weight. On the contrary, if the thread inclines downwards but slightly, it will describe a greater number of revolutions in a given space, so as to diminish the distance betwixt the threads, and the smaller will be the power required to turn the machine under a given weight; therefore the finer the screw, or the nearer the threads to each other, the less the power will require to be for a given resistance.

Suppose a case of two screws, one having the threads one inch apart, and the other half an inch apart; then the force which the first screw will give with the same power at the lever, will be only half that given by the second. The second screw must be turned twice as many times round as the first, to go through the same space. At the lever of the first, two men would raise a weight to a given height by making one revolution; while at the lever of the second, one man would raise the same weight to the same height by making two revolutions.

It is apparent that the length of the inclined plane up which a body moves in one revolution is the circumference of the screw, and its height the interval between the threads. The proportion of the power would therefore be—'as the circumference of the screw is to the distance between the threads, so is the weight to the power.' By this rule, the power of the screw could alone be found, provided the action of the machine was not affected by the lever which works it. As that is the case, the circumference described by the outer end of the lever employed is taken instead of the circumference of the screw itself.

The rule by which the true force of the screw is calculated, is by multiplying the circumference which the lever describes by the power. Thus—*The power multiplied by the circumference which it describes, is equal to the weight or resistance multiplied by the distance between the two contiguous threads.* Hence the efficacy of the screw may be increased, by increasing the length of the lever by which it is turned, or by diminishing the distance between the threads. If, then, we know the length of the lever, the distance between the threads, and the weight to be raised, we can readily calculate the power; or, the power being given, and the distance of the threads and the length of the lever known, we can estimate the weight which the screw will raise.

Suppose the length of the lever to be forty inches, the distance of the threads one inch, and the weight 8000; required—the power, at the end of the lever, to raise the weight. The lever being 40 inches, the diameter of the circle which the lever describes is double that, or 80 inches. Reckoning the circumference at thrice the diameter (though it is a little more), we multiply 80 by 3, which gives 240 inches for the circumference of the circle. The distance of the threads is one inch, and the weight 8000 pounds. To find the power, multiply the weight by the distance of the threads, and divide by the circumference of the circle.

$$8000 \times 1 = 8000 \div 240 = 33\tfrac{1}{3}$$

Thirty-three and a third is the product, and it would require that power or number of pounds to raise the weight. This, however, is only in theory. In practice, a third of the amount of power would require to be added to overcome the friction of the machine.

In the ordinary working of the screw, velocity is incompatible with great power. This is a truth, however, which applies only to a screw with one thread. There is a way of making a screw by which great velocity and power may be combined. This is done by forming the screw with two, three, or more threads. To understand how this is accomplished, we have only to conceive the idea of a screw with one thread, very wide betwixt its turns, and then imagine one or two other threads placed so as to fill up the intervals; thus composing a fine close screw. And as by this means all the threads descend with equal rapidity, we have a screw which will not only descend with great velocity, but which will apply a very great degree of pressure. A screw of this nature is used in the printing press, by which a pressure of a ton weight is applied instantaneously by a single pull of a lever.

The most common purpose for which the screw is applied in mechanical operations, is to produce great pressure accompanied with constancy of action, or retention of the pressure; and this quality of constancy is always procurable from the great friction which takes place in the pressure of the threads on the nut, or on any substance, such as wood, through which the screw penetrates.

The common standing-press used by bookbinders for pressing their books affords one of the best examples of the application of the screw to produce great pressure (fig. 40). The screw A has a thick round lower extremity B, into holes in which the lever is inserted. This extremity B is attached by a socket joint to the pressing-table C, so that when the screw is turned in one direction, the table sinks, and when turned in another, the table rises. The books D lie upon a fixed sole S, and are thus between the table and the sole. H is a cross beam above, in which is the box or overlapping screw, to give the necessary resistance.

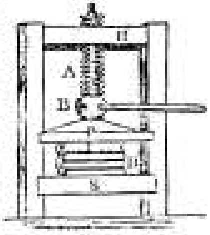


Fig. 40.

MECHANICAL COMBINATION AND STRUCTURE.

Mechanical action is applied to the action of forces that produce no change in the constitution of bodies, and is therefore distinguished from chemical or any other species of action, in which change of constitution is less or more effected. Great changes are continually taking place in nature and art by mechanical action. Mechanical action generally implies movement or change of place, and in most cases alteration of external features and circumstances. The whole of the planetary movements are mechanical; the motions of water and winds are mechanical; and the new appearances produced in art by placing different objects together are mechanical.

The action of forces upon solids, or mechanical action, is taken advantage of by mankind for the production of numerous useful results in the arts. And success in attaining these results depends in a great measure upon the knowledge we have of the principles of mechanics, and the skill and care we use in applying them. When skill, care, and ingenuity are brought fully into operation for these results, very great wonders are in many instances achieved. But where there is ignorance or negligence, the object in view may not only be defeated, but very mischievous consequences may take place.

Example first.—If a tall mast or beam break through at two-thirds of its height, and the two fractured ends be simply placed together and tied with a rope, the upper piece will, by the action of a small force, again fall. It will act like *the arm of power of a lever* against the rope, which is the *weight*; and as this weight is inconsiderable, the arm of power will preponderate. But if we take the two pieces and saw each of them lengthwise, so as to make four pieces, and then, as represented in fig. 41, lay a short piece alongside of a long piece, and another long piece on the top of the first short piece, with the second short piece opposite to this second long piece, the whole will be effectually *spliced* together; in such a case, with the aid of an overlapping rope, the beam will in all likelihood be stronger than it was before it was fractured. The cause of its being stronger, at least of its remaining firm, is, that the weaker part at one side is supported by a stronger part on the other side. Thus, by skilfully taking advantage of certain forces acting in connection with solids, we are able to rear a structure of the utmost possible strength.


Fig. 41.

Example second.—If a man, in making repairs upon the outside of a building, project a plank from a window for the purpose of standing upon it, and if he proceed to place himself near the outer extremity of the plank, without having placed a sufficient counterbalancing weight at its inner extremity, he will assuredly be precipitated to the ground, and perhaps killed; because the *gravity* of his body acted like a *power*, on the arm of a lever, while the lever was without a sufficient *weight* to preserve the apparatus in equilibrium. From such neglects of the operation of forces in nature dreadful consequences frequently ensue.

The study of the operation of mechanical forces, along with experience, teaches that there are certain bulks, positions, and forms of bodies which produce the greatest strength for purposes of art:—

The strength of beams or masses of the same kind and bulk, and fixed in the same manner, in resisting a transverse force which tends to break them, is simply as their breadth, as the square of their depth, and inversely as their length—that is, the thicker and shorter they are, they are the stronger. Thus if a beam be twice as broad as another, it will also be twice as strong; for the increase of breadth doubles the number of the resisting particles. By making the beam double the depth, the strength is four times as great; because the number of fibres is doubled, and the lever by which they act is also increased.

But this increase of strength, by increasing bulk, has a practical limit. It is found that in increasing the dimensions of a body, or combination of bodies, preserving all proportions the same, *the weight increases more rapidly than the increase of strength, or power of endurance*. This is one of the most important principles in mechanical science, and ought to prevent undue extension in structural arrangements.

Take a block of stone, and fix one end of it into a wall, leaving its other end projecting. By this arrangement of position, each particle of matter in the block acts as a weight pulling downwards as with a lever, the fulcrum of the lever being at the point of support, and the particles of matter in the mass forming at once the arm of power and the weight. Hence every particle we add to the length of the block adds to the length of the arm of the lever, and increases the weight. If we add to the block beyond a certain length (whatever may be its constitutional strength), we shall certainly cause the mass to break, and fall, from the effect of gravity, upon the outer extremity.

A similar lever action takes effect in the case of blocks or beams supported at both ends, the only difference being, that, in extending them to an undue length, they will break in the middle, or at the weakest point between the two supports. The strength of a beam supported at both ends is twice as great as that of a beam of half the length, which is fixed only at one end; and the strength of the whole beam is again increased if both ends be firmly fixed, as into a wall.

In the case of fibrous or grained materials—as, for instance, wood—the body sustains the greatest pressure when the weight is applied to the grain endwise, or to the beam longitudinally. The nearer that the pressure can be applied to any beam endwise, the better. Thus a beam supports most weight on its upper end, the other end being fixed to the ground, and its strength is next greatest when the pressure is applied to it leaning at top against another beam. This is exemplified in the angular roofs of houses, in which two beams lean against each other like the two sides of the letter A. In arranging beams to support great weights, as in building bridges, each beam is made to push obliquely upward with one end, while it pushes obliquely downward with the other, and thus an extensive combination of beams is firmly supported.

In rearing structures consisting of beams, it is an important point to convert, as far as possible, by mode of erection, cross or transverse strains into longitudinal strains, or into forces acting on the ends of beams in the direction of their length.

Nature appears to have designed that strength of structure should be accomplished with the least expenditure of material. It is obvious that, if trees and animals were made many times larger than we now find them, and of the same kinds of substance, they would be borne down by their own weight. Small animals endure greater comparative violence, and perform greater feats of strength, in proportion to their size, than large ones. The largest bulk which a human being can possess in his person, at the same time retaining activity of motion, is not more than is usually seen in well-grown men.

The same principles relative to mechanical strength apply to contrivances in the arts. As already stated, the strength or power of endurance in a material does not increase in proportion as the weight increases; hence there is a practical limitation of the magnitude of machines and other structures. For example, a bridge or roof of beams may be very strong when of small or moderate size, but if the dimensions be extended beyond a certain limit, the structure will fall, by not being able to support its own weight.

The strength or power of endurance of pressure upon a fixed body is greatly increased by giving the body a certain form. The strongest form in nature or art is that of an *arch*, which is a skilful disposition of parts, forming a convex and concave side, the convex side being that upon which the pressure is applied. The arch, which takes its name from *arcus*, a Latin word signifying a *bow*, may be either a portion of a circle or ellipse, or entirely rounded in form. Whether shaped like a bridge, a round tube, or the shell of an *egg*, the principle which causes the power of endurance of pressure is the same. The principle of endurance consists in the particles of the arched body bearing upon each other like a series of wedges (see fig. 42),

Fig. 42.

thus causing a compression of particles on the concave side of the circle, which enables the mass to bear an enormous pressure on the convex side. Indeed the greater the pressure is (to a certain extent) perpendicular to the convexity, so also the compression and power of resistance become the greater.

PRACTICAL MACHINERY.

Machines are usually formed of wood, iron, steel, brass, or other durable materials, with sometimes leather and cordage as part of the apparatus. In the construction of every machine, four objects are particularly desirable—*1st*, Strength or durability of materials; *2d*, Simplicity of arrangement of parts; *3d*, Exactness of fitting of one part to another; and *4th*, Easiness and correctness of motion. It is a general and well-recognised principle in mechanics, that the *fewer the parts* are in a machine, and the *more simple its construction*, the better.

Machines act from the impression of a certain power or force communicated to them. Whatever be the amount of power they receive, that amount they expend in their action. They cannot in the smallest degree increase the power. They can only convey, regulate, and distribute the quantity of power which has been communicated to them.

The power communicated to machines is derived from various sources—as human labour, the power of horses or other animals, the force of wind, water, or steam, or any other active agent which may be found suitable. Sources of power are technically called *moving forces*, or *first movers*.

Of the original impressed power, each moving part of the machine uses a certain portion. If the whole power which enters a machine be supposed to consist of 1000 parts, this large quantity is dispersed in various small quantities through the mechanism; some wheels taking perhaps 10 parts, others 5 parts, a third kind 1 part, a fourth a fractional part, friction another part, and so on, till the whole 1000 parts are expended. In some large cotton, flax, or silk-spinning establishments, a single water-wheel or steam-engine turns several thousands of spindles; each spindle, consequently, consumes a minute fraction of the originally-impressed power.

Whatever be the nature of the moving forces, it is generally sufficient for all purposes that they produce in the first instance *rotatory* or *circular motion*, and either in a horizontal or vertical direction. It is, however, indispensable that the power be of that magnitude which will cause each part of the machine to fulfil its assigned office. If the power be too small or weak, the machine will move languidly and ineffectually; and if too great, it will either cause the machine to move too rapidly, or at least power will be expended uselessly. In the application of moving forces, it is always a matter of importance to regulate the power to the precise wants of the machinery.

The circular motion communicated in the first instance to a machine is, by means of certain contrivances, diffused through the whole organisation, and changed into every conceivable direction; some parts being caused to revolve, others to rise and fall, a third kind to move horizontally to and fro, and so forth, in all possible ways. The various parts may also be made to move with any degree of velocity; there being methods of transforming quick into slow motion, or slow motion into quick. Most minute and complex operations are thus performed by machines with a precision which often exceeds the skill of the most expert artisan; but these operations are all necessarily marked by the quality of *uniformity of action*. As machines cannot reason, or act arbitrarily in stopping, moving, or altering their process, according to circumstances, they proceed in a blind routine, whether right or wrong, *mechanically* as it is called, and in every case less or more require the superintendence of reasoning beings. This apparent defect, however, is really advantageous. A machine, by being composed of inanimate matter, proceeds unswervingly in its assigned duty, and may be forced to accomplish tasks which it would be both inhuman and impolitic to demand from living creatures.

The purpose of machinery, therefore, is to *lessen and aid human labour*. At an inconsiderable expense, and with a small degree of trouble in supervision, a machine may be made to do the work of ten, fifty, or perhaps as many as five hundred men; and the work so simply effected by inanimate mechanism, serves to cheapen and extend the comforts and luxuries of life to the great body of the people. The following are the chief elementary parts of machinery:—

WHEELS.

A wheel moving on a central axis is a lever with equal arms radiating from the fulcrum at the centre, and is thus called a perpetual lever.

Wheels may be used in machines simply to transmit power from one point to another. This is done by means of toothed wheels. Projecting teeth or *cogs* are placed all round the circumference of a wheel, and when the wheel is turned, these teeth work upon or press against the teeth of another wheel, and so cause it to turn also, but in an opposite direction. Fig. 43 represents two wheels so working upon each other. As both of these wheels are of the same size, and consequently are levers with equal arms, they do not alter the effect of the power communicated to them. The motion of the axle in the wheel B is the same as the motion of the first axle in the wheel A. Thus power may be *transmitted* from one point to another.

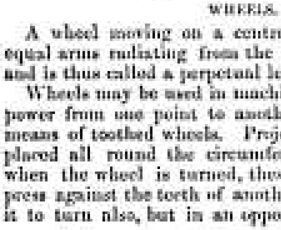


Fig. 43.

A long and large axle, in wheelwork, is called a *shaft*, and shafts of small dimensions are termed *spindles*. The terminating points of axles, shafts, and spindles, where they rest and turn upon supports, are called their *pivots* or *gudgeons*. The *sockets* upon which the gudgeons bear in turning are sometimes termed *bushes*.

WHEELS AND PINIONS.

When power has to be *accumulated* or increased in its effect in the course of its transmission, a large wheel is made to play upon a small wheel, by which means there is a diversity in the lengths of the levers. Fig. 44 is a representation of a large wheel W, working on a small wheel or pinion P. The wheel is turned by the handle C. In all arrangements in which large wheels are moved by small wheels, or small wheels by large, the small wheels are called *pinions*; and when these pinions are broad in their dimensions, they are termed *trundles*.

Fig. 44.

In this combination of a wheel and pinion, a long perpetual lever works against a short perpetual lever, by which a considerable mechanical advantage is gained. The wheel may be supposed to possess 48 teeth, and the pinion 6 teeth; hence, by one revolution of the wheel, the pinion turns 8 times, which gives the axle of the pinion eight times the velocity of the axle of the wheel; and if we suppose that the diameter of the wheel is ten times the diameter of the pinion, the power is increased in effect ten times.

Any degree of velocity greater than that of the first rotatory motion, may be imparted to the parts of a machine, by making these parts so much smaller than the primary moving parts. Thus if a large wheel, having a thousand teeth in its circumference, work upon and turn a small wheel having only ten teeth in its circumference, the small wheel will go round one time for every ten teeth of the large wheel which it touches; or in other words, it will go round one hundred times for one time of the large wheel. The respective velocities of wheels in a machine are in this manner always proportionate to their diameters or size, unless when specially arranged to be otherwise.

A combination of wheels acting as perpetual levers is represented in fig. 45. Three wheels are placed in a row close to each other, and it is supposed they are fixed by three axles to some upright object. On the side of the first wheel A, there is attached a small toothed pinion or wheel F, which, by the pressure of its teeth on the teeth of the second wheel B, causes this second wheel to turn round. The power applied to produce this motion is at the circumference of the first wheel at D. From D, then, to the centre of the pinion F, is the long arm of a lever, of which the centre of the pinion is the fulcrum; and from the centre to the ends of the teeth of the pinion is the short arm. The second wheel B having received its motion, the toothed pinion G, which is similarly attached to its side, presses against the teeth of the third wheel C, and so causes it also to turn. In this way a second lever is put in action. And the third wheel, from its circumference to the point from which the weight W depends, is a third lever. As the power or small weight P falls, therefore, from the circumference of the first wheel, the resistance W is raised, with the accumulated force of three levers acting on each other. The line across the figure represents the three levers in action.

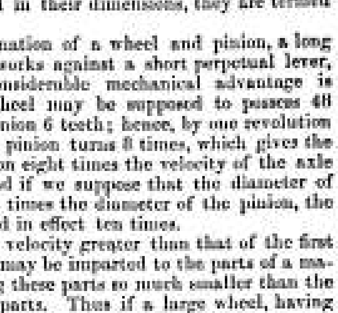


Fig. 45.

To calculate the power or mechanical advantage to be gained by such a machine—suppose the number of teeth on the first wheel to be six times less than the number of those on the circumference of the second wheel, then the second wheel would turn round only once, while the first wheel turned six times. And in like manner, if the number of teeth on the circumference of the third wheel be six times greater than those on the axle of the second wheel, then the third wheel would turn once, while the second wheel turned six times. Thus the first wheel will make 36 revolutions, while the third wheel makes only one. The diameter of the first wheel being three times the diameter of the axle of the third wheel, and its velocity of motion being 36 to 1, three times 36 will give the weight which a power of 1 pound at P will raise at W. Three times 36 being 108, one pound at P will balance 108 pounds at W.

WORKING OF TOOTHED WHEELS.

In the working of toothed wheels one upon another, or of wheels working on pinions, it is essential to set them in opposition with such exact adjustment, that the teeth of one will fall into the hollows betwixt the teeth of the other. When the teeth of each do not work with this nicety, they are apt to jar upon and break each other, and so damage the machine. In some cases teeth are made of a round or pointed form at their extremities, by which a very small degree of grinding or pressing on each other takes place. Fig. 46 is an example of a wheel and pinion with rounded and pointed teeth. From the centre of the axis of the pinion L to the centre of the wheel C, a dotted line is marked, called by mechanics the *line of centres*. The dotted circle OO round the pinion, and the dotted circle PP round the wheel, indicate the true point of working or contact of the teeth upon each other. These two circles are seen to join with exactness at A.

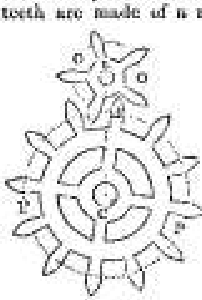


Fig. 46.

ALTERING THE DIRECTION OF MOTION.

Motion often requires to be *altered in its direction* in the course of its transmission. For example, rotatory horizontal motion requires to impart rotatory vertical motion, or rotatory vertical to impart rotatory horizontal. By means of a peculiar mode of setting the wheels, and a corresponding peculiarity in the shape of their teeth, any alteration may be effected in the direction of the motion. Fig. 47 represents a plan of changing the direction of motion. A is a pinion or trundle working with its shaft horizontally on a wheel B, whose shaft is turning vertically. As the case may happen to be, the horizontal movement is causing the vertical movement, or the vertical movement is causing the horizontal movement.

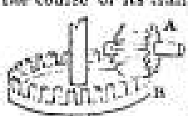


Fig. 47.

Fig. 48 represents a more common plan of changing the direction of motion. The wheels in this case are bevelled. A *bevel wheel* is one with teeth placed in a sloping or oblique direction on its circumference. When two bevel wheels are placed at right angles to each other, their respective teeth work against each other, and so a harmonious joint motion ensues. This is exemplified in the figure, in which a horizontal shaft with a bevel wheel is seen turning a smaller bevel wheel above it, placed on a vertical shaft.

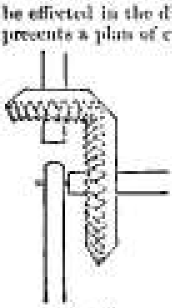


Fig. 48.

TRANSMISSION OF POWER BY BELTS.

A common mode of transmitting power from one point to another, when the interval is considerable, is by a flat leathern band, strap, or belt, communicating from a wheel at the source of power to a wheel connected with the machine. The wheels upon which straps work are usually called *pulleys*. They have flat and broad rims, and these rims have sometimes narrow ledges, to prevent the belt from slipping off. The rims must also be rather rough on the surface, so as to give the belt a sufficient friction or power of pulling in performing its revolutions.

Fig. 49 represents the transmission of power by a belt. A is the first pulley, which has received the power from its source, and C is the second pulley, moved by a belt, which passes over both pulleys. In this case, the motion of A is transmitted by the belt to C, which it causes to turn in the same direction as A. If these two pulleys were of precisely the same diameter, and the belt did not relax or slip, the second pulley would unavoidably go at the same velocity as the first, because the belt has exactly the property of a toothed wheel, and simply transmits the power it has acquired. As C appears to be somewhat smaller than A, it would consequently turn more frequently; therefore we have here an example of the mode of increasing the velocity while transmitting power. Fig. 50 represents two pulleys moving in different directions by means of a belt. The large pulley is supposed to be that which has received the power from its source. The belt, after leaving it, is crossed, and thereby causes the small pulley to move round in a direction contrary to that of the first.

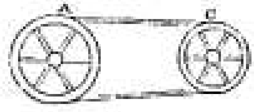


Fig. 49.

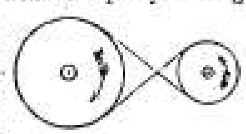


Fig. 50.

SHAFTS AND PULLEYS.

When power requires to be carried to a distance beyond that which belts can conveniently manage, the transmission is effected by a long shaft; and if it be necessary to change and rechange the direction of the motion, bevel wheels are added. Or the transmission may take place by a long flat chain acting like a belt, but caused to travel over small wheels or pulleys, to prevent the chain hanging down in any part of its course. A chain of this nature is called an *endless chain*.

Motion is often required to be communicated to many different machines, *at different points*, from one source of power. This is effected by means of a shaft and pulleys. From the pulley which receives the first motion, a belt is sent to a pulley fixed upon a shaft, which shaft is generally hung horizontally from the roof over the machines. As the shaft turns through its whole extent, it is able to turn pulleys fixed at any point upon it, and from these pulleys belts are sent down to pulleys at the respective machines.

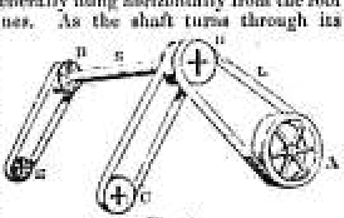


Fig. 51.

Fig. 51 represents an apparatus of a shaft and pulleys. A is the pulley receiving motion from the source of power, and, by means of the belt L, turns the pulley B on the end of the shaft S. At the same time, the pulley D at the opposite end of the shaft is turned. From a pulley on the shaft situated close to B, a belt descends to turn C, and from D another belt descends to turn E. Thus an extended axle or shaft from C will turn a machine, and an extended axle or shaft from E will turn another machine.

Shafts with pulleys, working on the plan now stated, are to be seen at almost every manufactory in which machinery is employed; and the power, by means of bevel wheels and upright connecting shafts, is carried upwards from storey to storey in a building, giving motion to hundreds of wheels, spindles, and other parts of the mechanism.

CHANGING VELOCITY.

It is sometimes necessary that a machine, or part of a machine, should be propelled with a velocity which is not equable, and is continually changing from fast to slow, and slow to fast. This happens in cotton-mills, where it is necessary that the speed of certain parts of the machinery should continually decrease from the beginning to the end of an operation. To effect this, an apparatus is used as represented in fig. 52. Two cones, or conically-shaped drums, are used, having their larger diameters in contrary directions. They are connected by a belt, which is so governed by proper mechanism, that it is gradually shifted along from one extremity of the cones to the other, thus acting upon circles of different diameter, causing a continual change of velocity in the driven cone with relation to that which drives it. The shifting of bands from large to small wheels, and from small to large, has similar effects.

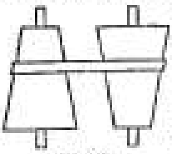


Fig. 52.

PRESERVING REGULARITY OF MOTION BY A VARIABLE FORCE.

In some mechanical contrivances, the force which is applied varies in its intensity, while the wheels of the machinery require to be kept at a uniform speed. This is generally the case when the force is communicated from a steel spring, which, after being wound up, is suffered to relax. *Fig.* 53 is a spring suited for operations of this kind. It is represented in a state of relaxation, and is wound up into a compact form by means of a spindle fixed to its inner extremity. The coiling of a strip of paper round the finger, and allowing it to unwind itself, is a familiar illustration of the action of a spring of this description. The force communicated by the relaxing of the spring varies in its intensity. The force is greatest when it begins to relax, and gradually weakens till its expansive energy is exhausted. To compensate this defect, a very ingenious plan is adopted in the apparatus of the common watch.

Fig. 53.

Fig. 54 represents the apparatus of motion of a watch, somewhat magnified. The spring is confined in a brass cylinder or barrel B. To this barrel the spring is attached by a slit at its outer extremity. The inner extremity of the spring is fixed by a similar slit to the central axis or spindle. F is a brass cone, broad at bottom, and narrow at top, with a path winding spirally round it as an inclined plane. This cone is called the *fusee*, and has also a central axis or spindle K, to which it is fixed. To a point on the lower inclined path of the fusee a small steel chain C is attached, and the other extremity of this chain is attached to the top part of the barrel. When the spring is relaxed, the chain is almost altogether round the barrel. To set the apparatus in motion, the watch-key is made to turn the spindle K, by which the chain is drawn from the barrel to the fusee, filling up the inclined path to the summit. The chain, in leaving the barrel, causes it to turn, and consequently to wind up the spring inside. The process of unwinding or relaxing ensues, and now the ingenious plan for regulating the motion is to be remarked. At first, when the force of the spring is greatest, the chain acts upon a small round of the fusee; in other words, it pulls with a small lever—for, as already explained under the head Wheel and Axle, a wheel or round object on an axis is simply a perpetual lever. In proportion as the intensity of the force weakens, and the barrel takes off the chain from the fusee, and winds it about itself, so does the chain act upon a longer lever, or so does it gain a greater lever advantage, by drawing at a wider part of a cone. Thus the gradual loss of force is counterbalanced by a gradual increase of lever advantage.

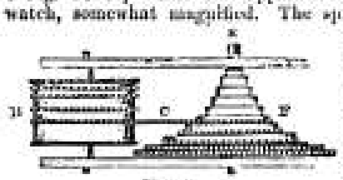


Fig. 54.

ALTERNATE OR RECIPROCATING MOTION—ECCENTRIC WHEELS.

Alternate or reciprocating motion is applied to movements which take place continually backwards and forwards in the same path. In most complex machines, both rotatory and reciprocating motion occur, and these motions may be converted into each other by various contrivances.

A common plan for gradually raising and depressing an object by machinery is that of an *eccentric wheel*; that is, one with an axis not in its centre. *Fig.* 55 represents the action of a wheel of this kind. W is the wheel, and A the axis upon which it is fixed. When the axis turns, the wheel turns with it. As the axis never moves out of its place, the wheel necessarily describes a path of gradual rising and falling in its revolutions. Suppose an object, as T, pressing upon the upper edge of the wheel, so as to accommodate itself to the motion, it is obvious that, by the action of the wheel, this object will be alternately raised and allowed to fall. Or suppose that a rod is hung from a point of the wheel near where T rests, it is similarly obvious that the rod would be raised or depressed according as the wheel turned. Thus a rising and falling motion may be effected by an eccentric wheel.

Fig. 55.

Eccentric wheels are made of different forms. According as they may be required to act, they are circular, oval, heart-shaped, or pointed at one end, and so forth—the object in each case being to produce alternate motion, by continually altering the distance of some movable part of the machine, from the axis about which they revolve. Technically, the projecting parts of eccentric wheels are called *cambs*.

In some cases eccentric wheels are not required to perform entire revolutions on their axes. It is perhaps sufficient for the purpose of the mechanism if they gradually rise to the height of their power, and then, without turning round, gradually descend by retracing their course.

When alternate rising and falling is required *thrice* by only one revolution of an axle, an eccentric wheel is used having three projecting cambs on its circumference, and as each camb comes round, it lifts and lets fall any object presented to it. An example of this apparatus is given in fig. 56. The object required is to work a heavy hammer upon an anvil for beating iron. W is the wheel with the three cambs, and it turns by an axle in upright supports. In turning, each camb, with its rounded or convex side, presses down the end of the handle of the hammer, so as to raise the heavy head H at the opposite end. After pressing down the handle and escaping, the head of the hammer falls with a heavy blow on the anvil A. There it remains till raised up and let fall by the next camb; and so on.

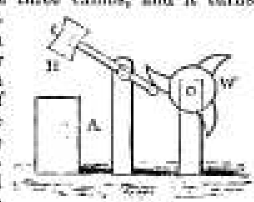


Fig. 56.

OBLIQUE ACTION.

A mechanical advantage, which is frequently of a very serviceable nature, is obtained by causing the points of two straight bars to meet each other, but fixed loosely, so as to be free to move from an oblique to a straight direction, and the reverse. The power consists in bringing the bars to the straight, by which they force asunder or press hard upon any object presented to their outer extremities. In the adjoining fig. (57), the bars are seen first in their oblique position, and next when brought towards a straight. Betwixt the two points a small hollowed piece of metal is inserted, in which the points work, and against which the power is exerted to produce the action. The straightening and bending of the apparatus resemble the action of the knee-joint in animals. The pressure produced by the forcing downwards of the outer extremity of the lower bar (the upper working against a fixed beam) is very easily and rapidly accomplished, and is almost unlimited; and these advantages, as well as the extreme simplicity of the mechanism, have led to the application of the power to the printing-press wrought by the hand, instead of screw pressure.

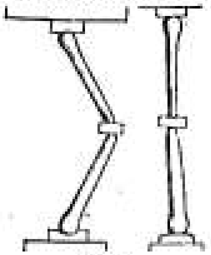


Fig. 57.

CRANKS.

The crank affords one of the simplest and most useful methods of changing an alternate rising and falling motion into rotatory motion. A crank resembles a common handle or winch for turning a machine by the hand; the chief difference being, that a rod or shaft jointed to the handle, and going up and down, works the machine. If the crank be made double, it will turn two wheels or machines.

Fig. 58 represents a double crank in action. S is the rod or shaft ascending and descending, and attached by a joint to the lower part of the crank C, which it alternately pulls up and pushes down, so as to cause the axles W W to turn a wheel at each side. Take away one of the sides of the crank and its support, and the apparatus becomes a single crank.

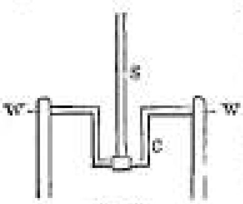


Fig. 58.

Turning-lathes, knife-grinders' machines, and similar apparatus, are usually turned by cranks wrought by an alternate pressing and raising of the foot of the operator; a rod going upwards from the foot-board to the crank causing the wheel or spindle to go round. The crank has been hitherto indispensable in the action of the steam-engine.

ACCUMULATION OF POWER.

Power is susceptible of accumulation—that is, of increasing little by little—and of being extended either gradually or in one or more violent efforts; the efforts being entirely the concentrated amount of the previous accumulation. The apparently wonderful powers displayed through the agency of levers and other simple machines are all a natural consequence of an accumulation of any degree of force into a small space; by which effects take place that could never have been accomplished by the original force. In consequence of this convenient accumulation of power, plans have been devised for establishing *reservoirs of power*, as they may be called, in connection with moving machinery.

A well-known method of accumulating power consists in suspending a heavy body by a chain or strong rope of considerable length—forming what is called by young persons a *swing*. This body may be put in motion by a very small degree of power, and will acquire a vibrating motion like a pendulum. By continuing the impulse as the body returns, it will continually acquire greater and greater force, the arcs through which it moves becoming continually larger, until at last it might be made to overcome almost any obstacle. Upon this principle, the battering-rams or engines for beating down the fortifications of towns in ancient times were constructed. The forcible expenditure of accumulated power in the swing apparatus resembles that which is observable in the case of a person occupying several minutes in bending a spring—that is, accumulating power—and then allowing the spring to unbend itself by one violent effort, which effort is nothing more than the giving out of the accumulated power.

A boy taking a race to gain force before making a leap, is another familiar example of accumulating power and expending it instantaneously. The boy is gathering up power at every step he runs, and the force of his leap corresponds exactly with the quantity of power he has acquired. In the same manner, the lifting of a hammer, axe, or other instrument to an elevation as far as our arm can reach, in order to give a blow with good effect, is a method we naturally pursue to gain an accumulation of power.

In contrivances in the arts, power is sometimes accumulated in order to be given out in the form of a rapid and effective blow. This may be done by means of a horizontal bar or lever, poised on a central axis, and loaded at each end with a heavy ball of lead or iron. After communicating to the machine a sufficient power of rotation, it will proceed with an enormous accumulated energy and momentum, till it expend its force either by friction in turning, or upon some fixed obstacle presented to it.

EQUALISATION OF POWER.

In most machines, both the moving force and the resistance to be overcome are liable to fluctuations of intensity at different times during the operation of working. For instance, when a man turns a winch or handle of a piece of machinery, he is apt to relax in his efforts for an instant from loss of strength, or from an inability to keep his attention closely and uniformly fixed to the labour he has to perform. These relaxations cause an irregularity of motion alike detrimental to the machine and to the work performed.

The irregularities in the motion of machinery, from whatever cause they rise, are remedied by giving to each machine a *reservoir of power*, from which force may be given at all times to equalise the motion according as it may be required. These reservoirs of power are usually in the form of *fly-wheels*. A fly-wheel is generally made of iron, and consists of a heavy rim or circumference, joined to a central axis by cross bars or spokes. In most cases it is placed in close connection with the first moving force, the effect of which it equalises in its passage to the machine.

OBSTACLES TO MOTION—FRICTION.

Moving bodies, as machines and wheel carriages, are less or more retarded in their velocity by friction, and the resistance of the atmosphere, while vessels moving through water are retarded by the resistance both of the atmosphere and of the liquid in which they are buoyant.

Friction is an effect of the action of rubbing of bodies against one another. This effect is produced by inequalities of surface. No such thing is found as perfect smoothness of surface in bodies. In every case there is, to a lesser or greater extent, a roughness or unevenness of the parts of the surface, arising from peculiar texture, porosity, and other causes; and therefore, when two surfaces come together, the prominent parts of the one fall into the hollow parts of the other. This tends to prevent or retard motion. In dragging the one body over the other, an exertion must be used to lift the prominences over the parts which oppose them, and this exertion is similar to that of lifting or drawing of bodies up inclined planes or over upright protuberances.

Friction acts as a retarding influence in the action of all mechanical contrivances, and a due allowance must in every case be made for it. In many instances it destroys more than a half of the power employed, and seldom destroys less than a third. However small it may be, it sooner or later causes the wearing down and destruction of mechanism, and therefore forms an insurmountable obstacle not only to the lasting duration of bodies, but to the perpetuity of motion. It is found to depend on the following circumstances:—1. The degree of roughness of the surfaces in contact; 2. The weight of the body to be moved; 3. The extent of the surfaces in contact—that is, the amount of surface presented to the action of friction; 4. The nature or molecular constitution of the bodies in friction-contact; 5. The degree of velocity of the motion; and 6. The manner of the motion.

Roughness.—It is of the utmost importance to smooth the surfaces. An apparently insignificant piece of matter, or even particles of dust, will greatly retard the motion of a body. But there is a limit beyond which it would be imprudent to smooth the surfaces of bodies having a close texture. If the surfaces be highly polished and levelled, the bodies will adhere by the effect of attraction of cohesion, even when the atmospheric air is not entirely expelled from between them, and more forcibly when the air is completely expelled. Practically, roads and similar surfaces cannot be made too smooth.

Weight.—Friction from weight differs in different bodies, and depends on concurring circumstances—as nature of surface, and so forth. Friction always increases in exact proportion as the weight increases, when all other circumstances remain the same. The parts of machinery, therefore, should be made as light as possible, consistent with strength and durability.

Extent of Surfaces.—Rough bodies are more easily drawn along when their surface of contact is narrow than when they are broad. For example, it is easier to draw two narrow brushes across each other, than two broad ones of the same weight. Friction may therefore be diminished in rough bodies by lessening the extent of surfaces in contact. But there is a limit to this diminution. If the moving surface be very thin, and that over which it moves be in any degree softer, the thin or edge surface will plough a groove in the soft one, and thus the friction will be increased, and the machine injured.

Nature of Bodies.—It is a remarkable truth, that two bodies which are of the same nature, or homogeneous, produce greater friction in movement than bodies which are different in their nature, or heterogeneous. Thus iron working against iron, steel against steel, or brass against brass, causes in each case greater friction and wearing of parts than when iron or steel is made to work against brass. This circumstance is always attended to in the construction of machinery.

Degree of Velocity.—Friction is a uniformly retarding force, except in the case of small velocities, when it is greater in proportion. The reason for its being greater in small velocities is, that in these cases time is allowed for the prominences of the moving body to sink deeply into the hollows of the surface on which it is moving, which has a retarding effect.

Manner of the Motion.—The least advantageous manner in which one body can be moved upon another, is to cause it to slide or drag. The most advantageous manner is to cause it to roll or turn. The causing of a body to roll instead of to slide, is one of the chief means of diminishing friction. The opposition presented by inequalities of surface to a rolling wheel, is overcome with ease, in proportion to the extent of diameter of the wheel. On a perfectly horizontal plane, the friction of wheels on the plane is very inconsiderable; the chief seat of friction in such cases being in the axles working in their sockets.

Friction is greatly diminished by lubricating the rubbing surfaces with an oily or greasy substance, which substance forms a medium of smooth incompressible or but slightly elastic molecules betwixt the bodies, and so prevents the tendency to grind or wear down the surfaces. Water, or any similar fluid, will also act as a medium to prevent friction; but the effects are only temporary, and would frequently be injurious, as the substance speedily evaporates and corrodes metals. Practically, fine pure oil is found to be the best lubricant for machinery.

One of the first considerations on the part of contrivers of mechanism, should be how to provide for and diminish the effects of friction in their machines. For want of forethought on this important point, thousands of ingenious schemes, which seemed perfect in the form of models and drawings on paper, have been completely frustrated when attempted to be brought into use.

Whatever may be the retarding and frequently inconvenient effects of friction in reference to the action of mechanism, it is certain that friction is indispensable in the economy of both nature and art, and serves as an essential auxiliary to gravitation. It is a property which is frequently necessary, to allow one kind of matter to possess a hold upon another, without actual cohesion. We walk and maintain our erect posture by means of gravitation and action and reaction; in other words, we are held to the earth by gravitation, and our pressure with our feet exemplifies action and reaction: but if there was no such property as friction, we should either stick to the earth by attraction of cohesion, or slide along it as upon the smoothest ice. In order to keep our feet from sliding when on ice, if we received any impulse, we either tie rough substances on our shoes, or scatter ashes in our path; and thus we receive the benefit of friction. It is by friction that rains wear down hills, and that rivers wear away their banks, by which ceaseless process the external configuration of the globe is constantly undergoing a change. The operations in art of washing, cleaning, scouring, sharpening, polishing, cutting, bruising, beating, and so forth, are all effected less or more by friction. The hold which one fibrous substance has on another, or mutual friction, permits the operations of weaving cloth, twisting ropes and threads, and the tying of one body to another. Thus friction is of universal service; and the only known instances in nature in which it seems not required, and therefore not present, are the movements of the heavenly bodies, which, as far as yet known, revolve in vacuity, and are consequently not impeded in their motions.

RESISTANCE OF AIR AND WATER.

Atmospheric air and water are fluids of different densities, and both present an obstacle to the motion of solid bodies through them.

There is a rule in respect to the resistance presented in moderate velocities which applies both to air and water. It is, that *the resistance is proportional to the square of the velocity.* For example, a velocity of twenty miles an hour causes a resistance four times greater than a velocity of ten miles an hour, for the square of twenty (which is 20 times 20, or 400) is four times the square of ten (which is 10 times 10, or 100). Thus, by increasing the velocity of bodies through air or water, we must increase the motive power in a greater proportion, in order to compensate the loss caused by resistance.

Although the above rule is nearly correct for moderate velocities, it deviates considerably from what is observable in the case of great velocities, such as that of a cannon ball. When the velocity is upwards of 1000 feet per second through the air, the quick passage of the body is supposed to cause a partial vacuum behind it, which causes a retardation of its motion.

Resistance to motion in fluids is greatly modified, also, by the form of the moving body. The form that gives least resistance is nearly that of a parabola, or a form somewhat resembling the breast of a duck, the head of a fish, or the rounded bow of a vessel, sharpened to cleave the fluid through which the body passes.

HYDROSTATICS—HYDRAULICS—PNEUMATICS.

GENERAL DEFINITIONS.

MATTER exists in three principal states—*solid*, *liquid*, and *aëriform*. These states respectively, and the various modifications of them, are the immediate result of certain principles of attraction and repulsion operating on the atoms or particles of which matter is composed.

The solid, liquid, and aëriform varieties of matter assume a position on our globe corresponding to their heaviness or density in a given volume: the solid sinks lowest, and composes the chief mass of the earth; above the solid lies the liquid variety, in the form of the ocean, lakes, and rivers; and above all is the atmosphere, consisting of an expanse of aëriform matter, which wraps the whole earth round to an elevation of from forty to forty-five miles above the highest mountains. In this great ocean of air, loaded less or more with particles of moisture from the liquids beneath, animals live, breathe, and move, and plants grow and receive an appropriate nourishment.

Though differing both in substance and appearance, the liquid and aëriform varieties of matter resemble each other in many of their properties and tendencies, and constitute the class of bodies termed *fluids*. Fluids signify bodies which will flow, or whose component particles are easily moved among each other. Some fluids are so thick and viscous, or sticky, that they can scarcely flow—as tar, honey, and some metals in a state of fusion; others flow with ease—as water and distilled spirits; while others are so light and volatile, as to be impalpable to the touch and invisible to the eye—as pure atmospheric air and various gases.

It is common to divide fluids into two kinds—*non-elastic* and *elastic*; that is, fluids which cannot be compressed into a smaller bulk, and those which are susceptible of compression. The non-elastic fluids are water, and all other varieties of liquid bodies; but recent experiments prove that the term is not strictly applicable to them. It has been found that water may be compressed in a confined vessel, to a small extent, by means of a very great pressure; and it is certain that water at a considerable depth in the ocean is more dense or compressed than at the surface: water, consequently, is an elastic substance; but as it can be compressed only with very great difficulty,* the term non-elastic fluid is not altogether inappropriate. Atmospheric air, and all gases, are elastic. They can, with little difficulty, be compressed into a much smaller volume than they ordinarily possess; and when the pressure is removed, they return to their original bulk. Some gases (as carbonic acid gas, for example) may be compressed to such an extent, as to assume the form of liquids and solids; in other words, from the condition of being perfectly invisible to the eye, they can be made to appear as a piece of solid matter, which may be touched and handled.

In treating the subject of fluids, it is convenient to refer in the first place to those which are of the liquid form, and afterwards to those which are elastic or aëriform. Pure water, at an ordinary temperature, furnishes the most suitable example of liquid bodies. Water also gives the name of the department of science which includes the laws of liquids. Thus *Hydrostatics*, from two Greek words signifying *water* and *to stand*, treats of the weight, pressure, and equilibrium of liquids in a state of rest; and *Hydraulics*, from two Greek words signifying *water* and *a pipe*, treats of liquids in motion, and the artificial means of conducting liquids in pipes, or raising them by pumps.

* The compressibility, and consequently the elasticity, of water, have been rigorously determined by the experiments of Professor Oersted. This compressibility, however, is all but inappreciable in the ordinary economy of nature; common spring water yielding only about 46·65 millionths of its bulk to the pressure of the atmosphere.

HYDROSTATICS.

In ancient times, water was believed to be an element or simple substance in nature. It is now ascertained by experiment that water is not an elementary body, but is a substance composed chiefly of two gases (oxygen and hydrogen) in a state of chemical union, and into these gases it can be resolved by an artificial process. The investigation of this subject belongs to the science of CHEMISTRY.

As a liquid, water consists of exceedingly small particles or atoms of matter in mechanical combination. The exact nature and form of the atoms composing water are not satisfactorily known, in consequence of their excessive minuteness. They may be compared to very small particles of sand, cohering slightly, and easily slipping or sliding over each other. Whatever may be the nature and form of these exquisitely fine atoms, it is certain that they can adhere firmly together, so as to assume the form of a solid, as in the case of ice; and be made to separate from each other, and disperse through the thinner fluid of the atmosphere in the forms of steam, clouds, or mist.

Thus *imperfect cohesion of atoms or particles* is a property common to all fluids. The atoms composing water being in closer union than those of air, are observable as a mass, and palpable to the touch. When the hand is dipped into them, and then withdrawn, a certain quantity is brought away on the surface of the skin; and this adhesion of the particles of water (caused by attraction of cohesion) is what what we in ordinary language call *wetness*. Certain substances, as is well known, absorb water to a great extent; in such cases the molecules of the water merely penetrate and fill up the crevices in the substance.

Solid bodies, as a stone, or piece of metal, or wood, have a natural tendency to press only in one direction—that is, downwards, or in the direction of the earth's centre—in obedience to the law of terrestrial attraction. Water has a similar natural tendency to press downwards, and from the same cause; as, for example, when a jug of water is spilled, the water is seen to fall in a stream to the ground. Water, however, is governed by a law of pressure, independently of this general law of gravitation. This peculiar or independent law consists of a tendency in the particles of any mass of water to press equally in all directions.

I. *Pressure equally in all directions* may be considered as the first or great leading law in reference to water, and generally all fluids, liquid or *gaseous*. This pressure is a result of the exceeding smallness of the individual particles, and of the perfect ease with which they glide over or amongst each other.

To exemplify equal pressure, fill a leathern bag with water, and then sew up the mouth of the bag so closely, that none of the water can escape. Now squeeze or press upon the bag so as almost to make it burst. The pressure so applied does not merely act upon the water immediately under the point of contact, but acts equally upon every particle of water in the mass—the particles at the centre being as much pressed upon as those at the outside; and it will be observed that the water will squirt out with equal impetuosity at whatever part in the surface a hole may be made. In this, as in all similar cases, there is a transmission of pressure throughout the mass. Each particle presses on those next it; and so, by the force communicating from particle to particle, the whole are equally affected. In the case of water lying at repose in an open vessel, the tendency to press equally in all directions is not observed to act upward, because the gravity of the mass keeps the water down; but on pressing upon the surface of the liquid, we observe that it rises against the compression, or tries to escape in any way it can.

To take another example—if we plunge our hand into a vessel of water, we displace so much liquid, and cause it to rise higher up the sides of the vessel. In this case the water is observed to rise without any reluctance; it as readily presses upward as downward. Although it is a property in fluids to press equally in all directions, the degree of intensity of pressure in any mass of fluid is estimated by the vertical height of the mass, and its area at the base.

II. *Pressure of water in proportion to its vertical height, and its area at the base*, is therefore a second leading feature in the laws of water. In other words, the pressure of a column of water does not depend on the width or thickness of the column, but on its height, and the extent of its base or lower part. The whole of any fluid mass may be imagined to consist of a number of columns of an inconsiderable thickness, which stand perpendicularly on the horizontal base of the containing vessel, and press the base of the vessel with their respective weights. The pressure, then, if the height of the fluid be the same throughout, is as the number of columns, and this number is according to the area of the base. Consequently, in vessels whose bases differ as to area, and which contain fluids of the same density, but different heights, the pressure will be in the compound ratio of the bases and heights.

If the columns of which a fluid mass was supposed to consist were formed of particles lying in perpendicular lines, the pressure of the fluid would be exerted on the bottom of the vessel only; but as they are situated in every irregular position, there must, of consequence, be a pressure exerted in every direction, which pressure must be equal at equal depths. For if any part of the whole mass were not equally pressed on all sides, it would move towards the direction in which the pressure was least, and would not become quiescent till such equal pressure was obtained. The quiescence of the parts of fluids is therefore a proof that they are equally pressed on all sides.

Several interesting experiments may be made to prove that the pressure of water is in proportion to its height and width of base:—Fig. 1 represents a vessel with a broad top EE, tapering to a narrow base CD. The dotted enclosure ABCD represents an ideal column of water the width of the base. The vessel is supposed to be filled with water to the surface EE. Yet the base or bottom sustains no more pressure than that described by the ideal column ABCD; for the other parts of the contained fluid can only press the column ABCD, and also the sloping sides, laterally, and therefore do not contribute to the increase of the pressure on the bottom CD. Again, if we take a vessel of the same capacity, but with a broad base, as in fig. 2, the pressure on the bottom is very different. In this case the base EF sustains a pressure equal to the weight of a column whose base is EF, and height equal to AC; for the water in the central column ABCD presses laterally, or sidewise, with the same force as it does on the part on which it stands; and thus a uniformity of pressure is established over every part of the bottom.

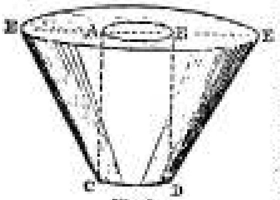


Fig. 1.

Fig. 2.

From these two cases combined, the reason is evident why fluids contained in the several parts of vessels remain everywhere at the same height; for the lowest part where they communicate may be regarded as the common base; and the fluids which rest thereon are in equilibrio then only, when their heights are equal, however their quantities may vary.

We may prove the truth of these propositions in various ways. Let ABCD, fig. 3, represent a cylindrical vessel, to the inside of which is fitted the cover G, which, by means of leather at the edge, will easily slide up and down in the internal cavity, without permitting any water to pass between it and the surface of the cylinder. In the cover is inserted the small tube EF, open at top, and communicating with the inside of the cylinder below the cover at G. The cylinder is filled with water, and the cover put on. Then, if the cover be loaded with the weight, suppose of a pound, it will be depressed, the water will rise in the tube to E, and the weight will be sustained. In other words, a very small quantity of water in this narrow tube will press with a force as great as if the vessel were of the dimensions KLCD, instead of ABCD. By filling the tube to F, a force will be gained sufficient to balance additional pound weights on the cover G, and as great as could be conferred by a vessel of equal breadth all the way up to F.

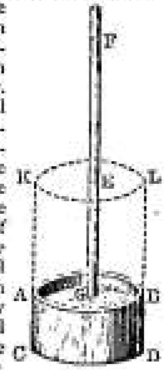


Fig. 3.

Water, in its pressure equally in all directions, presses upwards as well as downwards. This is seen in the above experiments. Take fig. 3 as an example. The water in the vessel ABCD, when the tube is filled, presses, as has been said, with a force equal to that of a column of water of equal breadth all the way up to F. This can only be in consequence of the water in the vessel ABCD pressing violently upwards against the cover G, which violence causes a corresponding reaction on the bottom of the vessel. This reaction, then, is equivalent to vertical height. To use a figure of speech, the water in the vessel is in the condition of a man pressing equally upwards with his shoulders and downwards with his feet at the same time; and the more he is acted upon by weight above, the more powerfully does he exert his pressure in both directions.

An instrument called the *hydrostatic bellows* has been constructed to exemplify the effect produced by the pressure of a small column of water. As represented in fig. 4, it consists of two circular stout boards connected together with leather, in the form of a pair of strong bellows, B; a tube A communicating with the interior between the boards. Supposing the instrument to be strong enough, a person standing on the upper board may raise himself by pouring water into the tube, and filling it along with the bellows. It is usual to estimate the pressure by means of weights, W. If the tube hold an ounce of water, and has an area equal to a thousandth part of the area of the top of the bellows, one ounce of water in the tube will balance a thousand ounces placed on the bellows.

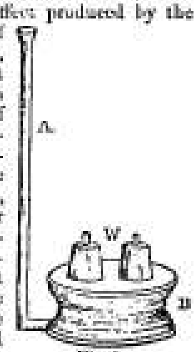


Fig. 4.

This remarkable property in liquids, which is called the *hydrostatic paradox*, is analogous in principle to that which in mechanics is called the Law of Virtual Velocities. According to this fundamental rule, a small weight descending a long way, in any given length of time, is equal in effect to a great weight descending a proportionally shorter way in the same space of time. The rule, as applied to liquids, may be stated thus:—A small quantity of water descending in a long column is equal in effect to a proportionately great pressure exerted by a large volume of water in a short column.

The law of pressure in proportion to height of column is shown in the annexed representation, fig. 5, of a vessel with a uniformly level base, and full of water. Dividing the depth into 10 equal sections, to represent feet, as marked from 1 to 10, it is found that, at the depth of 1, there is a pressure of one foot of water, at 2, two feet, and so on to 10 at the bottom, where there is a pressure of ten vertical feet of water. The average pressure of the whole is at the middle, at 5. These degrees of intensity of pressure have no reference to the horizontal breadth or length of the mass. The same pressure is sustained whether the vessel be a foot or a mile in breadth.

Fig. 5.

As in this example, whatever deficiency of pressure there is upon the perpendicular sides of a vessel of water *above* the middle or point of average pressure, is compensated by a corresponding excess of pressure *beneath* the middle; consequently, the entire pressure diffused over the sides is equal to that at the middle or point of average pressure. A perpendicular side of a cubical vessel, according to this statement, sustains a lateral pressure precisely equal to the half of that which is endured by the bottom.

We may calculate the degree of lateral pressure in vessels having perpendicular sides and flat horizontal bottoms, by first finding the number of square feet in the sides below the surface of the liquid; then multiplying that by the number of feet in half the depth of the liquid; by which calculation the product will express the number of solid feet of the liquid, whose weight is equal to the lateral pressure. We may find the number of square feet in the sides, by multiplying the number of feet in the circumference of the bottom by the number of feet in the depth of the liquid:—

Example.—To find the degree of pressure on the perpendicular sides of a vat 24 feet deep from the surface of the liquid, and 40 feet in circumference—Multiply the 24 by 40, and the product 960 gives the area of the sides; then multiply the 960 by half the height—that is, 12—and the product is 11,520 cubic feet of water, or the volume of liquid whose weight is equal to the pressure on the sides. We next find the weight per cubic foot, which is reckoned to be 1000 ounces; then 11,520, multiplied by 1000, gives 11,520,000 ounces, which is the pressure of the water on the sides.

In consequence of the pressure of liquids being as the vertical height and area of the base, it may happen that the lateral pressure on the sides of a containing vessel is greater than the whole weight of the liquid; this will be the case when the surface of the sides in contact with the liquid exceeds the ratio of double the magnitude of the bottom—at double the magnitude, both lateral and perpendicular pressures are alike, and each is equal to the weight of the liquid.

The circumstance of pressure increasing in proportion to depth, suggests the valuable practical lesson of greatly increasing the breadth of embankments for dams and canals from the top downwards, so as to give much greater strength to the base than the summit; also of increasing the strength of the lower hoops of large vats, to prevent their bursting. It likewise demonstrates the propriety of making dams, ponds, canals, and vessels for liquids generally, as shallow as is consistent with convenience or their required purpose. In each case, it is important to recollect that the degree of pressure on the sides is irrespective of shape or size of the contents, and depends exclusively on the height of the liquid from its upper surface to its base.

That pressure in water is not according to the volume, but the height above the point of pressure, is obvious from many facts both in nature and art. Whether we plunge an object a foot deep in the ocean or in a jar of water, the pressure upon it is the same. The mere extent of the volume of liquid is of no consequence. Therefore, a precipitous shore pressed upon by the sea to the height of any given number of feet, suffers no more pressure (supposing the sea to be at rest) than the side of a canal of the same number of feet in height.

If the law of pressure of fluids were otherwise than that now stated, no species of embankment could withstand the pressure of the ocean, particularly in a high state of the tide. In consequence of the law of pressure being simply as the vertical height, we are enabled by artificial means to stem the volume of a far-spreading ocean, and to secure the dry land from its invasion. A knowledge of this important law might induce the attempt to secure many thousand acres of land which are now covered by the tide.

If a vessel—as, for instance, a tall glass jar—be filled with water, and three apertures be made in its side, at different heights, as in fig. 6, the liquid will pour out with an impetuosity corresponding to the depth of the aperture from the top. The jet from the orifice A will issue with a comparatively small velocity; that from B with a greater; and that from C with the greatest. The expression of this fact is known as the theorem of Torricelli, and may be stated thus: 'Particles of fluid, on issuing from an aperture, possess the same degree of velocity as if they had fallen freely, *in vacuo*, from a height equal to the distance of the surface of the fluid above the centre of the aperture.' For instance, in the annexed diagram, the jet from A will possess the same velocity as if the particles of water had fallen, *in vacuo*, from H to A; that from B the same velocity as if the particles composing it had fallen from H to B; and that from C as if from H to C. The velocity of fluids thus escaping from orifices is, other things being equal, as the square roots of the depths of the orifices below the surface of the fluid; and when fluids escape from lateral orifices, they describe parabolic curves, and obey the laws of projectiles. [See LAWS OF MOTION.]

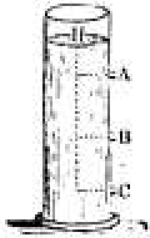


Fig. 6.

Practically, the discharge of liquids from apertures is partly affected by the shape and width of the aperture; for water is retarded by friction, and by its own impetuosity or cross currents in a small channel. It is reckoned that the pressure of water on any body plunged into it, or on the bottom or sides of the containing vessel, is about one pound on the square inch for every two feet of the depth.

Pieces of wood sunk to great depths in the ocean, become so saturated with water by the pressure of the superincumbent mass, that they lose their buoyancy, and remain at rest at the bottom. The depth to which divers can descend, is limited by the increased pressure they experience in their descent. If a bottle be firmly corked and sealed, and sunk to a great depth in the ocean, the cork will either be forced in, or the bottle broken by the pressure. An air-bell rising from a depth, expands as it approaches the surface. At the depth of a thousand fathoms, water is estimated to be about a twentieth part more dense, or compressed, than at the surface.

The great effects which may take place by the action of a small but high column of water, are sometimes exemplified in the rending of mountains. In fig. 7, a mountain or high rocky knoll is represented, with a small vertical crevice A reaching from the summit to an internal reservoir of water near the base. If there be no means of outlet to the liquid, and if rain continue to keep the crevice and its terminating reservoir full, the lateral force exerted by the upright column will be very considerable. Supposing the crevice to be an

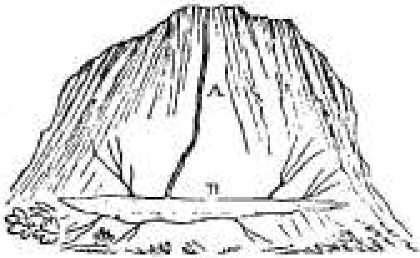


Fig. 7.

inch in diameter, and 230 feet deep, the pressure would be equal to nearly half a ton on every square inch: such a force continually acting on the sides of the mountain (laying out of view the great additional force given by expansion of the liquid in freezing during winter) would probably in time overcome the cohesiveness of the mass, and burst the whole asunder. In this property in water, therefore, we see one of the many provisions of nature for producing changes on the surface of the earth. Effects of a similar character, but on a less scale, are observable in the bursting of walls behind which earth has been piled, and in which no proper outlets for water have been provided; also in the bursting upwards of drains upon a declivity, when they become choked.

The easy motion of the particles among each other causes them to accommodate themselves to the shape of any vessel. The force of gravity also causes them to seek the lowest level for repose—each particle tries to get as low as it can. The result of this general tendency throughout the mass is a perfect levelness of surface—the top of the water is smooth.

III. *A uniform levelness of surface* takes place in every connected mass of water, whatever be its magnitude or its shape. This forms the third leading feature in the laws of water, and is the cause of many of the phenomena in nature. One of the most familiar examples of this law is that observable in a common teapot. In the representation of a teapot, fig. 8, the surface of the liquid in the pot is seen to be at A, and also at the very same height at B in the spout. A straight dotted line is drawn from the one to the other, to show that both surfaces are of the same level. It is customary to say that the small column of water in the spout balances the large mass of water in the pot; but, in reality, there is no balancing in the case. The water necessarily possesses the same surface level in all its parts; one portion cannot stand higher than another; all portions, great and small, are only distributed parts of a single mass.

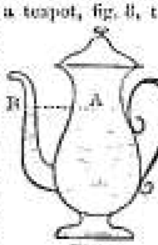


Fig. 8.

The tendency which water has to stand at the same surface level in all parts of its mass is usually referred to by the phrase, 'water finding its level.' It is this inherent tendency in water to find its level that produces the various phenomena of the trickling down of rain and moisture into the ground, the flowing of all kinds of streams, from the small brook to the mighty river, and the shooting of rapids and cataracts over precipices. In each case, the water, in obedience to the natural law or tendency which governs it, is only trying to find its level. In pursuit of this object, the water, by the rubbing force which it exercises, wears down all the solid objects which present an obstacle to it in its course. Thus the substances of which hills and plains are composed, are carried away by streams into the ocean—the ground of continents and islands diminishes in bulk—new land rises in the sea; and so, by the effects of a simple natural cause, great alterations are produced in the external features of the globe.

There are two kinds of levels—the *true level* and *natural level*.* The true level is a perfectly horizontal plane, as, for instance, an even line, thus, ——————; or a perfectly even surface of a floor.

The natural level is a surface, every point of which is at the same distance from the centre of the earth. The surface level of water is always the natural level. The character of a natural level is understood by a reference to the spherical shape of the earth and the pressure of gravitation. The globe is a ball, and any piece of water which lies upon it, lies in the form of a plaster round the ball. Water, therefore, cannot possibly have a true surface level; its level partakes of the sphericity of the ball. Every piece of water, in a state of entire or partial repose, is in this manner convex in its surface.

The degree of convexity of the earth is, as nearly as it can be stated in figures, 7 inches and 9-10ths of an inch, or nearly 8 inches, in each mile. The convexity, however, is somewhat less towards the north and south poles, because the earth is a spheroid, or a sphere flattened at the ends. The annexed diagram, fig. 9, represents a segment of the earth's surface, with the appearance of a true and natural level marked upon it. The curve ES is the earth's surface. PC is a perpendicular line pointing to the centre of the earth. At right angles from this line, a line TL is drawn, representing the true level. Supposing that the line TL is a mile in length, if we draw a line from L to the centre at C, it will cut across the surface of the earth at a point a mile distant from the line at T, which point will be 7 inches and 9-10ths depressed below the part at L.

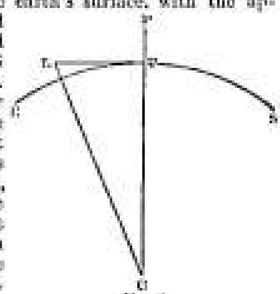


Fig. 9.

The convexity of the earth's surface is not observable in small quantities of water. The surface of a glass of water is not a true level, but the degree of convexity is so small, that it cannot be practically estimated or measured. It is only when a sheet of water is stretched out to an extent of several miles, that the convexity becomes conspicuous. It is very perceptible on the ocean when a ship is seen approaching on the horizon; first the masts and sails of the ship are seen, and lastly the hull. To catch the first glimpse of vessels at sea, the point of outlook for them is placed high above the water. By this means, the person who looks is able to see over a part of the convexity, and give information of the approach of vessels to those placed below. The convexity of the dry land is not so conspicuous, in consequence of the many risings and fallings in the surface. It is only in some extensive alluvial planes in different parts of the world that the convexity can be perceived in the same manner as at sea.

In forming roads, railways, and canals, it is necessary to make allowance for the convexity of the earth's surface. The first thing done in such cases is to survey the land by means of an instrument called a *theodolite*. One of the varieties of the theodolite is a small telescope fixed on a stand, which must, when looked through, be placed perfectly horizontal, or in a true level. To find a true level, an instrument is fixed below it, called a *spirit level*, and by that it is regulated. A spirit level is in universal request in works of art requiring level-

* In mathematics, the term *apparent level* is used instead of true level, and the term *dead level* instead of natural level.

ness of foundation or surface. It consists of a cylindrical glass tube, as in fig. 10, containing a quantity of spirits of wine sufficient to fill it, except a small part in which the air is left.

Fig. 10.

The tube being completely closed or sealed, the small vacancy where the air is left shows an air-bubble at whatever part of the tube is uppermost. The tube being set in a small wooden case with a level bottom, this case is laid upon the block of stone, wood, or other object to be levelled, and when the air-bubble is seen to rest in the middle of the upper side, it signifies that the object on which the instrument lies is a true level. In the accompanying figure, the air-bubble is seen at the middle at *b*; the slightest unevenness would cause the bubble to proceed either towards *a* at the one end or towards *c* at the other.

A true level being found for the theodolite, the surveyor looks through the glass or telescope towards a pole, the lower end of which rests on the ground, and is held in a perpendicular position by a man at (we shall suppose) the distance of a mile, previously measured. The pole having figures marked upon it, a certain figure on a level with the eye is ascertained; 7 inches and 9-10ths are then reckoned down the pole from the figure, and at that depth we have the natural level from which the surveyor makes his subsequent calculations. If a road were to be made on the plan of preserving a true level, it would proceed in its course at a tangent from the earth's convexity, like the line TL in fig. 9, and consequently would reach a point above that to which it was destined to go. It would be impossible to make the water in a canal pursue a true level; in the attempt to do so, it would not remain at rest in the channel prepared for it, but would rush towards the lower end.

As most countries are less or more irregular in surface, canals are usually constructed with different levels, so much of the length being on one level, and so much on another, as the case may be. At every change of level there is a lock, or portion enclosed with gateways, to keep the water at the proper level, and to allow the passage of vessels. The locks of a canal, therefore, are like steps of a stair, one at a greater height than another, and by their means vessels may be made to proceed up or down hill.

SPECIFIC GRAVITY.

The denser in substance that a body is, it is the more heavy or weighty, because it contains more particles to be operated upon by attraction of gravitation. In reference to the density of bodies, the term *specific gravity* is employed to denote the comparison which is made. Thus the weight of a lump of lead is greater than an equal bulk of cork; therefore its specific gravity is greater; and so on with all other substances when compared together. For the sake of convenience, pure distilled water, at a temperature of 62 degrees, has been established as a standard by which to compare the specific gravity or relative weight of solid and liquid bodies. Every such body is said to be of either a greater or less specific gravity than water, bulk for bulk.

We have an example of a difference in the specific gravities of liquids in mercury, water, oil, and spirits. Mercury is considerably more dense or heavy than any of the others; the next in density is water, then oil, and lastly spirits. If we put a quantity of each of these liquids into a glass vessel, one after the other, in the order here mentioned, we shall observe that all keep their respective places, without intermixture, the heaviest at the bottom, and the lightest at the top. Should they even be jumbled together in the vessel, it will be noticed that they in time rectify the disturbance, each assuming its own position. Again, sea or salt water, in consequence of being loaded with foreign matter, is of greater density or specific gravity than pure fresh water of the same temperature. If we therefore pour a quantity of salt water into a glass vessel, and then gently place some fresh water above it, we shall observe the same phenomenon of each kind of liquid retaining its position, the heaviest to the bottom, and the lightest to the top. Or further, if we fill a bottle with water, and dip it with the open mouth downwards into a jar or barrel of spirits, the water, in virtue of its density, will be emptied, and sink into the spirits, and the spirits will immediately rush up into the empty bottle, and supply the place of the water.

The force which liquids exert in opposing each other in a state of equilibrium, corresponds to their specific gravities; in other words, a small quantity of a heavy liquid will balance a much greater quantity of a lighter liquid. For example, take a bent glass tube, as in fig. 11, and pour as much water into it as will extend from the bottom at E to A. This quantity of water will be balanced or kept to its summit level at A by a quantity of mercury measuring from E to B, or by a quantity of oil from E to C, or by a quantity of spirits from E to D. Each of these experiments may be performed one after the other. The pressure of liquids being as the vertical height, and not as breadth, it would make no difference in the result of the experiments if the limb of the tube for the mercury, oil, or spirits, were increased to a foot, a mile, or any other diameter.

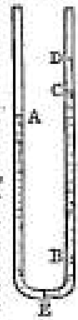


Fig. 11.

Water, at its ordinary temperature of 62 degrees, has a specific gravity of 1000 ounces to the cubic foot. Platinum is 22¼ times heavier, or 22¼ times the specific gravity of water; gold is 19½, mercury 13½, copper 8¾, iron 8, common stone about 2½, and brick 2. Alcohol is a little more than 8-10ths of the heaviness or specific gravity of water, or 0·815; and oil of almonds is a little more than 9-10ths, or 0·915. Atmospheric air at the earth's surface is 1-800th part, or 0·00125; in other words, while a cubic foot of water weighs 1000 ounces, a cubic foot of air weighs one ounce and a quarter. For an ampler list of specific gravities, see Laws of Matter, p. 198.

Though by no means of uniform constitution, the average specific gravity of sea water may be stated at 1·035—that is, to 1000 parts of fresh water there are, in addition, 35 parts of saline substances. Sea water being therefore 35 parts for every 1000 of water more dense than fresh water, it possesses a proportionally greater power of buoying up bodies. A vessel which will carry 1000 tons on fresh water, will thus carry 1035 tons on the sea.

FLUID SUPPORT.

The immersion of solid bodies in liquids develops some important principles in hydrostatics. Any body of greater specific gravity than water, bulk for bulk, will sink on being thrown into water; but a body will float if its specific gravity be less than that of water. The mode of stating the law in reference to the immersion and floating of solid bodies in any kind of fluids is as follows :—

First.—Any solid body immersed in a fluid displaces exactly its own bulk of fluid, and the force with which the body is buoyed up is equal to the weight of the fluid which is displaced; therefore the body will sink or swim, according as its own weight is greater or less than the bulk of displaced fluid. This refers to bodies of less density than water.

Second.—Any solid body of a greater density than water, when wholly immersed in that fluid, loses exactly as much of its weight as the weight of an equal bulk of the water—that is, of the water which it displaces.

It is of great importance that these propositions should be fully comprehended, for they explain innumerable phenomena in nature in reference to the floating or swimming of bodies in water or in the atmosphere. Water, as has been explained, consists of innumerable small particles pressing in all directions, or upwards as well as downwards. Let us fix our attention on a supposed single particle in the mass: while the liquid is in a condition of repose, we may imagine the particle to be sustained between contending forces—the force of a column of particles above, and the equally strong force of particles beneath, pushing to get upward or away from this column.

Let us now substitute any solid object for the supposed particle; for example, the quadrangular object AB represented in a vessel of water, fig. 12. This object, supposed to be of the same density as water, which we see is sunk in a buoyant condition in the water, has displaced a mass of particles, all of which were operated upon in the manner of the supposed single particle. This object, then, by taking the place of the mass of particles, has become subject to the same contending forces, and is consequently floated or sustained to the same extent as they were. If we suppose that the weight of the object is two pounds, liquid to the amount of two pounds is displaced, and the object is pressed upwards with the force of two pounds. Or, to vary the example—suppose that only the lower half beneath the line C is the solid object, and that the space occupied by the upper half is water, the object is still pressed upwards with a force of two pounds; but being one pound weight in itself, and having a pound of water above it, it remains suspended in equilibrium.

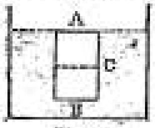


Fig. 12.

These examples refer to bodies which are of the same density or weight as water, bulk for bulk; we shall now take an example of a body specifically lighter than water, by which it will be observed that the buoyancy is governed by the same principle:—Fig. 13 represents a solid object AB half immersed in a vessel of water. In this, as in all cases in which there is a portion of the object above the water, the weight of that portion is borne by, and therefore conveyed to, the portion which is immersed. Thus, in the example before us, the portion B, though less than a pound weight in itself, by supporting A, becomes, we shall say, a pound, and displaces a pound of water; it is therefore buoyed up with the corresponding force of a pound.

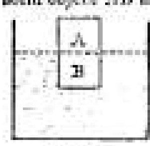


Fig. 13.

Whether a body be large or small in bulk in proportion to its weight, its displacement of water depends exclusively on its weight, so long as it is not heavier than water. A vessel of cork, wood, or any substance lighter than water, weighing a thousand tons, displaces exactly the same weight of water, or is buoyed up with the same degree of force.

From these circumstances, it appears that the entire weight of any *floating* body may be calculated by measuring the quantity of water which it displaces. On immersing a stone, or any other solid object, in water, it is found to be buoyed up in proportion as its specific gravity is less than that of water. If its specific gravity be greater than water, it will sink to the bottom, and if less, it will swim. As the water of the ocean becomes of greater specific gravity the greater the depth, it may happen that an object which sinks at the top of the water, will remain suspended in equilibrium when it descends to a point at which the specific gravity of the water is equal to its own.

Whatever be the weight of any solid object when weighed in air, its apparent weight is lessened when weighed in water. Thus a stone may be moved with comparative ease in water, which cannot be lifted without considerable difficulty on land. The apparent diminution of weight in these cases is caused by the support afforded by the liquid. Attraction of gravitation, which is the cause of what we call weight, is counteracted more in water than in air, because the water has a tendency to buoy up the object. The weight of any object in water is thereby lessened to the extent of the weight of a bulk of liquid equal to the size of the object. If the object displace a pound of water, it will weigh a pound lighter in water than in air.

The circumstance of any solid object displacing its own bulk of liquid, and losing exactly as much of its weight as the weight of that bulk of liquid which it displaces, has led to the use of the *hydrostatic* or *water balance*, for ascertaining the intrinsic value of gold and other precious metals. For example, by knowing, in the first place, how much water a pound of pure gold displaces, and then weighing in water, as in fig. 14, an object said to be a pound of gold, we should observe whether it displaced the proper quantity of water; if it displaced more than was proper, then we should be certain that it contained alloy, or some inferior substance, being too bulky for a pound of gold. Such weights are used by goldsmiths.

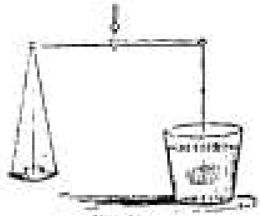


Fig. 14.

Thus if a piece of gold weigh 19¼ ounces in air, it would weigh only 18¼ ounces in water; the ounce of weight thus counteracted being just the weight of the water that the gold displaces. Therefore the weight of the gold would be to that of the water as 19¼ ounces to 1 ounce; that is, the specific gravity of gold is 19¼, if water is taken for the standard.

We may cause an object, such as a light hollow ball or bladder, to displace much more water than what is equal to its own weight; but in doing so, we must press the ball into the water, and that degree of pressure compensates the deficiency of weight in the ball. Thus extraneous pressure on a floating body, and weight in the body itself, are the same thing as respects buoyancy.

The human body, in a state of health, with the lungs full of air, is specifically lighter than water, and more so in the sea than in fresh water. Persons, therefore, on going or falling into water, cannot possibly sink, unless they struggle so as to prevent the liquid from buoying them up. The body will float with a bulk of about half the head above the surface; and thus a person who cannot swim may live and breathe, until chilled, or otherwise paralysed, by simply stretching himself on his back, and lying with his face above the water. By throwing the arms out of the water, the body does not displace so much liquid; its weight is increased, and it naturally sinks. Ignorance of these facts, and want of resolution, cause many deaths by drowning.

There are various kinds of apparatus for preventing drowning, called life-preservers. The most common are those which consist of pieces of cork, or other very light material, attached to the upper part of the body. But air-tight bags are preferable, as they may be said scarcely to encumber the body when empty, and, as danger approaches, they can be inflated with ease by being blown into. Life-boats have large quantities of cork in their structure, and also air-tight vessels made of thin metallic plates; so that, even when the boat is filled with water, a considerable portion of it still floats above the general surface. The bodies of some animals, as sea-fowl, and many other species of birds, are considerably lighter than water. The feathers with which they are covered add very much to their buoyancy. Quadrupeds swim much easier than men, because the natural motion of their legs in walking or running is that which best fits them for swimming. Fishes are enabled to change their specific gravity by means of an air-bag with which they are provided. When the air-bag is distended, they rise to the surface; and when it is contracted, they descend to the bottom.

The buoyant property of liquids is independent of their depth or expanse; for if there be only enough of water to surround an object plunged into it, the object will float as effectually as if it had been immersed in a large mass of water. Thus a few pounds of water may float an object which is a ton in weight. We account for these phenomena by the law of pressure in liquids being as vertical height, not as width of column, and by a body being buoyed up with a force exactly in proportion to the weight of water which it displaces. These important truths in hydrostatics teach the practical lesson, that if canals be made only as deep or wide as will afford water to surround the vessels placed upon them, they will be sufficiently large for all purposes of buoyancy and navigation. A ship floats no better on the face of a sheet of water miles in width, than it would do on a mill-pond, provided there be enough of water in the pond to keep it off the bottom.

Every solid body possesses a *centre of gravity*, which is the point upon or about which the body balances itself, and remains in a state of rest or equilibrium in any position. The equilibrium of floating bodies is regulated in the same manner. The floating body has a centre of gravity, about which the whole mass will balance itself in the liquid; the heaviest side will sink lowest, and the more light will be uppermost.

In reference to floating bodies, there is a point called the *centre of buoyancy;* this is the centre of gravity of the liquid which is displaced. If the floating body be of the same specific gravity as water, then the centre of buoyancy will be at the same point in the floating body, as it would have been in the water; but there is seldom this uniformity, at least not in vessels used for purposes of navigation. It is necessary that all such vessels should be of a less specific gravity than water, in order that a part of their weight may be composed of cargo, stores, passengers, &c. and that they may be sufficiently buoyant. Heavy materials, called ballast, are usually placed in the bottom of the holds of vessels, to insure a low centre of gravity. A ship of the largest capacity and burden, with its centre of gravity properly regulated, rests in the water with a stateliness and stability which cannot be destroyed, except by some extraordinary violence.

HYDROMETERS.

If a substance be weighed in two fluids, the weights which it loses in each are as the specific gravities of those fluids. Thus a cubic inch of lead loses 253 grains when weighed in water, and only 209 grains when weighed in rectified spirit; therefore a cubic inch of rectified spirit weighs 209 grains, an equal bulk of water weighing 253; and so the specific gravity of water is about a fourth greater than that of the spirit.

The instrument called a *hydrometer* is constructed upon this principle. Its name is derived from two Greek words, signifying *measure of water;* but it is of course used for ascertaining the density of all kinds of liquids. There are various kinds of hydrometers. One of them consists of a glass or copper ball with a stem, on which is marked a scale of equal parts or degrees. When immersed in any fluid, the stem sinks to a certain depth, which is indicated by the graduated scale. The depth to which it sinks in the standard of comparison being known, we can thus easily ascertain how much it is specifically heavier or lighter than the fluid.

Fig. 15.

Much in the same manner is constructed another hydrometer of great delicacy and exactness. It consists, fig. 15, of a ball of glass, *b*, about three inches diameter, with another, *c*, joined to it, and opening into it, of one inch diameter, and a brass neck *d*, into which is screwed a wire *ac*, divided into inches and tenths of an inch, about ten inches long and one-fortieth of an inch in diameter. The whole weight of the instrument is 4000 grains when loaded with small weights, such as shot, in the lower ball *c*. When plunged into water in the jar, this instrument is found to sink an inch if a single grain be laid upon the top *a*; hence a tenth of a grain sinks it a tenth of an inch. So great is the delicacy of this hydrometer, that the difference in specific gravity of one part in 40,000 can be detected. Its total weight of 4000 grains is convenient for comparing water; but the quantity of shot in the lower ball can be varied, so as to adapt the instrument to measure the specific gravities of fluids lighter or heavier than the standard of comparison.

There is another very simple hydrometer, which consists of a number of glass beads of different weights, but whose proportions are known, and the beads marked accordingly. These are dropped into the fluid under examination, until one is found which neither sinks to the bottom nor swims upon the surface, but remains at rest wherever it is placed in the liquid; and this bead being numbered, indicates the specific gravity.

In making calculations of the strength and specific gravity of spirits by the above or any other means, attention must be paid to the degree of temperature of the liquid. Heat expands the liquor, and renders it specifically lighter; all spirits are therefore more bulky, in proportion to their weight, in summer than in winter, and also *apparently* stronger, not really so.

HYDRAULICS.

Having detailed the laws and properties of water in a state of rest or equilibrium, we have now to mention some of the most important results of these laws, and also the effects which are produced upon liquids by the application of forces, whether natural or artificial.

WATER A MECHANICAL AGENT.

Water, as already explained in the LAWS OF MATTER AND MOTION, may be made a useful agent of power, merely by allowing it to act with the force of its own gravity, as in turning a mill; and in this manner it is extensively employed in all civilised countries possessing brooks which are sufficiently rapid in their descent. But water may be rendered otherwise useful as an agent of force in the arts. Although subtile in substance, and eluding the grasp of those who desire to handle and hold it, it can, without alteration of temperature, be made to act as a *mechanical power*, as conveniently and usefully as if it were a solid substance like iron, stone, or wood. The lever, the screw, the inclined plane, or any of the ordinary mechanical powers, are not more remarkable as instruments of force than water, a single gallon of which may be made to perform what cannot be accomplished (except at enormous cost and labour) by the strongest metal.

To render water serviceable as an instrument of force, it must be confined, and an attempt then made to compress it into less than its natural bulk. In making this attempt, the impressed force is freely communicated through the mass, and in the endeavour to avoid compression, the liquid will repel whatever movable object is presented to it. The force with which water may be squirted from a boy's syringe, gives but a feeble idea of the power of liquids when subjected, in a state of confinement, to the impression of external force.

The mechanical force of water is exemplified by the hydraulic press. This is an engine employed by paper-makers, printers, and manufacturers of various kinds of goods, for the purpose of giving a high degree of pressure or smooth glazed finish to their respective articles. It has generally superseded the screw press, on account of its much greater power, with a less degree of trouble and risk of injury to the mechanism. Fig. 16 represents the outline of a hydraulic press. AB is the frame, consisting of four upright pillars supporting a cross top of great strength, and against which the pressure takes place in an upward direction. C, the material to be pressed, is forced upward by D, a round iron piston. This piston is very nicely fitted into an iron case E, which has a cavity F for receiving the water; the neck of the case grasps the piston so tightly, that no water can escape. A small pipe G conveys water into the hollow cavity from a forcing-pump H, which stands in a trough of water T. All that part of the apparatus below the base of the pillars is sunk out of sight in the ground. The pump apparatus is here represented as exceedingly simple, but in real machines it is very complex, and of great power. The pump, on being wrought, forces the water into the cavity. There the water, in endeavouring to escape, operates upon the movable piston, which it causes slowly to rise with its burden. The pressure thus exerted by the liquid almost exceeds belief: unless the case for the water be of enormous strength, it will be rent in an instant, as if made of the weakest material. When the weight has been raised to the required height, a stopcock is turned upon the pipe, and the apparatus remains at rest. The opening of the cock allows the water to gush out, and the weight accordingly sinks.

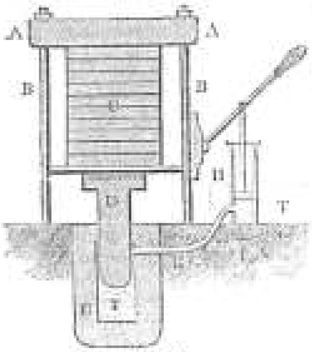


Fig. 16.

The mode of calculating the power of the hydraulic press is analogous to that for calculating lever powers. Thus the proportion is estimated between the small bore of the pump and the large bore of the cavity or barrel for the piston. Suppose that the pump has only one thousandth of the area of the barrel, and if a man, by means of its lever handle, press its rod down with a force of five hundred pounds, the piston of the barrel will rise with a force of one thousand times five hundred pounds, or more than two hundred tons. A boy working the pump by a long handle or lever, and taking a sufficiency of time, will raise a pressure of thousands of tons.

In the hydraulic press, a force-pump is employed for the sake of convenience; the same end could be attained by a small column of water of a great elevation, on the principle of pressure in liquids being as vertical height.

AQUEDUCTS—FOUNTAINS.

The tendency in a liquid to find its level, has permitted the construction of apparatus, consisting of pipes and cisterns, for supplying towns with water. No species of hydraulic machine has been of such great use to mankind as this apparatus.

In ancient times, the fact of water rising to a uniform level in every part of its volume, was either not perfectly understood, or there was a deficiency of materials wherewith to construct the apparatus required for carrying water a great distance. From whatever cause, towns were in these times supplied with water by means of open canals, either cut in the level ground, or supported on the top of arches built for the purpose. These structures, with their elevated channels, were called aqueducts. In Italy, and some other countries in the south of Europe, the remains of stupendous aqueducts, miles in length, still exist.

By a knowledge of the laws of fluids, and by possessing an abundance of lead and iron, we are enabled, in the present day, to construct apparatus for supplying towns with water in a manner the most effectual and simple; causing a cheap iron or leaden tube, sunk in the ground, to perform the office of the most expensive and magnificent aqueduct. The method of supplying towns with water consists in leading a pipe, of sufficient diameter, from a lake, river, or fountain of fresh and pure water, to the place where the supply is required. The iron pipes used for this purpose are composed of a number of short pieces soldered together, and extending to any length, or in any direction. From these main pipes smaller tubes of lead are led into the houses requiring the supply of water; and by means of these minor tubes, the water may be carried to any point which is not of a higher level than the original fountain affording the supply.

Fig. 17 is a representation of the mode of supplying towns with water in this convenient manner. A pipe is observed to proceed from a lake on the top of a hill down into a valley, and thence to supply a house situated on the opposite rising ground. From the pipe, in its passage across the valley, a small tube is carried to supply an ornamental fountain or jet d'eau. The water spouts from this jet d'eau with a force corresponding to the height of the lake above.

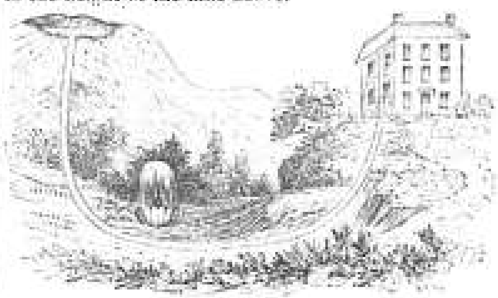


Fig. 17.

In towns not commanding a supply of water from a sufficient height, the water is forced by an apparatus of pumps to an elevated reservoir, and from that the pipes are laid. When the water is impure, or loaded with muddy particles, it is usual to purify it by filtration at the reservoir; it is made to filter or ooze through a mass of fine sand, in which the particles of mud are deposited.

Springs in the ground are natural hydraulic operations, and are accounted for on principles connected with the laws of fluids. One kind of springs is caused by capillary attraction, or natural attractive force by which liquids rise in small tubes, porous substances, or between flat bodies closely laid towards each other. This species of power is a remarkable variety of the mutual attraction of matter, and is as unaccountable as the attraction of gravitation, or the attraction exercised by the loadstone. Springs from capillary attraction are believed to be less common, and of smaller importance, than springs which originate from the obvious cause of water finding its level. The water which falls in the form of rain sinks into the ground in high situations, and finds an outlet at a lower level, though perhaps at a considerable distance.

Some springs are also accounted for by a reference to atmospheric action, but these will form a subject of notice under the head PNEUMATICS.

FRICTION BETWEEN FLUIDS AND SOLIDS.

The flowing of water through pipes, or in natural channels, is liable to be materially affected by friction. Water flows smoothly, and with least retardation from friction, when the channel is perfectly smooth and straight. Every little inequality which is presented to the liquid helps to retard it, and so likewise does every bend or angle in its path. A smooth leaden pipe will thus convey more water than a wooden pipe of the same capacity. Practically, an allowance is made in the magnitude of pipes for the loss of speed by friction. Where the length of the tube is considerable, and there are several bendings, it is not unusual to allow a third of the capacity for retardation. By increasing the capacity of pipes, a prodigious gain is secured in the transmission of water. The loss from friction on a small tube of an inch diameter of bore is so great, that one of twice the capacity will deliver five times as much water.

The rate at which water flows from an orifice in a reservoir, or containing vessel, is affected by the situation and the shape of the orifice. The most favourable situation for the orifice is at the bottom of the vessel; but the velocity of the emission is not in the ratio of the height of the liquid, or of a perpendicular column of particles; for as the water presses in all directions alike, there is from all parts of the vessel a general rush, as it were, to the outlet, thus putting the whole mass in motion.

Although the rush of water at the outlet is not as the ratio of the depth, it depends upon the depth. Thus if a vessel ten feet high be penetrated at the side on a level with the bottom, and the water stand at two feet and a half within, it will issue outwards with a certain degree of velocity. If the height of the water be quadrupled—that is, if the vessel be filled—the velocity will be doubled. In order to obtain a threefold velocity, a ninefold depth is necessary; for a fourfold velocity, sixteen times the depth is required; and so on. In fact, in whatever proportion the velocity of efflux is increased, the quantity of liquid discharged in a given time must be also increased in the same proportion; hence the quantity of water discharged conjointly with its degree of velocity will be increased in proportion to the pressure. There is here a striking coincidence between the descent of water and the relation which exists between the height from which a body falls and the velocity acquired at the end of the fall.

It has been ascertained that water rushes with most advantage from an orifice, when the orifice is in the form of a short round tube inserted into the vessel, and of a length equal to twice its diameter.

It has also been found that if the pipe, instead of being flush or level with the bottom of the reservoir, entered into it to some distance, it had the effect of making the flow of water even less than that which issued through the simple hole without any pipe. The singular fact of a pipe and hole of the same diameter discharging different quantities of water under different circumstances, whilst the head or pressure remains the same, must be accounted for by cross or opposing currents being created by the rush which all fluids make to the orifice. Currents will thus form from the top and sides of the containing vessel, and by their inertia they will cross each other, and thus impede the descent of the perpendicular column, causing the water which issues to run in a screw-like form; this, however, is in a great measure obviated by the application of a short tube from the aperture. That the projection of the tube too far into the interior of the vessel should make the flow less than if there were no pipe at all, may be thus explained:—The columns which descend from near the outside of the vessel, by turning up again to reach the discharging orifice, come into more direct opposition to the motion of the central descending columns, whilst they are at the same time themselves compelled to turn suddenly, in opposition to their own inertia, before they can enter the pipe. Thus the discharge is more effectually impeded than if it were proceeding from a simple opening in the bottom of the vessel.

The tube for the discharge of water should not only be short and round, but also trumpet-mouthed or funnel-shaped, both internally and externally, that being the form which admits the flow of liquid with the least possible retardation.

The effects of friction between liquids and solids are nowhere so conspicuous as in the flowing of rivers. The natural tendency in the water to descend at a certain speed, is limited by the roughness of the bottom, bends in the course of the stream, and small projections on the banks. From these causes, the water in a river flows with different velocities at different parts in any vertical section across the current. It flows at a slower rate of speed at and near the bottom than at the surface, and also slower at the sides than at the middle.

The resistance which a body moving in liquid meets with when it comes in contact with a solid, is as the square of the velocity of the moving body; in other words, the resistance is not twice, but four times, with a double rate of speed. This is easily explained:—A vessel moving at the rate of one mile per hour displaces a certain quantity of water, and with a certain velocity; if it move twice as fast, it of course displaces twice as many particles in the same time, and requires to be moved by twice the force on that account; but it also displaces every particle with a double velocity, and requires another doubling of the power on this account; the power thus twice doubled becomes a power of four. When the body is moved with a speed of three or four, a force of nine or sixteen is wanted, and so on. Thus the resistance increases as the square of the speed.

This important law suggests practical hints of considerable importance. For instance, in steam navigation, if an engine of fifty-horse power impel a vessel at the rate of seven miles an hour, it would require two of the same power to drive her ten miles an hour, and three such to drive her twelve miles an hour; hence the enormous expense of fuel attending the gaining of a high degree of velocity.

REACTION FROM THE EFFLUX OF FLUIDS.

If we suppose a vessel filled with water, the mass will be at rest, as every lateral pressure is counteracted by a perfectly equal but opposite one. But if an opening or orifice is made in any of the sides of the containing vessel, then the water will rush forth, and the pressure will evidently be removed at this spot, whilst the portion of the side diametrically opposite to the orifice continues to be pressed upon as strongly as ever. The consequence will be, that the whole vessel and its contents, if left free and unobstructed by friction, will move in a direction opposed to the direction in which the stream of water rushes out. This result may be compared to the recoil experienced in firearms, and has been taken advantage of as a motive force, though as yet with little practical benefit. The wheels or machines moved by this curious force are generally known as 'Barker's or Segner's water-mills,' and are variously constructed. In the accompanying diagram, fig. 18, the apparatus consists of a vertical tube AB, moving freely on a pivot C, and receiving a supply of water from a stream D. This water is discharged by two opposite horizontal arms ee', the jets issuing in contrary directions, and by their reaction causing a rapid rotatory motion of the whole machine. In practice, it is found more advantageous to reverse the apparatus, and compel the water to enter from below, by which means the friction occasioned by the weight of the main tube and its contained water is avoided.

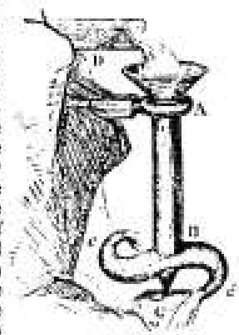


Fig. 18.

ACTION OF WATER IN RIVERS.

In cases where it is desirable to preserve the banks of rivers from injury, either from the regular action of the current or from floods, the water ought to be allowed a free open channel, with banks of a very gradual descent. The utmost violence of water in a state of motion may be rendered comparatively harmless, by allowing the flood or torrent to expand itself on a sloping or shelving shore. Inattention to this simple fact in hydraulics frequently causes much destruction to property on the banks of rivers.

A very small fixed obstacle, such as a stone or pebble, may partially impede and turn aside a brook of a slow current. The water, by striking on a stone at one side, is bent aside to the opposite bank, a little farther down; there it strikes upon the bank, and is returned to the side it formerly struck. Thus proceeding in currents from side to side, the banks become worn down at particular places, and in time a new and serpentine course is given to the stream. In the case of rivers flowing with considerable velocity, impediments of this kind are usually overcome, and the stream pursues its straight onward course, dashing down all obstacles to its progress. Thus rivers are generally winding in their course in flat countries, and straight in mountainous regions. (See GEOLOGY, p. 18.)

It sometimes happens that the water at the surface of a river may be moving in one direction, while the water at the bottom is flowing in an opposite direction. This is an exceedingly interesting phenomenon, which is observed to occur in certain rivers communicating with the sea, and is caused by the action of the tides, and the difference of specific gravity in salt and fresh water. When the tide is flowing inwards, the salt water rushes up the channel of the river, but not in such a manner as to stem the current of fresh water, which, being lighter, floats on the top of the salt water, and pursues its downward course to the ocean. In those instances in which there is no great disturbance of the two liquids, the fresh water, by its specific lightness, floats on the surface of the sea to a distance of many miles from the land.

WAVES.

Waves are the risings and fallings of the water, caused by some power, such as the blowing of the wind. The power, whatever it happen to be, communicates a force to the mass of liquid, and a series of undulations is the consequence.

These undulations or waves exhibit the transmission of the communicated force. The force does not advance or alter the lateral position of the water at any given point; it only alters the water in its vertical position, or in relation to its depth. When, therefore, waves advance, the water does not advance with them: the water but rises and falls, and assumes the figure of undulations on its surface. When the undulations approach the shore, the water then acquires a progressive motion, where it is shallow; and by friction on the bottom, or impulsion against the shore, the communicated force is exhausted. The shaking of a carpet affords an exact representation of the action of waves or undulations.

Waves are comparatively superficial; they seldom, even in the greatest storms, rise to a height of more than twelve feet above the level of calm water, and make an equal descent beneath, making altogether an appearance of twenty-four feet: at eight or ten feet below the intervening hollow or trough of the waves, the water is tranquil. Waves 'mountains high' is only a figure of speech.

ALTERATION OF TEMPERATURE.

By altering the temperature of liquid bodies, they become liable to peculiar laws, and exhibit peculiar phenomena.

At a temperature of 40 degrees of Fahrenheit's thermometer, water is at the point of greatest density. When the temperature is reduced below this point, the liquid gradually increases in volume till it reaches 32, when it freezes. When the temperature is raised above 40, the volume increases till it reaches the boiling-point, at which it has expanded to the extent of 1-23d additional to its bulk.

In consequence of this expansibility in heating, hot or warm water is specifically lighter than cold water; therefore, in heating any mass of water in a vessel over a fire, the lighter or warmed particles rise to the top, while the cold and heavy particles sink to the bottom, to be heated and to rise in their turn. In this manner the process of heating proceeds, until all the particles are of a uniform temperature, which is at the boiling point, when the liquid gradually flies off in steam.

If water be heated by the action of fire or the sun's rays on its upper surface, the mass is longer in attaining the vaporific point than when heated below, because water is a bad conductor of heat, and therefore the heat penetrates with difficulty through the upper stratum of warmed liquid to reach that which is beneath; and if the mass be very large—as, for instance, the ocean—no intensity of heat applied above can warm it throughout, or to any considerable depth.

Certain currents or sets of the ocean are known to be produced by the effort to attain an equability of temperature throughout. The power of the sun's rays at and near the equator heats the sea in that part of its volume to the depth of two or three hundred feet. This upper stratum of heated water flows in currents towards the north and south poles, and there, to a certain extent, tempers the severity of the cold. The waters of the northern and southern tracts of ocean, displaced by these currents, necessarily sink below them, and push on towards the equator, to supply the deficiency caused by the departure of the waters above. Thus in the economy of nature, we see a process in constant action precisely the same in principle as that upon which the artificial hot-water apparatus has been established.

PNEUMATICS.

Pneumatics, from the Greek word *pneuma*, breath or air, is the name of the department of science which relates to the weight, pressure, or motion of air, or of any aëriform or gaseous fluid.

It was anciently supposed that the air of the atmosphere was an element or simple substance in nature. It is now satisfactorily established that air is not an elementary body, but is composed of certain gases (almost wholly of nitrogen and oxygen, as explained under METEOROLOGY) in intimate union, and these gases can be separated from each other by a simple chemical process.

Air, in its common condition, is a thin transparent fluid, so subtile, that it cannot be handled, and when at rest, it cannot be felt. That it is a body, however, is quite obvious, because we feel its impression or force when agitated as wind, or when we wave our hand quickly through it. In the quick motion of the hand, we feel that it is partially opposed by something; and in inhaling breath into the lungs, we feel that we are drawing something through the mouth—that *something* is atmospheric air.

Air, like every other substance, whether solid or fluid, possesses a certain gravity or weight. The weight of air certainly, bulk for bulk, is much less than that of water; still the weight may be accurately computed. A bottle full of air weighs heavier in a balance than a bottle of the same capacity from which the air has been extracted. A cubic foot of water, as has been mentioned, weighs 1000 ounces. A cubic foot of air weighs only 523 grains, being a little more than one ounce; water, therefore, is about 840 times heavier than the air of our atmosphere. Inasmuch as water is a standard for comparing the gravities of liquids, air is a standard in the same respect for all aërial substances.

The specific gravity of air being denominated 1000, oxygen gas is 1111; nitrogen gas 972; hydrogen gas 69; and carbonic acid gas 1529. The lightest of these kinds of gas, therefore, is hydrogen, and the heaviest carbonic acid. Hence, if indefinite quantities of these aëriform bodies were placed in a vessel, or in an apartment, we should find that, after certain portions had gone into intimate union, according to the laws by which they combine, the surplus portions of each would assume relative positions according to their respective weights—the heaviest to the bottom, and the lightest to the top. Such an experiment would resemble that previously noticed of the mixture of mercury, oil, water, and spirits.

Air, and all kinds of gases, are rendered lighter by the application of heat, for then the particles in the mass are repelled from each other, and occupy a greater space; this process of lightening or thinning is called rarefaction. Rarefied air, being specifically lightest, mounts above that of a common density. The warmest air is always at the top of a room, and the coldest at the bottom.

Air is distinguished from water not only by its extreme comparative lightness, but by the property of elasticity; it is a compressible and elastic fluid. When any quantity of air is compressed into a smaller space than it naturally occupies, it will return to its natural bulk on the pressure being withdrawn. A small bladder of air may be squeezed between the hands so as to be considerably reduced in size; and on opening the hands again, and withdrawing the pressure, it will instantly resume its former bulk. If a metallic tube or barrel be fitted with a movable plug or piston, which is made to work in it perfectly air-tight, the air which occupies the space between the top and the bottom of this barrel when the piston enters, can be compressed to a hundredth part, or even less, of its usual bulk. If the force, however, by which the piston is pushed down be withdrawn, the air, by its elasticity, will force it up again with a power equal to that by which its descent was resisted. In proportion as any given volume of air is diminished by pressure, its elastic force is increased; in other words, the elastic force or elasticity of air is proportional to its density.

THE ATMOSPHERE.

The air, as formerly explained, is a great ocean wrapped round the earth to a depth of from forty to forty-five miles above the highest mountains, and forms a menstruum which is essential to the existence of all animals and plants. This ocean of air penetrates into all unoccupied places, in the same manner as water flows into all crevices and holes beneath the level of its surface; and it also finds a place in the bodies of animals, plants, and liquid substances: hardly anything, indeed, that we see in nature or art is free from air, unless force has been employed to extract it.

The height of the atmosphere, though usually estimated at forty or forty-five miles, is in reality unknown. The highest point above the level of the sea which has ever been reached by any human being, is 21,000 feet, which has been attained in a balloon. It is only conjectured, from the refraction of the sun's rays and other circumstances, that the height of the atmosphere is about forty-five miles. At and near the level of the ocean it is most dense, in the same manner as water at the bottom of the sea is more dense than it is at the surface, on account of the incumbent pressure. As we ascend mountains, or in any other way penetrate upwards into the atmosphere, the air becomes gradually less dense; and so thin is it at the height of three miles on the summit of Mont Blanc, that breathing is there performed with some difficulty. Beyond this limited height the density of the air continues to diminish, and at the elevation of about forty-five miles it is believed to terminate. (See Nos. 3 and 4.)

The extreme height of the atmosphere is not observable from the situation in which we are placed on the earth. Our eye, on being cast upwards, perceives only a vast expanded vault, tinted with a deep but delicate blue colour; and this, in common language, is called the sky. The blueness so apparent to our sense of sight is the action of the rays of light upon the thin fluid of the upper atmosphere, and the brightness is in proportion to the absence of clouds and other watery vapours. In proportion as the spectator rises above the surface of the earth, and has less air above him, and that very rare, the blue tint gradually disappears; and if he could attain a height at which there is no air, say at above fifty miles in height, the sky would appear perfectly dark or black. Travellers who have ascended to great heights on lofty mountains, describe the appearance of the sky from these elevated stations as dark, or of a blackish hue.

The atmosphere possesses the capacity of absorbing and sustaining moisture, but only to a limited extent. When saturated to a certain degree, it is relieved by the falling of the moisture in the form of rain. It is calculated that the whole atmosphere round the globe could not retain at one time more moisture than would produce about six or seven inches of rain.

By an elevation of temperature, the capacity of the atmosphere to absorb and sustain moisture is increased, and by a lowering of temperature, decreased. Cold breezes, by lowering the temperature of the air, cause the aeriform moisture to assume the appearance of clouds, and then to fall as rain.

LAWS OF AIR.

First—The pressure of the air is equal in all directions: *Second*—Its degree of pressure depends on the vertical height or depth, and at any place is proportional to its density: *Third*—Its surface is level in all parts of its volume: *Fourth*—It affords support according to its density and to the weight of the fluid displaced.

That air presses equally in all directions, may be rendered evident by filling a bladder with that fluid, and then pressing upon it so as almost to make it burst. The pressure is freely communicated through the mass, as in the case of the bag of water, and it will be observed that the confined air will rush out with equal impetuosity at whatever part the bladder is punctured.

The level of surface of air is less perfect than the uniform level of water, on account of the greater elasticity of the substance. In a series of strata of air of different densities, one above the other, a small portion of each mingles with those which immediately adjoin it—the particles of one commingle to a certain extent with those of another. There is thus, as respects aërial bodies, a modification of the law of uniform levelness of surface in all parts of the volume of fluid.

PRESSURE OF AIR.

The pressure depending on the vertical height or depth of air is an important property in the atmosphere, and on it depends the explanation of numerous phenomena. Air being a substance possessing gravity, it must of necessity press downwards in the direction of the centre of the earth, and therefore the degree of pressure on any given point will be equal to the weight of the column of air above the point, and proportional to the density of the air at that point.

The idea of the atmosphere possessing the property of gravity or pressure is of comparatively modern date. No such notion was entertained by the ancients, in consequence of living animals being observed to move with perfect ease in all directions, and because there was no other appearance in nature calculated to suggest it to their minds. It was, however, remarked, that when the air was sucked out of a small glass tube, the lower end of which was immersed in water, the water rushed up into the tube, and occupied the situation of the displaced air. In consequence of this and similar phenomena, it was alleged as a doctrine in physics, that 'nature abhors a vacuum.' A vacuum is a space destitute of air or any other kind of matter; and the notion was, that whenever by any chance such an empty space was found, nature interposed, with all imaginable haste, to fill it. With this very rude idea, pumps were formed to raise water—the rising of the water in these instruments being ascribed simply to nature's abhorrence of a vacuum. At length it was discovered that water could not be drawn up by a pump above a height of about thirty-two feet, and that a vacuum above that elevation remained unfilled; whereupon the terms of the doctrine were changed, and it was said that nature abhorred a vacuum only to a height of thirty-two feet, but no further.

This explanation was seemingly unphilosophical, and men's minds being carefully turned to the subject, various experiments were performed, and the important truth became manifest, that the atmosphere possessed gravity or pressure; also that that pressure was the sole cause of the rushing of liquids into tubes exhausted of air—the height of the ascending liquids being in every case limited by the degree of pressure of the incumbent atmosphere. Thus the discovery of a simple truth in science at once abolished the fantastic doctrine of nature's abhorrence of a vacuum, and all the laboured sophistry with which it was supported.* Nature has no dislike to a vacuum; a vacuum will occur in all situations from which solids or fluids are accidentally or artificially excluded.

The degree of pressure imposed by the atmosphere on any given spot on the earth's surface, as already noticed, is equal to the weight of the column of air above that spot, and is also proportional to the density of the air at the place. The atmosphere is deepest, or of greatest vertical height, at the level of the ocean, and there it exerts the greatest pressure. The pressure of the air at the level of the sea is usually reckoned to be about 15 lbs. on every square inch, or more accurately 14·6 lbs.

The pressure of 15 lbs. to the square inch refers to every shape of surface at or near the sea's level. The pressure is sideways, upward, oblique, and in every other direction, as well as downward, because fluids press equally in all directions. Thus in every crevice, nook, or vessel in which air happens to be, the pressure is equally intense. The human being, for example, sustains the pressure of 15 lbs. to the square inch all over his person, and this is a load (about 31,500 lbs. on an average-sized man) under which he could not possibly move, unless the pressure was also exerted in the interior of his body, or through his whole system of muscles, viscera, and bones, by which means the external pressure is counteracted, and he feels no pressure whatever.

If, however, the air by any means be withdrawn from the interior of any object, that object becomes immediately susceptible of the external atmospheric pressure. There are many familiar examples of this pressure around us. One of the most common consists in causing a thimble to adhere to the hand by sucking the air from beneath it: the adhesion is the result of the pressure of the atmosphere on the exhausted space on the hand. Another consists in lifting a stone by means of a sucker, formed of a string and a wetted piece of leather, as in the accompanying figure. The wetted leather is in this case pressed down upon the stone, and the string is then pulled: if air were admitted under the end of the string, the sucker would come off; but none being admitted, the atmosphere presses on the sucker, a rigid adhesion of the sucker to the stone is produced, and the stone, if not too heavy, is lifted.

Fig. 19.

The surgical process of cupping is upon the same principle. A small glass cup is held with its mouth near the part to be operated on, and the air being consumed within it by a lighted taper, it is instantly applied, and adheres with great force. The part having been previously lanced, the blood rushes from the wounds to fill the partial vacuum.

The feet of flies and some other insects are formed on the principle of the sucker, by which means they are enabled to walk and run with security on the ceiling of an apartment, back downwards, or on an upright and smooth pane of glass. At each step in advance, they procure a hold by the formation of a vacuum or air-tight space beneath their feet. The rapidity with which these vacuums or air-tightnesses are formed and destroyed, is an exceedingly interesting phenomenon in the economy of the animal, and cannot be rivalled by the utmost efforts of human skill. On a very moderate computation, a fly, in travelling six feet in the space of a minute, creates and destroys as many as 10,000 vacuums. When deprived of the outer extremities of its legs, on which the apparatus for adhesion is situated, a fly can walk without any apparent difficulty on a horizontal surface, such as a table, but is quite incapable of adhering to the roof, or of climbing any upright surface.

Limpets, snails, and some other testaceous animals, adhere to rocks and stones by causing a vacuum within their shells, which they accomplish by shrinking into a smaller bulk; by this simple contrivance, nature has effectually provided for their safe adhesion to their appropriate places of residence.

THE AIR-PUMP.

Air may be artificially withdrawn from a containing vessel by means of an apparatus called the air-pump. This apparatus is usually small, for standing on a table, and consists chiefly of a glass jar called a receiver, placed mouth downwards, over a flat surface, and with a small brass pump to draw the air from it. The annexed cut, fig. 20, represents an outline section of an air-pump, the working of which may be described. R is the glass receiver standing on a flat and smooth plate SS, and fitting so exactly, that no air can penetrate between the edges of the receiver and the plate. In the plate SS, there is a channel AB issuing into the barrel of a pump. P is the piston of the pump, with its rod C above, which is moved upwards and downwards by a handle and winch. The rod C works in a tight collar D. At the bottom of the pump there is a valve V, by which the air escapes, and is prevented from again entering. On depressing the piston, a portion of the contained air is expelled by the valve, and on raising the piston again to its position at the top, another column of air is admitted from the receiver into the pump, which is expelled in its turn. Thus, by a process of expulsion, the air in the receiver becomes at every stroke downwards more rare, till at length a vacuum sufficient for all practical purposes is established. The valve V, which opens outwards, is kept forcibly shut at every rising of the piston by external pressure of the atmosphere.

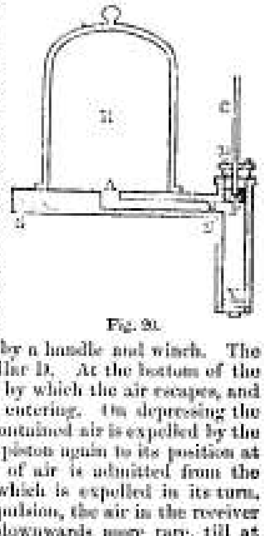


Fig. 20.

By means of the air-pump, a number of interesting experiments in pneumatics may be performed. For example, if a bladder, half full of air, and tightly tied at the neck, be placed under the receiver, and a vacuum then produced, the air in the bladder will expand by the removal of the external pressure, and seem as if ready to burst. Dried raisins, during a similar operation, will expand, and have all the plumpness of new fruit; and an egg, by the expansion of its confined air, will explode. Small animals, such as mice, placed below the receiver, and deprived of air, will immediately die, both from want of breath and the expansion of their bodies.

The atmosphere serves to retard the falling of bodies of a light and porous nature; and therefore, in the exhausted receiver of an air-pump, all such bodies descend with the same velocity as bodies of a heavy compact nature. A piece of coin and a feather let fall at the same instant of time from a hook within the top of an exhausted receiver, will strike the bottom at the same moment. (See LAWS OF MATTER.)

That atmospheric air is useful for the transmission of sound, in the absence of other media, is also exemplified by the air-pump. If we place a small bell in a

* This great discovery in physical science was made by Torricelli, an eminent Italian mathematician, about the year 1644. It was suggested by an ineffectual attempt to raise water from a deep well near Florence, by means of a pump of a greater height than thirty-two feet.

receiver, in such a manner as to admit of being rung easily from the outside without admitting air into the inside, whilst the receiver is full of air, the sound of the bell will be distinctly heard; but after the receiver has been exhausted, and although the bell be struck with the same force, the sound will be inaudible, or nearly so. If a small portion of air be admitted, it will be faintly heard, and it will gradually increase according to the quantity of air which is allowed to enter the receiver. Thus we are indebted to the air as a medium for conveying to us the sound of each other's voices, and all the melodious notes which constitute music.

The act of inspiring and expiring air resembles the alternating action of an air-pump. The air, on being drawn in through the appropriate tubes, fills the lungs, and the chest is expanded; having performed its office, the air is expelled in an impure condition, leaving a partial vacuum within, until another inspiration causes another expansion.

A machine, called a condensing-pump or syringe, is formed for the purpose of showing experiments with air more dense than that of the common atmosphere. The apparatus, which is represented in fig. 21, consists of a close glass jar or receiver fixed in a frame. A wire and hook serve to communicate with the interior during the performance of experiments. The syringe *i* is wrought by a piston with the handle *k*. From the bottom of the syringe there is a tube communicating with the interior of the receiver. When the piston is raised, a valve beneath opening inwards admits air into the cylinder of the syringe, and when it is depressed, this quantity of air is forced into the receiver; by the alternate raising and depressing of the piston, an immense quantity of air is forced into the receiver.

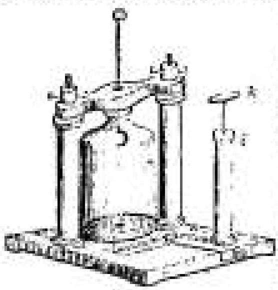


Fig. 21.

The elastic force of air so condensed is very great, and is employed for the projection of balls from an instrument called an air-gun. A certain quantity of compressed air is confined in a chamber at the inner end of the barrel, and when allowed to escape by touching a valve, a ballet is projected with a force resembling that of gunpowder.

PRESSURE OF AIR ON SOLIDS AND LIQUIDS.

The pressure of the atmosphere affects all liquids as well as solid bodies. The load of the incumbent air is as sensibly exerted within any given mass of water as on the surface. Thus atmospheric pressure keeps water and other liquids at the density they are commonly seen to possess.

If a glass be filled with water, and placed under the receiver of an air-pump, the abstraction of the air, by the removal of the atmospheric pressure, will cause the water to expand or become less dense, and it will overflow the vessel in which it is contained.

Water in its ordinary condition contains a certain quantity of particles of air mixed up with it. When the atmospheric pressure is lightened, these particles of air expand, and being of a less specific gravity than water, they mount to the top of the liquid in the form of small globules, and so fly off. The same effect is produced by expanding water by means of heat; the globules of air rise to the surface, and escape or remain attached to the inside of the vessel. Crystal bottles of water may be observed to be covered inside with small air-bells when the weather becomes suddenly light or warm. Water which has been boiled is comparatively free of air, and has an insipid flavour.

Certain gases are generated in some liquors, such as in porter, beer, and champagne wine, and unless the bottles in which they are contained be of sufficient strength to endure the expansive tendency, they will burst. On drawing the cork from a bottle of one of these liquors, the confined gas or air is suffered to expand, and the contents gush forth, a mixture of froth and liquid. If the liquid remain in an open glass for a short time, a large portion of the long-confined gases escapes into the atmosphere, and the liquor seems flat or dead. A portion of confined air, however, still remains, in consequence of the atmospheric pressure. If we take a glass of ginger-beer which seems quite dead, and place it under the exhausted receiver of an air-pump, it will again froth and appear brisk.

Some mineral waters, on springing from the ground, sparkle like beer. These most likely rise from great depths, where the incumbent pressure is considerable, and on attaining the surface of the earth, they expand, and give forth the gases pent up in their mass.

If a bladder full of air be carried from a low situation to a great height, the contained air will expand, and the bladder will burst, the same as if placed under the exhausted receiver of an air-pump. And, conversely, if a bladder be filled with air at a great height, where the fluid is rare, and brought to a low situation, the contained air will be compressed by the more dense fluid without, and the bladder will appear as if only half or partially filled.

The fluids in the animal and vegetable system are similarly affected by atmospheric pressure. Our bodies, for instance, would expand, and our blood-vessels probably be ruptured, if placed for a short time in a vacuum. On the same principle, any change in the density of the atmosphere has an effect, though not always perceptible, on the animal frame.

The atmospheric pressure, in ordinary conditions of the air, and at the level of the sea, as already stated, is equal to 15 lbs. to the square inch. If by any means, such as digging into the earth, we should go below the sea's level, the weight will be found to increase. In deep coal mines, for instance, the pressure of the atmosphere is something more than 15 lbs. to the square inch. This effect, however, is generally counteracted in mines and other deep excavations by an increase of temperature, which has the effect of rendering the air even lighter than it is at the normal surface.

The pressure diminishes, in a similar degree, as we ascend into the atmosphere. At every step upwards from the shore, the burden of the superincumbent mass lightens. At the height of three miles, one-half of the weight is lost; or, in other words, at that height the air is only half the density of air at the sea's level.

The breathing apparatus of animals is suited to an atmospheric density and pressure such as is found at the sea's level, or at a moderate elevation above it. By ascending in the atmosphere, as in climbing hills, we are deprived of the quantity of air to which we have been accustomed; and when we reach a height of three miles, we in reality inhale only one-half of the weight of air into the lungs that we use at the sea's level. Consequently, those who ascend to great elevations experience difficulty in breathing, and feel an expansion in their blood-vessels and muscles by the removal of a portion of the ordinary pressure. All the joints in our bodies, particularly those of the knee and shoulder, are in a great measure held together by the external pressure of the atmosphere; and thus a principle in pneumatics compensates for a binding of muscular ligaments.

A consideration of the effects of atmospheric pressure, and its variability at different elevations, also the alterations in pressure caused by the expansion or lightening of the air by heat, and its increased density by cold and moisture, tends to explain the remarkable influence which change of climate has upon the human constitution. Thus the inhabitants of countries possessing a light dry atmosphere, are usually more lively than those of countries with a heavy moist climate.

THE BAROMETER.

The pressure of the atmospheric column, at any given point, may be weighed with considerable exactness, by balancing it against an opposite column of mercury, water, or other liquid.

The pressure of 15 lbs. to the square inch at the ocean's level, is found by experiment to be equal to the weight of a column of mercury of 30 inches in height, a column of water 33 feet in height, or a column of oil 37 feet in height. In other words, the burden of the whole of our atmosphere is equivalent to an ocean of mercury covering the earth to a height of 30 inches, an ocean of water to a height of 33 feet, or an ocean of oil to a height of 37 feet.

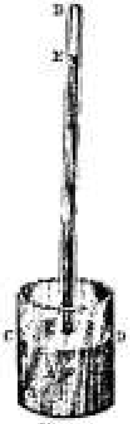


Fig. 22.

The fact of such being the degree of atmospheric pressure admits of easy proof, by means of a glass tube upwards of thirty-two inches in length, and a cup half filled with mercury, as represented in fig. 22. The tube is close at its upper end at B, but open at its lower extremity, which is immersed in the mercury below the surface level C P D. The tube having in the first place been filled with pure mercury, a finger is placed on its open end to prevent the egress of the liquid; and thus held, the lower end of the tube is turned downwards, and plunged into the vessel of mercury, when the finger is removed from the orifice. The mercury in the tube will now be observed to fall to E, or the height of about thirty inches above the surface C P D, and there it will remain.

The question now arises, Why the mercury in the tube does not run out altogether into the cup, instead of standing to a height of thirty inches in the tube? The explanation of the phenomenon is, that from E to B in the tube is a vacuum, and therefore the mercury at its upper extremity is entirely free of atmospheric pressure—there is no superincumbent weight to push it out. The column of mercury E P presses with nothing but its own weight on the mercury of the cup. This weight of thirty inches of mercury is counterbalanced by the pressure of air on the surface of the mercury in the cup; and thus it is evident that the weight of the atmosphere is equivalent to the weight of thirty inches of mercury. If by any means we remove the atmospheric pressure from the mercury in the cup, the mercury in the tube will immediately sink into the cup.

The circumstance of the column of mercury in the tube being narrow, and the surface of the mercury in the cup being broad, makes no difference in the experiment, because the pressure of elastic fluids is as their density, not as width of volume. The same result would occur if the surface of the mercury presented to the atmospheric pressure were only the width of the tube. The height at which mercury stands in a tube of this kind always bears reference to the incumbent weight of the atmosphere on the open and lower extremity of the column. If we increase the external pressure by artificial means, or by descending below the sea's level, the mercury rises; if, on the other hand, we decrease it by artificial means, or by ascending into the atmosphere, or if the atmosphere is rarefied by heat, the mercury falls.

This very obvious connection between the rising and falling of mercury in a tube and the atmosphere, has suggested the construction of an instrument called the *barometer* (a word from the Greek, signifying *weight* and *measure*), by which the effects of atmospheric pressure may be accurately known. The barometer in common use consists of a narrow glass tube upwards of thirty inches in length, and bent upwards at its lower extremity, as represented in fig. 23. The mercury is introduced into the tube with great care, so that a perfect vacuum exists at the upper extremity. The surface of the mercury in the bent part is open to the action of the atmosphere, and buoys up a small plummet or float F, to which a thread is attached; the thread proceeds upwards to a small pulley G, over which it goes, and terminates in a small ball W. The friction of the thread on the pulley turns a small index H, which points to figures on the surrounding dial. Commonly, the whole apparatus, except the dial-plate, is concealed in an ornamental frame. Barometers of this description are adjusted in such a manner, that the smallest rising or falling of the mercury from atmospheric action affects the index on the dial, and shows the degree of pressure.

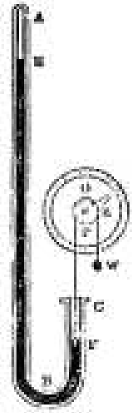


Fig. 23.

In common circumstances, the mercury ranges from 29 to 30 inches. It seldom sinks so low as 28, or rises to 31. When it falls, an indication is given of diminished pressure, and as diminished pressure causes the air to expand, and consequently to be sensibly cooled, moisture is liable to be precipitated in the form of rain; hence a fall in the mercury of the barometer is considered a prognostic of rain or wet weather, and a rise the reverse. The dial of the barometer is marked accordingly.

The barometer, besides being a weather-glass, is used as an instrument for measuring the heights of mountains, or heights attained in balloons, above the level of the sea. As the entire atmosphere sustains thirty inches of mercury in the tube, it follows that at every step as we ascend, the pressure will become less, and a less body of mercury be sustained. It is found that at the height of five hundred feet the mercury has sunk half an inch. But the fall does not proceed in this ratio as we go upwards, because a half of the whole atmosphere is within about three miles, and the other half expanded to an altitude of about fifty miles; hence, on gaining a height of three miles, the mercury is found to have sunk to fifteen inches, or one-half; and on gaining a height of four miles, to twelve inches.

Barometers for measuring heights are constructed with a determined scale, marked along the tube of mercury, and by consulting it as we ascend, we learn the height of any spot that we may reach. Perfect exactness, however, is not to be expected in this mode of measurement, because the atmospheric pressure is liable to variation from temperature, and the mercury is liable to contraction or expansion from the same cause. To guard against error, a thermometer, as well as a barometer is consulted in ascending heights, and the indications of both instruments, according to a scale established by experiment, determine the degree of elevation. Thus for a diminution of one degree of temperature between 0 and 32 degrees, the mercury in the barometer falls 0·0034 of an inch, and between 32 and 52 degrees it rises 0·0033 of an inch.

PUMPS.

The effect of atmospheric pressure on water is observable in various contrivances in the arts.

Fill a glass to the brim with water, and lay a piece of paper over the whole surface of the liquid: then turn the glass carefully upside down, holding on the paper by the hand; the water will now remain in the glass, being upheld by the pressure of the atmosphere against the paper. Glass fountains of water for bird-cages, ink-holders, and reservoirs of oil for lamps, are constructed on the principle of the liquid being upheld by atmospheric pressure.

The apparatus for lifting water from wells, forming the common sucking-pump, acts on the principle of removing the atmospheric pressure from a column of the liquid, thus causing a vacuum in the pump, and allowing the atmospheric pressure on the surface of the liquid in the well to force up and balance the column of liquid. Fig. 24 represents the outline of a common sucking-pump. It consists of a cylinder, furnished with a piston A, made to fit air-tight. In this piston there is a valve opening upwards, but here indicated as closed. When the piston is raised, the air is rarefied more and more at each stroke in that portion of the cylinder through which it has moved upwards, and the pressure of the air upon the surface of the water on the outside of the tube forces the fluid into it. The valve B is at the same time opened upwards, and the water, after several strokes, rushes in above it. When the upward stroke of the piston is complete, it is again depressed—the water passes through the valve in the piston, and on the next stroke it is discharged at the spout. It is evident that when the piston is sunk downwards, the water cannot be again forced out of the pump, because the valve at the bottom is pressed down, and prevents its escape.

Fig. 24.

Water may in this manner be lifted by a pump to any height, but in each case the lower or fixed valve in the pump must be less than 34 feet from the surface of the water. It is, however, disadvantageous to lift water from great depths by this means. In such cases it is usual to employ a succession of pumps, one above another.

It is customary to call pumps hydraulic machines; properly speaking, they are both hydraulic and pneumatic machines, for water is raised by them in a great measure through the agency of atmospheric pressure.

The form of pump used for forcing water to a height above the ground, as in the case of fire-engines or portable forcing-pumps for gardens, is different from the common suction-pump. The object in the forcing-pump is to lift water to a certain height by the formation of a vacuum, and then to inject it with violence into the air. The action of this kind of pump apparatus is represented in fig. 25. The piston A sucks the water by its upward motion; but on depressing it, the valve B is closed, and the water is consequently forced through the pipe C.

Fig. 25.

In the case of supplying water to the boiler of a steam-engine, it is necessary to employ a forcing-pump, to overcome the pressure of steam within the boiler. The force with which the water is injected overcomes the tendency which the steam has to rush out.

Cold or moderately warm water can only be lifted by a pump. If the water be above a certain temperature, about 150 degrees at the utmost, the sucker cannot form a perfect vacuum, because, in the attempt to do so, the water yields a steam or vapour which fills the space; in other words, by removing the atmospheric pressure by the piston, the water begins to vaporise, as if about to boil. When a pump is made to operate upon hot water, it labours in vain to raise the liquid. This circumstance limits the heat of water injected into the boilers of steam-engines; or if the water is injected at a high temperature, it must receive its heat between the pump and the boiler. This is sometimes done by causing the tube from the pump to pass through a vessel of waste steam.

SYPHONS.

Atmospheric pressure is very conspicuous in the case of the *syphon*.

A syphon is a tube bent in a particular manner, and is used for drawing off liquors from casks, or water from reservoirs. One kind is represented in fig. 26, and consists of a tube bent into two equal limbs, each open at the extremity. If such a syphon be filled with water, and inverted, so as to turn the two orifices downwards, the liquid will not run out, but remain suspended in the tube, because the pressure of the column of water within is not so great as the pressure of the air without, and thus its escape outwards is prevented. If one end be put into a vessel of water, the vessel will be emptied down to a level with the orifice. It is evident that, when one end of the syphon is inserted in water, the pressure of the atmosphere upon the surface of the water impels the liquid through the tube, and it could be forced upwards to an elevation of above thirty feet, or the height to which water rises in a vacuum. The diagram represents an instrument of this kind furnished with two cups, firmly attached to the ends, which, by retaining a portion of the liquid, keeps the syphon always full and ready for use.

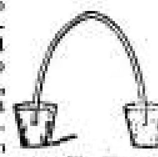


Fig. 26.

Syphons are more commonly made with a long and short limb, as in fig. 27. On inserting the short limb into a vessel of liquid, and drawing the air out of the tube at the mouth A, the liquid will rush out in a stream, and continue flowing till the vessel is emptied. The pressure upwards into the tube at A is the excess of the atmospheric pressure above the vertical pressure of the column of fluid AB; and the similar pressure at C is the excess of the atmospheric pressure above the vertical pressure of the column of fluid BC; but the latter excess is evidently the greater, and hence the liquid in the vessel is necessarily forced upwards through the tube from C to B; and thus the vessel is drained of its contents. By placing a stopcock on the tube above A, the stream can be checked, and permitted to flow at pleasure. There are instances of towns being supplied with water by means of large syphons of this kind. In these cases the syphon is brought over a rising ground from a lake or fountain at some distance. Certain kinds of springs are accounted for on the principle of the syphon; they act from the combined effects of a vacuum and atmospheric pressure.

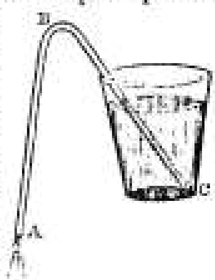


Fig. 27.

APPLICATION OF HEAT TO WATER.

The pressure of the atmosphere affects the boiling of water. At the common pressure of about 15 lbs. to the square inch, water will boil, or attain the vaporific point, at 212 degrees Fahrenheit. If we remove the atmospheric pressure by an air-pump, as is done in the boiling of sugar, we can produce the phenomenon of boiling at a much lower temperature. At the summit of Mont Blanc, where the atmospheric pressure is light, water is found to boil at 187 degrees.

Steam produced from boiling water is a transparent, colourless, and invisible substance, like air. If we could look into the boiler of a steam-engine, we should see nothing but the water in a state of ebullition. The white cloudy-looking matter which is emitted in the form of vapour, is moisture produced by the partial condensation of the steam in the atmosphere—taking the form of vapour is a step towards becoming liquid again. A cubic inch of water produces exactly a cubic foot, or 1728 cubic inches, of steam, at 212 degrees of temperature; in other words, when water is transformed into steam, it occupies 1728 times its former bulk. In this expanded condition, steam is of a less specific gravity than air. Its density is expressed by 0·625, that of air being 1.

The elastic force of steam in the process of heating —that is, the force with which it seeks to expand—differs at different temperatures. At first the force is inconsiderable, but it rapidly increases as the temperature is raised. At a temperature of 212 degrees, the elastic force is 15 lbs. on the square inch of the containing vessel, or equal to the external pressure of the atmosphere; at 250 degrees, it is 30 lbs.; at 272 degrees, it is 45 lbs.; and at 290 degrees, it is 66 lbs.

BUOYANT PROPERTY OF AERIFORM FLUIDS.

The atmosphere, as has been stated, possesses the property of buoying up bodies which, bulk for bulk, are lighter than itself. The law governing buoyancy in liquids is precisely the same as that governing buoyancy in aeriform fluids, and may here be repeated in reference to air.

1st, Any solid body immersed in a fluid displaces exactly its own bulk of fluid, and the force with which the body is buoyed up is equal to the weight of the fluid which is displaced. This refers to bodies of less density than air. *2d*, Any solid body of a greater density than air, when wholly immersed in that fluid, loses exactly as much of its weight as the weight of an equal bulk of air—that is, of the air which it displaces.

The support afforded to bodies in the atmospheric fluid by its resistance, is very evident from many appearances in nature—as the support of vapours or clouds, the rising of smoke and fine particles of dust, and the flying of birds; in art, it is exemplified by the flying of a boy's paper kite, the rising of soap-bubbles, and its buoyant property by the floating of balloons.

The flight of birds is not accomplished altogether by the buoyant property in the air. These animals support themselves by striking their wings against the fluid through which they are passing; and this friction, along with the property of buoyancy in the atmosphere, sustains them at any height to which they are pleased to ascend. Birds do not generally fly above half a mile in height, and seldom above a few hundred yards. At considerable elevations, the air is so specifically light, as to be unsuitable for their easy support. Those which rise to the higher regions of the atmosphere, as, for instance, the eagle, are provided with large wings, which enable them to support themselves in the comparatively thin fluid in which they move. A small bird, when let out from a balloon at the height of three miles, drops almost like a plummet, till it arrive at an aërial stratum against which its little wings can take effect.

The buoyant property of the air thus obviously diminishes in proportion as it becomes less dense; and there is a point above which the lightest imaginable body or particle of matter would inevitably sink. By this means, independently of terrestrial attraction, an effectual limit has been set to the distance attainable by substances from the surface of our planet. Not an atom of matter, since the period of the creation, has been suffered to escape beyond the higher regions of the atmosphere, or which has not, in making the attempt, been brought back to the earth.

The support given to bodies by the atmosphere diminishes their apparent weight, in the same manner as the apparent weight of bodies is diminished in water. A stone is moved more easily in water than in air, and so likewise is it moved more easily in air than in a vacuum. The diminution in weight of a body in air, as already stated, is equal to the weight of the bulk of air displaced. Thus, if an object which displaces one grain of air weigh a pound in a vacuum, it will weigh one grain less than a pound in air, and therefore one grain will require to be added to it to make up the apparent deficiency. The weight of air displaced by any marketable commodity is so exceedingly trifling, as not to be worth reckoning in ordinary circumstances. Strictly speaking, however, this weight of air has an influence in the value of the transaction. In all cases in which the object weighed is more bulky than the weight employed to balance it, a certain quantity must be added to overcome the force with which it is buoyed up by the atmospheric fluid.

The light heated air which escapes from a fire ascends, and is buoyed up by the more dense air beneath. Hydrogen, or any other gas of a less specific gravity than air, in the same manner ascends and floats in the atmosphere at the height at which it finds air of its own specific gravity. On the same principle, if heated air or any light gas be enclosed in a large silk bag, it will ascend in the atmosphere till it reach a region of air which is incapable of supporting it. Thus a soap-bubble enclosing warm air readily ascends to the ceiling of an apartment. If the bubble be made with cold water, it will sink instead of rising.

A *balloon* is a bag made of fine varnished silk, and of such a magnitude, that the difference betwixt the weight of its contents and that of the displaced air is sufficient to support the weight of the silk and the other parts of the apparatus. Balloons were originally made to rise by being filled with heated air from a fire hung beneath them; but this dangerous and inconvenient practice was in course of time superseded by the use of hydrogen gas, one of the lightest airs which can be prepared. Hydrogen gas has latterly been succeeded by carburetted hydrogen, which, though not so light, is more easily obtained, being the gas with which towns are now generally lighted. Employing a moderately pure and light gas, the contents of a balloon may be estimated to weigh only an eighth of the weight of the atmosphere, bulk for bulk; and hence, after adding another eighth for weight of apparatus, it will ascend with a force of six-eighths; in other words, if the gas and apparatus weigh two pounds, the balloon will lift from the ground a weight of other six pounds. The force with which a balloon will ascend is therefore to be calculated by measuring its capacity in cubic feet, and comparing the result with an equal bulk of atmospheric air: the difference of weight is the buoyant force of the balloon.

Balloon.

Of *aërostation*, or the art of moving through the air in balloons, great expectations were originally entertained; but the experience of half a century has proved that it is of no practical value. Its only use is the exhibition of an interesting principle in pneumatics. A balloon constructed in the best-known manner, and moving upwards with a powerful force, is subject to the following drawbacks:—As the balloon ascends, its contents expand, in consequence of the increasing rarefaction of the atmosphere; if, therefore, it has been entirely filled when on the ground, a portion of the gas must be allowed to escape as it rises, otherwise it will burst. Discharges of ballast are also required, in consequence of the absorption of moisture from clouds; and there being no means of recovering the lost ballast, the balloon, on the return of heat, rapidly rises in the air, its contents expanding in the ascent, and rendering further liberations of gas necessary to prevent explosion. These alternations continuing to operate more or less frequently, it is evident that they must soon put an end to the buoyant power, however great originally, and, along with the contending effects of winds, forcibly terminate any aërial excursion.

OPTICS—ACOUSTICS.

OPTICS.

The term *Optics* is derived from a Greek word which signifies *seeing*, and applies to that branch of natural philosophy which treats of the phenomena of *light* and vision. Of the precise character of light there are various theories, but none which admits of actual demonstration or proof. By some it has been described as consisting of very minute particles or molecules, which are thrown off from what are called luminous bodies in all directions, and with immense velocity; while others consider it as the effect of an undulation or vibration produced by luminous bodies in the thin and elastic medium which is interposed between them and the seat of our vision—this vibration producing an effect upon our organs, which we recognise as light, in a manner analogous to the impression of sound on the ear caused by vibrations of the atmosphere. The latter is called the *undulatory* theory of light; and the former, in which light is supposed to consist of *material* particles, the theory of *emission*.* Whatever may be the cause or absolute nature of light, we know it is a property of luminous bodies which enables us to see the luminous objects themselves, as well as others in their vicinity, and that its absence produces darkness.

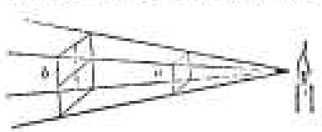
All visible bodies may be divided into two classes—*self-luminous* and *non-luminous*. Under the first head are comprised all those bodies which possess in themselves the property of exciting the sensation of light or vision, such as the heavenly luminaries, terrestrial flames of all kinds, phosphorescent bodies, and those bodies which shine by friction or by being heated. Under the second class we recognise such bodies as have not of themselves the power of throwing off particles or undulations of light, but which possess the property of reflecting the light which is cast upon them from self-luminous bodies. A non-luminous body may thus, by reflection, receive light from another non-luminous body, communicate it to a third; and so on. All reflected light, however, is inferior in brilliancy to that which comes direct from a self-luminous body.

Anciently, it was believed that light was propagated from the sun, and other luminous bodies, instantaneously; but the observations of modern inquirers have shown that this was an erroneous hypothesis, and that light, like sound, requires a certain time to pass from one part of space to another, though the velocity of its motion is truly astonishing, as has been manifested in various ways. Astronomers have proved, by observing the eclipses of Jupiter's satellites, when that planet is nearest and when it is farthest from the earth, that light moves from the sun to the earth, a distance of 95,000,000 miles, in seven and a half minutes, or about 200,000 miles during a single vibration of a pendulum. So prodigiously great is this velocity, that, as far as any common observation is concerned, light may be regarded as perfectly instantaneous in its action.

* The theory of emission was devised by Newton, and for a long time it was thought to explain the facts better than any other. It is not necessary to suppose that the particles succeed each other closely, so as to crowd the whole of space with a luminous stream. It is found that a single impression of light will remain on the eye for the eighth of a second, and therefore if eight particles fell upon it every second, there would be a permanent impression produced. But in the eighth of a second a ray passes through 25,000 miles, so that if one particle followed another at this distance, constant light would be maintained, and the shower would be so thin and scattered, as to allow room enough for all the innumerable crossings of luminous rays. At present, however, there are many phenomena which cannot be explained by this theory, and are found more consistent with the undulatory hypothesis.

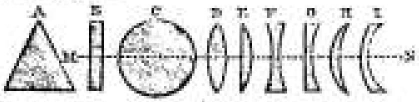
Light proceeds in a straight direction from the luminous body which produces it, towards the part or situation against which it is permitted to act. In consequence of this directness, a shadow or darkened spot is observable behind any opaque object presented to the light. During night, we are in the earth's shadow; and this shadow reaches so far beyond us into space, that when the moon plunges into it in her course, she undergoes an eclipse. The direct shining of the sun, or any other luminous body, is in the form of rays, or thin ethereal lines, each acting independently of the other; no such separation of parts, however, is observable in common circumstances, in consequence of the diffusive properties of the atmosphere. Seeing is simply the reception of the direct or reflected ray from an object by our eye. Until the rays of the sun reach the spot on which we are placed, we are neither conscious of light nor of the presence of the sun as an object. In the same manner, a candle being lighted and exposed in the open country in a dark night, all who are able to see it are within the influence of its rays; but beyond a given distance these rays are too weak to produce vision, and all who are in this remote situation cannot see the faintest appearance of the candle. It will therefore be understood that the seeing of any luminous object is equivalent to being within the influence of rays of sufficient intensity proceeding from it. The number of rays which proceed from even a common candle is so vast, as to be beyond our conception; for if such a light is visible within a range of four miles, it follows that if the whole of that space were surrounded with eyes, each eye would receive the impression of a ray of light.

In proportion as light advances from its seat of production, it diminishes in intensity. The ratio of diminution is agreeable to that which governs physical forces—that is, the intensity of the light will diminish as the square of the distance increases, or at the rate of 1, 4, 16, &c. But in proportion as we lose in intensity, we gain in volume; the light is the weaker the farther it is from the candle, but it is filling a wider space. Thus if a board, *a*, a foot square be placed at the distance of one foot from a candle, it will be found to hide the light from another board, *b*, of two feet square, at the distance of two feet from the candle. Now a board of two feet square is just four times as large as one of one foot square, and therefore the light at double the distance being spread over four times the surface, has only one-fourth the intensity.



Preliminary to any farther exposition of the nature and action of light, we offer the following definitions of terms:—Any parcel of rays passing from a point is called a *pencil* of rays. By an optical *medium* is meant any pellucid or transparent body—as, for example, air, water, or glass, which suffers light to pass through it. *Parallel rays* are such as move always at the same distance from each other. If rays continually recede from each other, they are said to *diverge*; if they continually approach each other, they are said to *converge*. The point at which converging rays meet is called the *focus*; the point towards which they tend, but which they are prevented from coming to by some obstacle, is called the *imaginary focus*. When rays, after passing through one medium, on entering another medium of different density, are bent out of their former course, and made to change their direction, they are said to be *refracted*;

when they strike against a surface, and are sent back again from the surface, they are said to be *reflected*. A *lens* is a glass ground into such a form as to collect or disperse the rays of light which pass through it. These are of different shapes, and thence receive different names. The following figures individually represent sections of the variously-shaped lenses and other glasses used in optics:—



A is a triangular stalk of pure glass, of which we have here a cross sectional or end view, and which is called a *prism*; each side of the prism is smooth. B is a section of a piece of plane glass, with sides parallel to each other. C is a sphere or ball of glass, and consequently is convex on all parts of its surface. D is a piece of glass convex, or bulging on its two sides, and is called a *double convex lens*. It is this kind of lens which is used for magnifying objects, in spectacles, telescopes, and other instruments. E is a *plano-convex lens*, flat, or planed on one side, and convex on the other. F is a *double concave lens*, or glass hollowed on each side. G is a *plano-concave lens*, or planed on one side, and concave on the other. H is a *meniscus*, or lens convex on one side, and concave on the other, both surfaces meeting, and of which we have an example in watch-glasses. I is an example of the *concavo-convex lens*, in which the surfaces disagree, or do not meet when continued. In all these lenses an imaginary line, represented by M N, and passing through the centres of the surfaces, is called the *axis*. Thus the line said to pass through the centre of any lens, in a direction perpendicular to its surface, is called its axis.

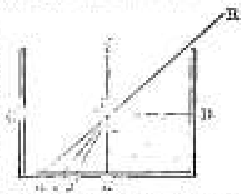
In treatises on optics, it is customary to divide the subject into two sections, under the heads Dioptrics and Catoptrics. The term *dioptrics* is compounded of two Greek words signifying *to see through*, and refers to the transmission of rays of light through transparent bodies, as well as the laws by which they are produced. *Catoptrics* is also from the Greek, and signifies *to see from or against*: it refers to the reflection of light from surfaces, and the formation of images by means of mirrors and other objects.

REFRACTION OF LIGHT.

Refraction, as already mentioned, is the bending of rays of light from the course they formerly pursued. If the rays, after passing through a medium, enter another of a different density, perpendicular to its surface, they are not refracted, but proceed through this medium in their original direction. For instance, if the sun's rays were to strike upon the surface of a river at right angles, or perpendicularly, to its surface, they would go straight to the bottom, and the line they observed in the air would be continued in the water. But if they enter obliquely to the surface of a medium either denser or rarer than what they moved in before, they are made to change their direction in passing through that medium; that is, they are refracted.

The mode of the refraction depends on the comparative density or rarity of the respective media. If the medium which the rays enter be denser, they move through it in a direction nearer to the perpendicular drawn to its surface. On the contrary, when light passes out of a denser into a rarer medium, it moves in a direction farther from the perpendicular. This refraction is greater or less—that is, the rays are more or less bent, or turned aside from their course—as the second medium through which they pass is more or less dense than the first. To prove this in a satisfactory way, take an upright empty vessel into a darkened room, which admits but a single beam of light obliquely through a hole in a window-shutter. Let the empty vessel stand on the floor, a few feet in advance of the window which admits the light, and let it be so arranged that, as the beam of light descends towards the floor, it just passes over the top of the side of the vessel next the window, and strikes the bottom on the side farthest from the window. Let the spot where it falls be marked. Now, on filling the vessel with water, the ray, instead of striking the original spot, will fall considerably nearer the side towards the window. And if we add a quantity of salt to the vessel of water, so as to form a dense solution, the point where the ray strikes the bottom will move nearer to the window. In like manner, if we draw off the salt water, and supply its place with alcohol, the beam of light will be still more highly refracted; and oil will refract yet more than alcohol.

The property of refraction may also be observable in the following experiment:—Let the annexed oblong figure represent a vessel half filled with water, and R the ray of light which may be expected to pass through it to the bottom at *d*. The direction of the ray is perfectly straight until it enters the water at *j*, when, instead of proceeding in a straight line to *d*, it is bent from its course, and compelled to strike the bottom of the vessel at *e*. If oil instead of water had been used, the ray would have been still more bent, and have reached the bottom at *f*. If the ray had been sent directly downwards, as from *i* to the surface of the water at *j*, it would not have been refracted, but have proceeded straight to the bottom at *k*.



The following simple experiments are well known:—Take an empty basin and place it on a table, then lay a shilling at the bottom of the basin, in such a position that the eye of the observer will not see it. Now fill the basin with water, and the shilling, though lying unmoved, will come completely into sight. The explanation of this phenomenon is, that the ray of light producing vision in the eye is bent on emerging from the water, and has all the effect of conveying our sight round a corner. In like manner the refractive power of water is observable when we thrust a straight stick or instrument into it, on aiming at any object. We see that the stick seems to be bent, and fails in reaching the point which we desired it should. On this account, the aim by a person not directly over a fish must be made at a point apparently below it, otherwise the weapon will miss by flying too high. Persons who spear salmon in rivers require to calculate upon this refractive power in taking their aim.

With regard to the refractive power of transparent substances or media, the general rule, with certain limitations, is, that it is in proportion to the densities of the bodies. It increases, for instance, from the most perfect vacuum which can be formed, through air, fresh water, salt water, glass; and so on. But those substances which contain the most inflammable matter, have the greatest refractive power. It was from the great refractive powers of the diamond and water, that Newton, with admirable sagacity, predicted that they contained inflammable principles. This fact future discoveries in chemistry verified. Tables of the refractive powers of substances most interesting in optics will be found in Brewster's 'Optics.' From these it would appear that substances which contain fluoric acid have the least refractive power, as inflammable ones have the greatest. With regard to the cause of refraction, on the theory of emission, the refracting medium would attract the particles of light, and increase their velocity during their transmission, and would alter the direction of their motion, thus causing refraction; but the intensity of the attractive force would require to be different for light of different colours; and on the undulatory theory, the ether within the refracting medium would be condensed by the attraction of its particles on the ether, and the velocity of transmission of the wave of light through this condensed ether would be less than in free space, and from this cause the direction of the motion would be altered, or refraction would take place; and from the different lengths of the waves of different colours, the velocity of their transmission would be different, thus causing different degrees of refrangibility according to the difference of colour.

The refraction of rays of light is observable in the case of common window-glass. The two sides of a pane not being perfectly parallel to each other, bodies seen through it appear as if distorted; and as the obliquities in the glass are very various, the distortions are equally grotesque and numerous. Some windows are purposely ground on the surface, to produce universal and minute refraction; and thus so great a confusion is introduced among the rays, that objects are not distinguishable through the glass. When the obliquities on the surface of one side of a piece of glass stand distinct from each other, so as to admit of refraction in a clear and distinguishable manner, then each obliquity affords a separate view of an object on the opposite side, and thus an object seems to be multiplied as many times as there are obliquities.

The refraction of light is observable on a great scale in relation to our atmosphere. The rays of the sun, on reaching the confines of the atmospheric fluid which envelops the earth, enter a medium of greater density than that which they have previously been pursuing, and consequently are refracted or bent. One obvious effect of this is, that we never see the sun in the actual position which he occupies. He is always less or more, in relation to our eyes, what the shilling is said to be in the above experiment with the basin of water. This is peculiarly the case in the morning, when his earliest rays reach our eyes; entering a denser medium, these rays bend round to meet our vision, and we actually see the body of the sun a few minutes before he has risen above the horizon—like the shilling in the basin, we see him round a corner. In proportion as the sun approaches the zenith, the refraction diminishes; and as he recedes towards setting, it increases. So considerable is it in the hazy atmosphere of the evening, that we retain a sight of his disk after he has set.

From these explanations, it will appear that the directness of our vision is at all times liable to be disturbed by atmospheric conditions. So long as the atmosphere betwixt our person and the object we are looking at is of the same density, we may be said to see in a straight line to the object; but if by any cause a portion of that atmosphere is rendered less or more dense, the line of vision is at once refracted or bent from its course. A thorough comprehension of this simple truth in science has banished a mass of superstition. It has been found that, by means of powerful refraction, objects at a great distance, and round the back of a hill, or considerably beneath the horizon, are brought into sight. In some countries this phenomenon is called the *mirage*. The following is one of the most interesting and best authenticated examples:—In a voyage performed by Captain Scoresby in 1822, he was able to recognise his father's ship, when below the horizon, from the inverted image of it which appeared in the air. 'It was,' says he, 'so well defined, that I could distinguish by a telescope every sail, the general rig of the ship, and its particular character; insomuch that I confidently pronounced it to be my father's ship the *Fame*, which it afterwards proved to be; though, on comparing notes with my father, I found that our relative position at the time gave our distance from one another very nearly thirty miles, being about seventeen miles beyond the horizon, and some leagues beyond the limit of direct vision. I was so struck by the peculiarity of the circumstance, that I mentioned it to the officer of the watch, stating my full conviction that the *Fame* was then cruising in the neighbouring inlet.'

A curious phenomenon of this kind was seen by Dr Vince, on the 6th of August 1806, at seven P.M. To an observer at Ramsgate, the tops of the four turrets of Dover Castle are usually seen over a hill between Ramsgate and Dover. Dr Vince, however, when at Ramsgate, saw the whole of Dover Castle, as if it had been brought over and placed on the Ramsgate side of the hill. The image of the castle was so vivid, that the hill itself did not appear through the image.

In the sandy plains of Egypt, the mirage is seen to great advantage. These plains are often interrupted by small eminences, upon which the inhabitants have built their villages, to escape the inundations of the Nile. In the morning and evening, objects are seen in their natural form and position; but when the surface of the sandy ground is heated by the sun, the land seems terminated at a particular distance by a general inundation: the villages which are beyond it appear like so many islands in a great lake, and between each village an inverted image of it is seen.

That the phenomena of the mirage are produced by variations in the refractive power of the atmosphere, can be proved by experiment. If the variation of the refractive power of the air takes place in a horizontal line perpendicular to the line of vision—that is, from right to left—then we have the lateral mirage; that is, an image of a ship may be seen on the right or left hand of the real ship, or on both, if the variation of refractive power is the same on each side of the line of vision. If there should happen at the same time both a vertical and a lateral variation of refractive power in the air, and if the variation should be such as to expand or elongate the object in both directions, then the object would be magnified as if observed through a telescope, and might be seen and recognised at a distance at which it would not otherwise have been visible. If the refractive power, on the contrary, varied so as to contract the object in both directions, the image of it would be diminished as if seen through a concave lens.

In order to represent artificially the effects of the mirage, Dr Wollaston suggested the viewing of an object through a stratum of spirit of wine lying above water in a crystal jar, or a stratum of water lying above one of syrup. These substances, by their gradual incorporation, produce a refractive power diminishing from the spirit of wine to the water, or from the syrup to the water: so that, by looking through the mixed or intermediate stratum at a word or object held behind the bottle which contains the fluids, an inverted image will be seen. The same effect, it has been shown, may be produced by looking along the side of a red-hot poker at a word or object ten or twelve feet distant. At a distance less than three-eighths of an inch from the line of the poker, an inverted image is seen, and within and without that an erect image.

The method employed by Sir David Brewster to illustrate these phenomena, consists in holding a heated iron above a mass of water bounded by parallel plates of glass; as the heat descends slowly through the fluid, we have a regular variation of density, which gradually diminishes from the bottom to the surface. If we now withdraw the heated iron, and put a cold body in its place, or even allow the air to act alone, the superficial stratum of water will give out its heat, so as to produce a decrease of density from the surface to a certain depth below it. Through the medium thus constituted, the phenomena of the mirage may be seen in the most interesting manner.

Double Refraction.

In the preceding part of this section, we have considered a single ray of light, reflected or transmitted through the substance of a transparent body, as leaving it in the same way in which it came into contact with it—namely, in a single pencil or ray. But there are a great many bodies which have the power of breaking the pencil of light incident upon their surfaces into two separate parts or pencils, more or less inclined to one another, according to the nature and state of the body, and according to the direction of the incident pencil. This is called *double refraction*, and the bodies which produce it are called doubly refracting bodies or crystals. They are very numerous, and include all salts and crystallized minerals not having the primitive forms of the cube, the regular octohedron, and the rhomboidal dodecahedron. Of all known bodies, the Iceland spar, or rhomboidal carbonate of lime, shows the fact with the greatest certainty; and as it is a mineral easily procured, it has been generally used in experiments upon this subject. Its crystals are of a rhomboidal form, having six acute solid angles, and two obtuse. Double refraction of light is employed to advantage in some kinds of lighthouses; and those who wish to investigate its nature and properties, may be referred to advanced treatises on the subject.

With respect to the *polarisation of light*—which is the separation of a ray of light into two rays, having different properties from each other, among which properties is that of producing colour in a variety of ways, although the original ray may be common or white light—we must also refer to works of higher scope than the present.

Colour by Refraction.

One of the most remarkable phenomena attending refraction is, that the rays of light, which seem to us to be white, may be separated into rays of various colours. It will be obvious that light has the effect of representing colours, where no colour substantially exists, by noticing the glancing and varied hues on irregular surfaces of glass, ice, or other crystallised substances.

The proper method of analysing the rays of light, and discovering into what colours they may be resolved, is to procure a prism, and perform the following experiment in a darkened chamber:—In the window-

shutter, E, of a darkened room, make a small hole, H, through which admit a beam of the sun's light, S, which, when nothing is interposed, will proceed in a straight line to P, and form a luminous white spot. If we now interpose a prism B A C, whose refracting angle is B a C, so that the beam of light may fall on its surface C A, and emerge at the same angle from its second surface B A, in the direction *g* G, and if we receive the refracted beam on the opposite wall, or on a white screen M N, 'we should expect,' says Sir David Brewster, 'from the principles already laid down, that the white beam which previously fell upon P would suffer only a change in its direction, and fall somewhere upon M N, forming there a round white spot exactly similar to that at P. But this is not the case. Instead of a white spot, there will be formed upon the screen M N an oblong image K L of the sun, containing seven colours—namely, red, orange, yellow, green, blue, indigo, and violet—the whole beam of light diverging from its emergence out of the prism at *g*, and being bounded by the lines *g* K, *g* L. This lengthened image of the sun is called the *solar* or *prismatic spectrum*. If the aperture H is small, and the distance *g* G considerable, the colours of the spectrum will be very bright. The lowest portion of it at L is a brilliant red. This red shades off by imperceptible gradations into orange, the orange into yellow, the yellow into green, the green into blue, the blue into a pure indigo, and the indigo into a violet. No lines are seen across the spectrum thus produced; and it is extremely difficult for the sharpest eye to point out the boundary of the different colours. Sir Isaac Newton, however, by many trials, found the lengths of the colours to be as follow, in the kind of glass of which his prism was made:—Red, 45; orange, 27; yellow, 40; green, 60; blue, 60; indigo, 48; violet, 80—Total length, 360.'

These colours are not equally brilliant. At the lower end, L, of the spectrum, the red is comparatively faint, but grows brighter as it approaches the orange. The light increases gradually to the middle of the yellow, where it is brightest; and from this it gradually declines to the upper or violet end, K, of the spectrum, where it is extremely faint.

From the phenomena which we have now described, Sir Isaac Newton concluded that the beam of white light is compounded of light of seven different colours, and that for each of these different kinds of light, the glass of which his prism was made had different indices—that is, measures of refraction; the index of refraction for the red light being the least, and that of the violet the greatest.

By means of a second prism placed behind a hole in the screen M N, opposite the centre of each coloured space, Sir Isaac Newton refracted the light a second time. In this case it was not drawn out into an oblong image as before, and was not refracted into any other colour than that which formerly belonged to each particular ray. Hence this great philosopher concluded that the light of each particular colour possessed the same index of refraction; and he termed such light homogeneous—that is, of the same kind, or simple; white light being regarded as heterogeneous—that is, of different kinds, or compound.

By various experiments, Sir Isaac proved that all the colours, when again combined, formed or recomposed white light. Indeed the doctrine may be illustrated by mixing together, in proper proportions, seven colours as like those of the spectrum as can possibly be got. By their union a grayish white is formed, for powders of the exact tint as those of the spectrum cannot be obtained. It may also be proved in this manner:—Let a circle of paper be divided into sections of the same size, and coloured like the spaces in the spectrum, and placed upon a humming-top, which is made to revolve rapidly; the effect of all the colours, when combined, is to produce a grayish white.

'All transparent substances, in bending light,' observes Dr Arnott, 'produce more or less of the separation of colour; but it is an important fact, that the quality of merely bending a beam, or of *refraction*, and that of dividing it into coloured beams, or of *dispersion*, are distinct qualities, and not having the same proportion to each other in different substances. Newton, from not discovering this, concluded that a perfect telescope of refraction could never be made; he supposed that the bent light would always become coloured, and so render the object indistinct. We now know, however, that by combining two or more media, we may obtain bending of light without dispersion—thus, by opposing a glass which bends five degrees and disperses one degree, to another glass which bends three degrees and disperses one, the opposing dispersions will just counterbalance each other, while the two degrees of excess of bending will remain to be applied to use.'

It having been found, by the experiments of Newton and others, that none of the seven colours of the solar spectrum could be broken by the prism into new colours, the theory was in some measure established that there were *seven* primitive colours. In time, however, practical men discovered that there were only *three* simple or homogeneous colours, and that all others resulted from them. These three primitive colours were *red*, *blue*, and *yellow*. That this was the true doctrine of colours, has been completely set at rest by the experiments of Mr D. R. Hay (Edinburgh), author of a treatise on the 'Laws of Harmonious Colouring.' We extract the following account of Mr Hay's experiments from the work in question:—

'Although this theory (that of there being only three primitive colours) was not set up in opposition to that of the natural philosophers, but seemed only to be established in a practical point of view, neither was it supported by any scientific experiments; yet it appeared to me more consistent with the general simplicity of nature, and I could not believe that she required seven homogeneous parts to produce what art could do by three. For instance, an artist can make all the colours, and indeed a correct representation of the prismatic spectrum (so far as the purity of his materials will allow), with three colours only; while, according to the theory of Sir Isaac Newton, seven simple or homogeneous colours were employed to produce the real one.

'The following discovery, made by Buffon, and illustrated by succeeding philosophers, helped to strengthen me in the conviction that the scientific theory might, like that of the practical artist, be reducible to three simple or homogeneous parts. If we look steadily for a considerable time upon a spot of any given colour, placed on a white or black ground, it will appear surrounded by a border of another colour. And this colour will uniformly be found to be that which makes up the triad: for if the spot be red, the border will be green, which is composed of blue and yellow; if blue, the border will be orange, composed of yellow and red; and if yellow, the border will be purple—making in all cases a tri-unity of the three colours called by artists homogeneous.

'With a view to throw such light upon the subject as my limited opportunities would permit, I went over the experiments by which Sir Isaac Newton established his theory, and the same results occurred: I could not separate any one colour of the solar spectrum into two. The imperceptible manner in which the colours were blended together upon the spectrum, however, and the circumstance of the colours which practical people call compound being always placed at the adjunct of the two of which they say it is composed, with my previous conviction, induced me to continue my experiments; and although I could not, by analysis, prove that there were only three colours, I succeeded in proving it to my own satisfaction, synthetically, in the following manner:—

'After having tried every colour in succession, and finding that none of them could be separated into two, I next made a hole in the first screen in the centre of the blue of the spectrum, and another in that of the red. I had thereby a spot of each of these colours upon a second screen. I then, by means of another prism, directed the blue spot to the same part of the second screen on which the red appeared, where they united, and produced a violet as pure and intense as that upon the spectrum. I did the same with the blue and yellow, and produced the prismatic green; as also with the red and yellow, and orange was the result. I tried, in the same manner, to mix a simple with what I thought a compound colour, but they did not unite; for no sooner was the red spot thrown upon the green, than it disappeared.

I tried the same experiment with two spectra, the one behind, and of course a little above the other, and passed a spot of each colour successively over the spectrum which was farthest from the window, and the same result occurred. It therefore appeared to me that these three colours had an affinity to one another that did not exist in the others, and that they could not be the same in every respect, except colour and refrangibility, as had hitherto been taught.

'These opinions, the result of my experiments, I published in 1828, as being a necessary part of a treatise of this nature; and I did so with great diffidence, well knowing that I was soaring far above my own element in making an attempt to throw light upon such a subject. I had, however, the gratification to learn that these facts were afterwards proved in a communication read to the Royal Society of Edinburgh by Sir David Brewster, on the 21st of March 1831, in which he also showed that white light consists of the three primary colours—red, yellow, and blue; and that the other colours shown by the prism are composed of these.

'The three homogeneous colours—yellow, red, and blue—have been proved by Field, in the most satisfactory manner, to be in numerical proportional power as follows—yellow, three; red, five; and blue, eight.

'When these three colours are reflected from any opaque body in these proportions, white is produced. They are then in an active state, but each is neutralised by the relative effect that the others have upon it. When they are absorbed in the same proportions, they are in a passive state, and black is the result. When transmitted through any transparent body, the effect is the same; but in the first case they are material or inherent, and in the second impalpable or transient. Colour therefore depends entirely on the reflective or refractive power of bodies, as the transmission or reflection of sound does upon their vibratory powers.'

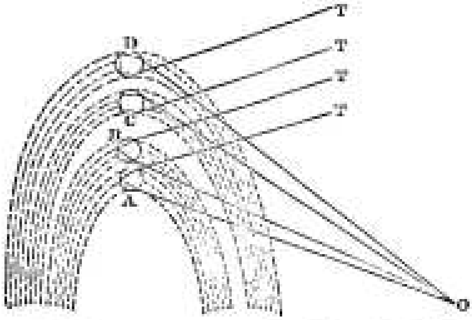
THE RAINBOW.

Every one knows that the rainbow is that brilliant and many-coloured arch occasionally seen spanning the sky opposite to the sun. Rainbows are only visible when rain is falling between the spectator and that part of the sky which is opposite to the sun, which is in its centre, as if at the end of a straight line, drawn from the sun through the eye of the spectator towards the opposite horizon; and being always under the horizon, the bow is less than a semicircle. It consists of two bows or arches—the one inner or primary, the other outer or secondary; and within the primary rainbow, and in contact with it, and without the secondary one, there have been seen supernumerary bows.

The primary or inner rainbow, which is commonly seen alone, is part of a circle whose radius is 41°. It consists of seven differently-coloured bows—namely, violet, which is the innermost, indigo, blue, green, yellow, orange, and red, which is the outermost. These colours have the same proportional breadth as the spaces in the prismatic spectrum. This bow is therefore only an infinite number of prismatic spectra, arranged in the circumference of a circle; and it would be easy, by a circular arrangement of prisms, or by covering up all the central part of a large lens, to produce a small arch of exactly the same colours. All that we require, therefore, to form a rainbow, is a great number of transparent bodies capable of forming a great number of prismatic spectra from the light of the sun.

Sir David Brewster thus explains the cause of the arc of the sky:—As the rainbow is never seen unless when rain is actually falling between the spectator and the sky opposite to the sun, we are led to believe that the transparent bodies required are drops of rain, which we know to be small spheres. If we look into a globe of glass or water held above the head, and opposite to the sun, we shall actually see a prismatic spectrum reflected from the farther side of the globe. In this spectrum the violet rays will be innermost, and the spectrum vertical. If we hold the globe horizontal, on a level with the eye, so as to see the sun's light reflected in a horizontal plane, we shall see a horizontal spectrum, with the violet rays innermost. In like manner, if we hold a globe in a position intermediate between these two, so as to see the sun's light reflected in a plane inclined 45° to the horizon, we shall perceive a spectrum inclined 45° to the horizon, with the violet innermost. Now, since in a shower of rain there are drops in all positions relative to the eye, the eye will receive spectra inclined at all angles to the horizon, so that, when combined, they will form the large circular spectrum which constitutes the rainbow.

To explain this more clearly—let A B be drops of rain exposed in the sun's rays, incident upon them in the direction T A, T B, out of the whole beam of light which falls upon the drop; those rays which pass through or near the axis of the drop will be refracted to a focus behind it; but those which fall on the upper side of the drop will be refracted, the red rays least, and the violet most, and will fall upon the back of the drop with such sufficient obliquity that many of them will be reflected, as shown in the figure. These rays will be again refracted, and will meet the eye at O, which will perceive a spectrum or prismatic image of the sun, with the red space uppermost, and the violet undermost. If the sun, the eye, and the drops A B, are all in the same



vertical plane, the spectrum produced by A B will form the colours at the very summit of the bow, as in the figure. Let us now suppose a drop to be near the horizon, so that the eye, the drop, and the sun, are in a plane inclined to the horizon, a ray of the sun's light will be reflected in the same manner as at A B, with this difference only, that the plane of reflection will be inclined to the horizon, and will form part of the bow distant from the summit. Hence it is manifest that the drops of rain immediately above the line joining the eye, and the upper part of the rainbow, and in the plane passing through the eye and the sun, will form the upper part of the bow; and the drops to the right and left hand of the observer, and without the line joining the eye and the lowest part of the bow, will form the lowest part of the bow on each hand. Not a single drop, therefore, between the eye and the space within the bow is concerned in its production; so that, if a shower were to fall regularly from a cloud, the rainbow would appear before a single drop of rain had reached the ground.

If we compute the inclination of the red ray and the violet ray to the incident rays T A, T B, we shall find it to be 42° 2′ for the red, and 40° 17′ for the violet, so that the breadth of the rainbow will be the difference of these numbers, or 1° 45′, or nearly three times and a half the sun's diameter. These results coincide so accurately with observation, as to leave no doubt that the primary rainbow is produced by two refractions and one intermediate reflection of the rays that fall on the upper sides of the drops of rain.

It is obvious that some of the rays will suffer a second reflection at the points where they are represented as quitting the drop; but these reflected rays will go up into the sky, and cannot possibly reach the eye at O. But though this is the case with rays that enter the upper side of the drop, as at A B, or the side farthest from the eye, yet those which enter it on the under side, or the side nearest the eye, may after two reflections reach the eye, as shown in the drops D C, where the rays T T enter the drops below. The red and violet rays will be refracted in different directions, and after being twice reflected, will be finally refracted to the eye at O; the violet forming the upper part, and the red the under part of the spectrum. If we now compute the inclination of these rays to the incident rays T T, we shall find them to be 50° 58′ for the red ray, and 54° 10′ for the violet ray; the difference of which, or 3° 12′ will be the breadth of the bow, and the distance between the bows will be 8° 15′. Hence it is clear that a secondary bow will be formed without the primary bow, and with its colours reversed, in consequence of their being produced by two reflections and two refractions. The breadth of the secondary bow is nearly twice as great as that of the primary one, and its colours must be much fainter, because it consists of light that has suffered two reflections in place of one.

Many peculiar kinds of rainbows have been observed, such as lunar ones, in which, however, the colours are faint and barely perceptible. Supernumerary rainbows are sometimes seen. 'On the 5th of July 1828,' says Sir David Brewster, 'I observed three supernumerary bows within the primary bow, each consisting of green and red arches, and in contact with the violet arch of the primary bow. On the outside of the outer or secondary bow, I saw distinctly a red arch, and beyond it a very faint green one, constituting a supernumerary bow, analogous to those within the primary rainbow.'

Red rainbows, distorted rainbows, and inverted rainbows on the grass, have been observed. The latter are formed by the drops of rain suspended on the spiders' webs in the fields. It is only necessary to mention that the iris, so frequently seen overarching a cataract, is produced by the refraction of light in passing through the misty vapour generated by the falling water.

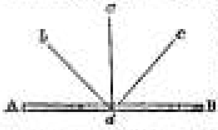
REFLECTION OF LIGHT.

Light, as has been mentioned, is diffused around us by the refractive power of the atmosphere, and therefore objects are quite visible though the rays of the sun do not strike directly upon them; in plainer terms, the atmosphere may be compared to the thick piece of glass called a *bull's eye* fixed in the deck of a ship, by which rays of light are collected and dispersed into all corners of the apartment beneath. The atmosphere being thus a vehicle of light, it may be supposed that, if we were to ascend to a great height above the level of the earth, or beyond the sphere of the atmosphere, we should be almost in darkness, although we were in reality nearer the sun. There is reason to believe that such would be the case; for travellers who have ascended to the summit of Mont Blanc, or about 15,000 feet above the level of the sea, mention that at that height the sky appears to be of an exceedingly dark blue colour, or almost black, and the light so faint that the stars are visible. We may understand from this, that the rays of the sun travel through immense regions of darkness before they reach our atmosphere, and are diffused into that universal soft light which we observe around us.

But besides being diffused by a pure atmospheric medium, light is greatly increased in brilliancy by *reflection*. If all the objects on the surface of our planet were to be black, which is a negation of all colour, the sun's light would be absorbed, or at least return no part of the rays which fell upon them; and we should, even while the sun shone, possess much less light than we now enjoy. Nature has avoided this calamity, and by producing all varieties of colours in objects, the sun's rays which fall upon them are less or more reflected, or sent back into the general mass of light. We now, then, understand that every object we see reflects rays of light, and that these rays travel from the object to our eye, as soon as we bend our vision upon it; inasmuch, however, as a thousand or more individuals may see the same object at the same instant of time, it is evident that the rays proceed at all points, and fall upon eyes at every variety of angle.

If the object be clear or polished in its surface, it will possess the power of representing the image of any object within reach of its rays. Thus the surface of a smooth lake will represent the image of the sky above, or the neighbouring hills, or of any object floating on its surface. This natural property in clear surfaces has suggested the formation of mirrors or looking-glasses. A mirror, or *speculum*, as it is scientifically called, is any instrument of a regular form, employed for the purpose of reflecting light or forming images of objects. Mirrors usually consist of metal or glass, having a highly polished surface. Those which are constructed of glass are coated upon the back with quicksilver, or rather with tinfoil mixed with a little mercury, for the purpose of reflecting more light; were this not the case, so little light would be thrown back, on account of glass transmitting it to a considerable extent, that a very indistinct image would be formed. The word speculum is generally confined to metallic mirrors, and they are either plane, concave, or convex. The plane ones are perfectly flat, like a looking-glass; and a common watch-glass conveys a very good idea of the other two species of mirrors. Coat the hollow surface with mercury, and place it before a candle, it forms a convex mirror; coat it upon the other side, and employ it as before, it becomes a concave mirror.

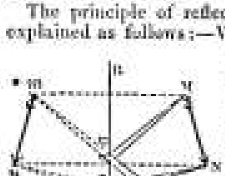
If a plane mirror, A B, be placed exactly in a horizontal position, a ray of light, c, darting downwards in an exactly perpendicular direction, and striking it at d, will be thrown back in the exact path which it traversed in its descent, without any deviation. If, however, it descends in an oblique manner, as is shown at e—a point midway between the perpendicular c and the horizontal A B—it will not return, as in the former instance, to the place whence it came, but will be reflected from the mirror at an angle exactly equal to that at which it descended upon it. The ray e d is called the *incident* ray, and d b the *reflected* ray. In the figure, c d e is called the *angle of incidence*, and b d c the *angle of reflection*; and they are both, as we have observed, exactly equal to each other. This being the fact, we have afforded us a method of universal application by which, when once the angle of incidence, or that at which the ray falls upon a body, is found, that of reflection is easily obtained. This holds true whatever shape the mirror may be of—plane, concave, or convex—and whatever number of rays may fall upon it.



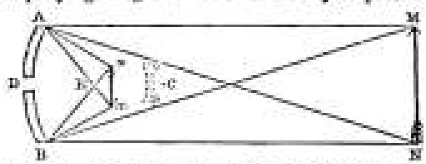
Let us apply the principle here mentioned to the simple phenomenon of seeing ourselves in a plane looking-glass. When we stand directly in front of a mirror, we see our image represented in it; and as we move, so does the image appear to move also, but with a peculiarity in its motion: if, for example, we walk towards the mirror, the image is seen to approach in a similar manner, but the approach is with double the velocity, because the two motions are equal and contrary. Suppose, however, while we stand at the glass, another person walks up behind us, his image will appear to us to move at the same rate as he walks, though to him the velocity will seem double, because, with regard to us, there will be but one motion, and with regard to him there will be two equal and contrary motions.

In the case of standing directly in front of the mirror, the image is necessarily before us, for the rays proceeding from our eye to the mirror are sent back from the surface without any angle of incidence. The case is otherwise when we stand so far at a side that we cannot see ourselves in the glass, though we can see the image of another person equally far off on the opposite side. Two persons so situated will see each other though they cannot see themselves, because the line of rays from the first person striking on the glass form an angle of reflection, and dart off in the direction of the second person, while the rays from the second person are similarly reflected towards the first. Such is a practical exemplification of the angle of reflection in mirrors.

The principle of reflection may be more minutely explained as follows:—We suppose R R to be the surface of a plane mirror, the arrow M N any object placed in front of it, and E the eye of an observer placed at i k. Of the rays which shoot in a rectilinear direction from the points M N of the object, and are reflected from the mirror, those which enter the eye are few in number, and must be reflected from portions D F and G H of the mirror, so situated with reference to the eye and the object, that the angles of incidence of the rays which fall on these portions must be equal to the angles of reflection of those which enter the eye between i and k. For instance, the ray M D is reflected in the direction D i, and the ray M F in the direction F k. In the same manner, the rays N G and N H will be reflected severally in the directions G i and H k. If the rays i D and k F be continued backwards, they will meet at a point m, whence they will appear to have come to the eye. For the same reason, the rays G i and H k, if continued in the same manner, will seem to meet at the point n as their focus, and m n will be the virtual image of the object M N. It is called *virtual*, because it is not formed by the actual union of rays in a focus, and cannot be received upon paper. The virtual image m n is as far behind the mirror as the object M N is before it; consequently, if we join m n, it will be of the same dimensions as M N, and have the same position behind the mirror as the object has before it. If we join the points M m and N n, the lines M m and N n will be perpendicular to the mirror R R, and consequently parallel. In every position of the eye the image is seen in the same spot; its absolute size is always the same, and its apparent size is also the same when seen at equal distances from the eye. If the object M N is an individual surveying himself in the mirror, he will see his perfect image as if at m n.



The manner in which rays are reflected from a concave mirror, next deserves our attention. It will have been frequently observed by the reader, that when he looked at himself in the hollow of a polished metal spoon, his face and bust appeared to be inverted, or upside down. We explain this by referring to the accompanying diagram. M N is an object placed at



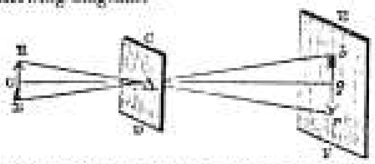
some distance from a concave mirror A B, whose centre is C, and whose principal focus is E. The rays from M fall diverging upon the mirror, and are reflected to a focus at m (a little without the principal focus), where they form an image of the extremity M. In the same way, a representation of the extremity N will be painted at n, so that a complete but inverted image of N M will thus be formed; and it is evident that it will be very bright, though small, because a great number of rays are concentrated, and concur in forming each point of the image. The size of the image thus formed corresponds to the distance of the object from the mirror. If the latter be large, and the former very bright, a series of beautiful experiments may be made by varying the distance of the object, and observing the variations in the size and place of the image. As the object recedes from the mirror, the picture approaches E, and gradually decreases in size.

If we consider m n as a small object, a magnified representation of it will be formed at M N, which, when viewed by a convex lens, such as will be afterwards described, constitutes a *reflecting microscope*. If we place a small concave mirror o p behind it, so as to enlarge the image, and reflect the rays through an opening D in the large mirror A B, then this second image may be magnified still more by means of a lens, in which case it constitutes a Gregorian reflecting telescope. If instead of a concave we employ a convex mirror o p, and place it between E and n m, so as to reflect the rays which would otherwise have met at n m, then an enlarged image would in this case also be painted at D, where it can be magnified as in the former instance.

An image formed by a concave mirror is always highly magnified when the object is near the focus; but as it passes that point, and approaches the mirror, the image gradually decreases in size, and becomes equal to the object when the latter touches the mirror. Indeed, when the object is placed between the principal focus and the mirror, the image is a virtual one apparently formed behind the mirror, or would be so formed behind it if the substance of the mirror permitted. Concave mirrors, from their property of converging rays into a focus, may be used as burning-glasses; practically, mirrors of this shape are used to gather the rays from lamps, and reflect them, with increased brilliancy, into the darkness. The lamps of coaches, lighthouses, &c. are fitted up with these reflectors.

With respect to convex mirrors, they always form images of a diminished size, because the rays which form them become convergent in their passage to the eye of the spectator; in other words, the rays from the object proceed to a virtual or imaginary focus behind the mirror, and thence the image, in a miniature form, seems to be reflected to the eye. In this, as in all cases of reflection from concave mirrors, the size of the image represented is exactly what it might be expected to be if we could see through the glass, and observe the dimensions at the virtual focus.

It is perhaps not generally known that images may be formed upon a piece of paper, by placing a small hole between the object and the paper, and excluding all extraneous light. This will be best understood by the following diagram:—

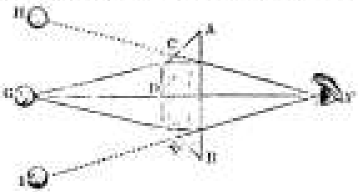


Let C D be a window-shutter having a small aperture A, and E F a piece of paper placed in a dark chamber. Then if an illuminated object, R G B, is placed on the outside of the shutter, we shall observe an inverted image of this object painted on the paper at *r g b*. In order to understand how this takes place, let us suppose the object R G B to have three distinct colours—*red* at R, *green* at G, and *blue* at B; then it is plain that the *red* light from R will pass in straight lines through the aperture A, and fall upon the paper E F at *r*. In like manner the *green* from G, and the *blue* light from B, will severally fall upon the paper at *g* and *b*, and an inverted image *r g b* of the object R G B will be painted upon it. Every coloured point in the object R G B having a coloured point corresponding to it, and opposite to it, on the paper E F, the image *b g r* will be an accurate picture of the object R G B, provided the aperture A is very small. If it be increased in size, indistinctness in the image will ensue; for with a large aperture, two adjacent points of the object will throw their light on the same point of the paper, and thus create confusion in the picture. It is perfectly clear that if the paper E F be moved to a further distance from the hole A, the size of the image will be increased; and if it be brought nearer to it, it will be diminished.

LENSES.

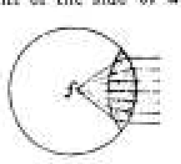
Lenses, as already mentioned, are of different forms, and consequently possess different refractive powers. A lens may be composed of any transparent substance—as glass, diamond, a globule of water, &c.; in the arts, a lens is made of glass, as pure and colourless as possible. The design in forming lenses is to procure a medium through which the rays of light from any object may pass, and converge to a corresponding point beyond. The manner in which the rays proceed through the glass, and then centre in a focal point, will depend on the form of the lens, its capacity for refraction, and the distance of the object.

If we take a piece of glass, flat on one side, and cut into different faces on the other, and then look through it from the flat side at any object—for instance, a pea, we shall see as many peas as there are faces receiving the rays from the single pea. We may exemplify this principle of multiplication by the following figure, in which A B is a lens flat on one side, and cut into three faces on the other *c d e*. F is the eye of the spectator, and G the pea to be looked at. The eye receives a pencil of rays direct through the lens at *d*, and sees the object without refraction. A pencil also proceeds from

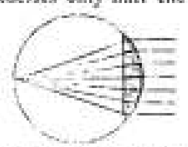


G to the face *c*, and another pencil to the face *e*, and in both cases the rays are bent and refracted to the eye. This eye, however, does not recognise the path of either of these oblique rays, but perceives the image of a pea at H and at I; and thus three peas seem to be seen in place of only one.

In smoothly ground lenses, in which there are no distinct faces to multiply the images of an object, the rays bend, as we have said, so as to meet in a corresponding point beyond them. A lens may consist of a perfect globe of glass, or globe filled with pure water, in which case the refractive power will be considerable; a double convex lens, which is the more common kind, may be viewed as a portion cut out of the side of a sphere, as seen in the annexed fig.

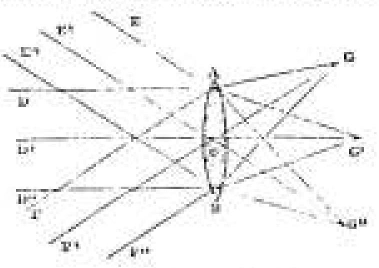


Here, as in all such cases of convexity, the focus of the parallel rays passing through the lens is at *f*, which is the centre of the sphere of which the farther or anterior side is a portion, or a point at half the diameter, or *radius*, of the sphere from it. Should we take a plano-convex lens, the focal point would be considerably different. In the next figure we have an example of this kind of lens, which evidently possesses only half the refractive power of the double convex glass.



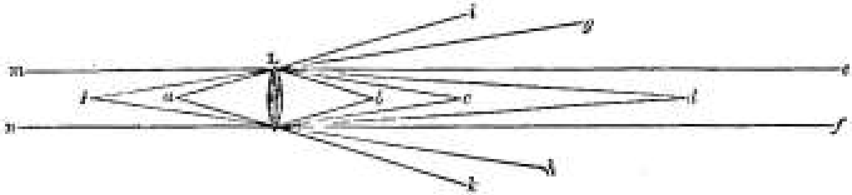
Here the parallel rays, falling on the convex side of the lens, are seen to converge at the distance of the whole diameter of the sphere. Thus the focal point at which the rays of light fall, is always regulated by the degree of curvature of the lens. We shall illustrate this by various diagrams, to which we ask the reader's careful attention, for the subject is somewhat difficult, and cannot be comprehended by a superficial glance.

We take a double convex lens represented by A B, the axis of which is the line G' C D'. The ray D' G', being straight through the centre, suffers no refraction;



but the rays D A and D'' B are refracted so as to meet at the focal point G'. We now observe that the parallel rays E A, E' C, and E'' B, and also F A, F' C, and F'' B, falling obliquely on the lens, will in a similar manner be refracted, and have their foci at G and G'', at the same distance from the lens. Those lines which pass through the centre—as E' C G'' and F' C G—do not alter their direction, not being refracted. Thus in whatever way parallel rays pass through a lens, we have a focal point beyond it, be it straight forward or in an oblique direction.

The distance at which the rays meet beyond the lens is exemplified in the next diagram, given by Dr Arnott in his treatise on Physics, and whose definition of the focal point we beg leave to offer :—' Rays falling from *a* on a comparatively flat or weak lens at L, might meet only at *d*, or even farther off; while with a stronger or more convex lens, they might meet at *c* or at *b*. A lens weaker still might only destroy the divergence of the rays, without being able to give them any convergence, or to bend them enough to bring them to a point at all, and then they would proceed all parallel to each other, as seen at *e* and *f*; and if the lens were yet weaker, it might only destroy a part of the divergence, causing the rays from *a* to go to *g* and *h*, after passing through, instead of to, *i* and *k*, in their original direction.



In an analogous manner, light coming to the lens in the contrary direction from *b c d*, &c. might, according to the strength of the lens, be all made to come to a focus at *a* or at *l*, or in some more distant point; or the rays might become parallel, as *m* and *n*, and therefore never come to a focus, or they might remain divergent.

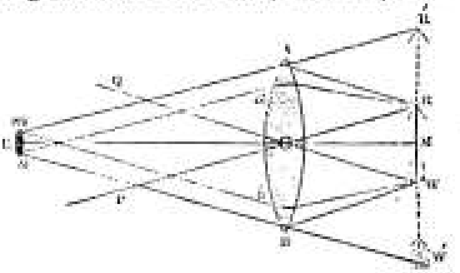
'It may be observed in the above figure that the farther an object is from the lens, the less divergent are the rays darting from it towards the lens, or the more nearly do they approach to being parallel. If the distance of the radiant point be very great, they really are so nearly parallel that a very nice test is required to detect the non-accordance. Rays, for instance, coming to the earth from the sun do not diverge the millionth of an inch in a thousand miles. Hence, when we wish to make experiments with parallel rays, we take those of the sun.

'Any two points so situated on the opposite sides of a lens, as that when either becomes the radiant point of light, the other is the focus of such light, are called *conjugate foci*. An object and its image formed by a lens must always be in *conjugate foci*; and when the one is nearer the lens, the other will be in a certain proportion more distant.

'What is called the *principal* focus of a lens, and by the distance of which from the glass we compare or classify lenses among themselves, is the point at which the sun's rays—that is, parallel rays—are made to meet; and thus, by holding the glass in the sun, and noting at what distance behind it the little luminous spot or image of the sun is formed, we can at once ascertain the focus of a glass, as at *a* for the rays *e* and *f*.'

From the preceding explanations, it will be understood that when an object is placed at any distance from a lens, an image of it will be formed in the corresponding conjugate focus; but to see this image distinctly, the eye must generally be placed at least six inches behind it—that is, farther from the lens. When, however, the object is placed in the principal focus, the rays are refracted parallel, and the image in this case is distinct when seen at any distance. But the most remarkable quality of a double convex lens remains to be noticed; we allude to its magnifying power. This quality is entirely a result of the refractive powers of the glass: embraced within the sphere of the rays from the lens, the object is apparently expanded in size, and seems brought nearer to the eye. This may be elucidated, for small objects seen near, by a reference to the succeeding diagram:—

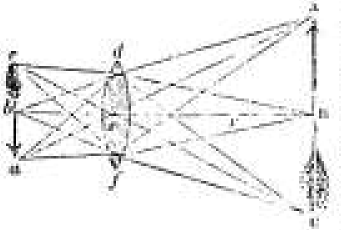
Let E be the eye, and *m n* the diameter of its pupil, R W a small object placed at the least distance of distinct vision (about six inches from the eye for small objects), and let R W be its apparent size when seen by the unaided eye. If a convex lens, A B, is now interposed between the eye and the object, so that the object, R W, shall be in the principal focus of the lens, an enlarged image, R′ W′, of the arrow will then be seen, its extremities R′ W′ lying in the directions E A, E B. The directions of these rays are determined thus :—From R and W draw the central rays R C P, W C Q, through the centre C of the lens; then the rays of the



conical pencil, proceeding from the point R to every point of the nearer surface of the lens, are refracted in such a manner by the lens, that they all emerge in directions parallel to the central ray R C P; but of the whole refracted pencil only a small portion enters the eye—namely, the pencil A *m n a*, limited by the size of the pupil *m n*; and the head A of the arrow, whence this pencil proceeds, appears to lie in the direction of the pencil E A R′ at R′. It is shown exactly in the same manner, that the point W will appear in the direction E B W′ at W′. The enlarged image of the small arrow, R W, is therefore R′ W′. The proportion in which the image is enlarged will be easily ascertained thus:—The triangles E R′ W′, C R W, are similar, and therefore the ratio of R′ W′ to R W, is that of E R′ to C R, or of E M to C M; that is, as the least distance E M of distinct vision, to the focal length C M of the lens. If, therefore, the least distance of distinct vision be divided by the focal length of the lens, the quotient will be its magnifying power. If E M be reckoned 6 inches for small objects, and if the focal length C M be 2 inches; then since 6, divided by 2, gives 3 for a quotient, the magnifying power is 3 times. If C M were one quarter of an inch, then 6, divided by $\frac{1}{4}$, gives 24 for a quotient, and the magnifying power would in this case be 24 times.

A more simple explanation may be attempted :—Turn to the figure in the preceding page, representing the lens with three faces on one side, and flat on the other. There it will be observed that the vision travels in the direction of the ray from the object, as it passes through the glass, and therefore sees an appearance of three objects. Now in the above case of a magnifying lens, the vision in the same manner travels from the eye at E in the direction of the angle of refraction; it goes on to R′ and W′, and thus the actual object being drawn out, as it were, to meet these points of vision, or seemingly expanded by the bent rays, we of necessity see an apparently larger object. If the glass were cut in faces, instead of being smooth, the object would not appear drawn out, but would be multiplied in as many points as there are faces.

The inversion of the image by a lens may be illustrated by the next diagram. A B C is an arrow, with the point uppermost, placed beyond the focus at F, of a double convex glass *d e f*. In virtue of the refractive power of the lens, the rays which proceed from A meet at *a*, and form an image of the arrow point inverted; while the rays from C meet at *c*, and form a similarly inverted image of the feather part of the arrow. The rays proceeding from B unite at *b*. Here only rays from A, B, and C, are represented for the sake of clearness; but in point of fact, rays from all parts of the object proceed through the lens; hence an entire image is



formed in an inverted position. Should the object A B C be brought nearer the lens, the image will be removed to a greater distance, because then the rays are rendered more divergent, and cannot so soon be collected into corresponding points beyond. To procure a distinct image, the object must be removed farther than the focal point F from the glass. In this exemplification the object seems to be diminished; but if we make the small arrow the object, the larger one will be the image of it magnified.

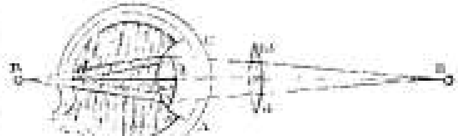
In order to explain the power of lenses in magnifying distant objects, and bringing them near us, let us suppose an object placed at one hundred feet distance from the eye of a spectator. Let us place a convex glass of twenty-five feet focal distance half way between the object and the eye; then, as has been previously observed, an inverted image of the object, and of the same size, will be formed fifty feet behind the lens. If this picture is looked at six or eight inches behind it, it will be very distinctly seen, and nearly as well as if the object itself had been brought to within six or eight inches of the eye of the spectator. If, however, instead of a lens of twenty-five feet focal length, a lens of a shorter focus is made use of, and so situated with respect to the eye and the object that its conjugate foci are at the distance of twenty and eighty feet from the lens—that is, the object is twenty feet before the lens, and its image eighty feet behind it—then the size of the image will be four times that of the object. If the eye, therefore, looks at this magnified image six inches behind it, it will be seen with great distinctness. In this case the image is magnified four times directly by the lens, and 200 times by being brought 200 times nearer the eye; so that its apparent magnitude is 800 times larger than before. At distances less than the preceding, the rule for finding the magnifying power of a lens, when the eye views the image which it forms at six inches' distance, is, according to Sir David Brewster, as follows:—'From the distance between the image and object in feet subtract the focal distance of the lens in feet, and divide the remainder by the same focal distance. By this quotient divide twice the distance of the object in feet, and the new quotient will be the magnifying power, or the number of times that the apparent magnitude of the object is increased. When the focal length of the lens is quite inconsiderable, compared with the distance of the object, as it is in most cases, the rule becomes this:—Divide the focal length of the lens by the distance at which the eye looks at the image; or, as the eye will generally look at it at the distance of six inches, in order to see it most distinctly, divide the focal length by six inches, or, what is the same thing, double the focal length in feet, and the result will be the magnifying power.'

THE EYE—VISION.

Having, in our Account of the Human Body, described the anatomical construction of the eye, we shall here confine ourselves to the actual process of vision. As mentioned in the article referred to, the eye, in front, consists of the *iris*, or variously coloured ring, which has the property of contracting or expanding to regulate the admission of light through the little dark spot in the centre called the *pupil*. Immediately behind the iris and pupil there is a transparent substance resembling in shape a double convex *glass*, which is thence called the *crystalline lens*. The use of this lens is to collect and refract the rays of light, so that they may converge to a point beyond; in other words, cause them to fall on the back part of the eye, called the *retina*. Such are the main instruments of vision; and the sense of seeing is produced by certain nerves which convey intelligence of the image on the retina to the brain. If these nerves be injured, the image will still be pictured on the retina, but the mind will possess no power of recognising their presence.

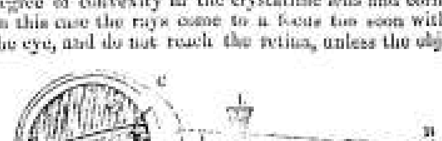
It will be understood from these explanations that the main instrument of vision is the crystalline lens, which collects the rays, and brings them to a focus on the retina. If the lens be perfectly transparent, and of the proper convexity, the light is enabled to act with due effect on the retina, and the representation of the object looked at will be correctly pictured to the mind. But if the transparent coating of the eye be dull, or the lens be either too flat or too convex, every object will appear dim.

Two kinds of defective vision are more common than any other, and they are known by the name of *long-sightedness* and *short-sightedness*. Long-sightedness, or the power of seeing objects best at a considerable distance, is caused by too great a flatness in the crystalline lens and outer coating of the eye; and the deficiency of vision in old persons is usually from a similar cause. To remedy this defect, as far as possible, artificial lenses of glass are employed. These lenses are called *spectacles*, and act in the manner we are now to describe. The annexed figure represents an eye in which the



crystalline lens is too flat. C A is the cornea or outer covering, *b* is the crystalline lens, and *d* is the retina behind; B is the object looked at. We may observe, that in consequence of the flatness of the lens *b*, the rays proceeding from the object are not sufficiently refracted, but proceed to a focus as far back as R; in other words, the focus would be at R, if the retina would permit; but as the retina is in the way, the rays, from not being focalised upon it, cause imperfection in the vision. To remedy this, we interpose an artificial convex lens, or glass of a pair of spectacles (*a a*), and by its aid the rays, represented by dotted lines in the figure, are brought to a focus on the retina at *d*. Thus by selecting spectacles of a proper focalising power in relation to the eye, one kind of imperfect vision is very happily remedied.

Short-sightedness arises from a cause the reverse of that just alluded to, being produced by too great a degree of convexity in the crystalline lens and cornea. In this case the rays come to a focus too soon within the eye, and do not reach the retina, unless the object



is brought quite close to the organs of vision. We here offer a representation of this condition. In consequence of the projecting globularity of the cornea, C A, and the too great refracting power of the crystalline lens, the rays from the object B fall short of the retina at R. To remedy this, we interpose a double concave lens, L L, by which the rays are rendered more divergent before they reach the eye, and are brought to a focus, where they should be, on the retina.

We have said above, that in short-sighted persons the rays do not reach the retina unless the object is held close to the eyes. The effect produced by this is similar to that of employing concave spectacles; because the nearer we hold an object to our sight, the angle of the rays from it is the wider; the rays are more expanded before they enter the eye—that is, more divergent. Thus the extreme rays from a point to the pupil of the eye make a

greater angle at o than those from a point of a more distant object make at a; that is, the rays from o are more divergent on entering the eye than the rays from a, and thus nearness of an object is equivalent to seeing it at a greater distance through a concave lens. So when the object a is farther distant than o, the rays from a have a less divergence, which is equivalent to viewing it at a nearer distance with a convex lens. These remarks, however, refer merely to the distinctness of the vision, and not to the apparent size of the object.

The apparent magnitude of the same object when viewed at different distances, depends on the size of what is called the *visual angle*—that is, the angle formed at the eye by the rays from the extremities of the object. We may exemplify this as follows:—

An eye, E, is looking at an object *a b*, and another object *c d*, at double the distance. It is evident that the rays from *a b* are more expanded, or cause a larger angle on the eye, than the rays from *c d*. Various familiar phenomena are explained from the law of the visual angle under which an object is seen; the apparent size being less always in proportion as the distance of an object is greater. Hence the principles of perspective in drawing, by which objects are made to appear at a great distance in the background of a picture, although in reality they are as far forward as the objects in front.—(See Drawing and Perspective.)

Another important circumstance connected with vision requires to be noticed. In consequence of the refractive power of the crystalline lens, the rays from an object fall upon the retina in such a manner that the image is there pictured upside down; and this inversion of the real appearance of things requires to be corrected by an act of the mind under the influence of experience. We beg leave to offer Dr Arnott's explanations on this somewhat puzzling point:—'Because the images formed on the retina are always inverted as respects the true position of the objects producing them—just as happens in a simple camera obscura—persons have wondered that things should appear upright, or in their true situations. The explanation is not difficult. It is known that a man with a wry neck judges as correctly of the position of the objects around him as any other person, never deeming them to be inclined or crooked, because their images are inclined in relation to the natural perpendicular of his retina; and that a bedridden person, obliged to keep his head upon his pillow, soon acquires the faculty of the person with wry neck; and that boys who at play bend themselves down to look backwards through their legs, although a little puzzled at first, because the usual position of the images on the retina is reversed, soon see as well in that way as in any other. It appears, therefore, that while the mind studies the form, colour, &c. of external objects in their images projected on the retina, it judges of their position, not by the accidental position of the images on the retina, but by the direction in which the light comes from the object towards the eye, no more deeming an object to be placed low because its image is low in the eye, than a man in a room into which a sunbeam enters by a hole in the window-shutter, deems the sun low because its image is on the floor. A candle carried past a keyhole throws its light on the opposite wall, so as to cause the luminous spot there to move in a direction the opposite of that in which the candle is carried; but a child is very young indeed who has not learned to judge at once of the true motion of the candle by the contrary apparent motion of the image. A boatman, who, being accustomed to his oar, can direct its point against any object with great certainty, has long ceased to reflect, that to move the point of the oar in some one direction, his hand must move in the contrary direction. Now the seeing things upright, by images which are inverted, is a phenomenon akin to those here reviewed.'

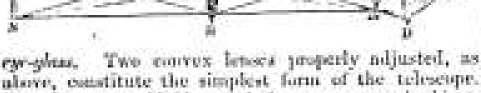
The same able writer on physics proceeds to a definition of another peculiarity in visual arrangements—namely, why, from having two eyes, the object does not appear to us to be double: 'In answer to this, we shall only state the simple facts of the case. As in two chess-boards there are corresponding squares, so in the two eyes there must be corresponding points, and when on those points a similar impression is made at the same time, the sensation or vision is single; but if the impression be made on points which do not correspond, owing to some disturbance of the natural position of the eyes, the vision becomes double. Healthy eyes are so wonderfully associated, that from earliest infancy they constantly move in perfect unison. By slightly pressing a finger on the ball of either eye, so as to prevent its following the motion of the other, there is immediately produced the double vision; and tumours about the eye often have the same effect. Persons who squint have always double vision, but they acquire the power of attending to the sensation in one eye at a time. Animals which have the eyes placed on opposite sides of the head, so that the two can never be directed to the same point, must possess this faculty in a more remarkable degree.

The corresponding points in the two eyes are equidistant, and in similar directions from the centres of the retinæ, which centres are called the *points of distinct vision*, and at them the imaginary lines named the axes of the eyes terminate; but it is worthy of remark that these points, in being both to the right or both to the left of the centres, must be one of them on the inside of the centre, as regards the nose, and the other on the outside—that is to say, a point of the left eye between the centre and nose has its corresponding point in the right eye between the centre and the cheek—and from this fact arise consequences meriting attention. When the two eyes are directed to any object, their axes meet at it, and the centres of the two retinæ are opposite to it, and all the other points of the eyes have perfect mutual correspondence as regards that object, giving the sensation of single vision; but the images formed at the same time, of an object nearer to or further from the eye than the first supposed, cannot fall on corresponding points; for an object nearer than where the axes meet, would have both its images on the outsides of the centres, and an object more distant would have both its images on the insides of the centres—and in either case the vision would be double. Thus if a person hold up one thumb before his nose, and the other in the same direction, but farther off, by then looking at the nearest, the more distant will appear double, and by looking at the more distant, the nearest will appear double. The reason for applying the term 'point of distinct vision' to the centre of the retina, is felt at once by looking at a printed page, and observing that only the one letter to which the axis of the eye is directed is distinctly seen; and consequently that, although the whole page be depicted on the retina at once, the eye, in reading, has to direct its centre successively to every part.'

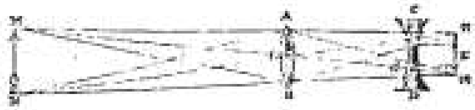
The retina of the eye possesses such exquisite sensibility, that it retains the impression of the image of any bright object presented to it for the space of the eighth of a second after the object has been withdrawn, or after the eye has been shut. Thus the burning end of a rapidly-whirled stick will appear to form hoops of fire; and a fiery meteor or skyrocket shooting rapidly through the air will appear as a long line of light. The mind is in these and similar instances deceived, as the eye, in reality, sees only one point of fire at precisely the same time. The retina, for the same reason, retains for a time an impression of any vivid colour. When we look at the sun, the retina is so strongly affected as to be incapable for a time of seeing other objects distinctly. The most remarkable circumstance connected with these phenomena is, that when the eye is shut after such impressions, a spot of colour, *different* from the colour looked at, is apparently seen. A spot of this nature is in optics called a *spectrum*; and works of an extended character on the science, embrace lengthened definitions of the various spectra with which the eye will be affected. We need here only refer to the experience of our readers on this interesting point, and mention generally, that no satisfactory explanation has ever been given of the reason why the colours in the spectra differ from those which were actually seen.

OPTICAL INSTRUMENTS.

Telescopes.—Telescopes, sometimes called spying-glasses, are instruments in the form of tubes, fitted up with lenses of different kinds and powers, and used for examining distant objects. The word telescope is from the Greek, and signifies *afar off*, and *to see*. A telescope, in its simplest construction, contains two lenses—one is used to create a picture of the object looked at, and therefore called the *object-glass*; the second to magnify that picture, or more properly to enable the eye to come very close to it, and yet have a distinct picture of it, and for this reason called the



eye-glass. Two convex lenses properly adjusted, as above, constitute the simplest form of the telescope. Let the arrow, M N, stand for any outward object, and let its rays fall upon a convex lens, A B, which is seen edgeways in the figure. The rays will be all bent, so that, at a certain distance on the other side of the lens, a new representation of the arrow, *n m*, will be made. The rays from the point of the arrow at M will be so acted on at the two surfaces of the lens, that they will all come together again, and make, as it were, an arrow point at *m*. The rays from the feather at N will fall into their places at *n*, in a new arrow head; and so on throughout, the whole being inverted. A second lens, C D, is used, not to form a second picture (as it would do if distance were allowed it), but to enable the eye at E to look closer at *n m* than it could otherwise do. What the eye sees, therefore, by the two lenses, is a near picture of the original arrow turned upside down. This picture is nearer and larger to the sight in proportion to the roundness of the magnifying lens. Suppose the image, *n m*, is 6 inches from the picturing or *object* lens, then if the eye look at it at a distance of 6 inches, the picture will have the same apparent size as the original, and nothing will be gained. But if the second lens, or *eye-piece*, enables the eye to come within 1 inch of the picture, and yet see it without confusion, it will be 36 times as large to appearance as the original—6 times each way. In fact the view is now improved as much as if a six-mile object were brought within 1 mile. Now the greater the distance of the picture from the object lens which forms it, the greater its focal distance; and the nearer that the eye can be brought to the picture by the eye lens, the larger the appearance will be, or the greater will be the magnifying power of the telescope. Two such lenses shut up in a tube make what is called the *astronomical telescope*. In looking at the heavens, the inversion of the picture causes no inconvenience. In the Galilean telescope, represented below—so called



from Galileo—a concave eye-piece is placed behind the position of the picture, which lodges it at once in the eye. There is no inversion in this telescope.

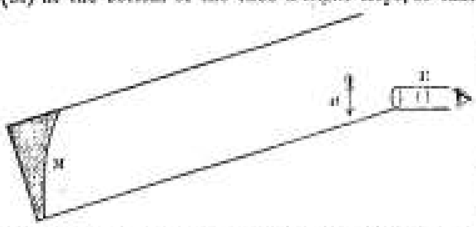
For land objects, which must appear erect, a telescope is formed with additional lenses, which make a second picture, as in next fig. The lens, A B, makes the first picture, and the two lenses, CD and EF, cross the rays

again, and make a second picture, which is upright. This is viewed by the eye-piece, G H. To increase the power of these telescopes, the object-glass, A B, is made with a very long focus, or so as to form its picture as far off from itself as possible. This requires its shape to be very much flattened, and still to preserve a perfect roundness—a matter difficult of execution. All lenses are more or less imperfect; that is, the picture they form is liable to be somewhat confused, which takes off from the advantage of the instrument. The greatest evil is one that cannot be cured by a single lens—that is, the fringing or colouring of the picture. But this action has been done away with by using a double lens, or two lenses of different kinds of glass joined together. The difference in the quality of the glasses to produce colour is so managed that they neutralise one another; and a picture free from coloured and indistinct edges is produced. This compound lens is called *achromatic*, or wanting in colour. With these lenses very perfect telescopes are made of 2, 3, 6, or 10 feet in length, and with eye-pieces of half or quarter of an inch, and under, of focal distance. A three-feet telescope—that is, a telescope where the picture is made 36 inches from the object-glass, and an eye-piece that lets the picture come within half an inch of the eye (a half-inch eye-piece)—would magnify 72 times each way, and have the same effect as if the distance of the original were divided by 72. This, and other instruments in which refracting lenses are employed, are called *refracting telescopes*, and they magnify or bring near in proportion as the focal distance of the object-glass is greater than the focal distance of the eye-glass.

Refracting telescopes require to be of considerable length where much power is required, and on that account reflecting telescopes are for many purposes preferred. The *reflecting telescope* was invented by Sir Isaac Newton, but has been much improved since his time. A view of the improved instrument is given beneath. The peculiarity of this instrument is, that the

image of the object is reflected from a concave mirror within the tube, and this image is again reflected from a small mirror to the eye. Referring to the figure, T is the tube, and A B the object to be represented. At the end opposite from the object, there is a small tube *t t*. At the main end of the wide tube, there is a concave mirror D F, with a hole in the middle at P. The principal focus of this mirror is at I K; here the image *m* is inverted, and the rays, crossing each other at *n*, go on to the small reflector L. From this they are reflected in parallel lines through the hole P. At P they enter the plano-convex lens R, which causes them to converge at *a b*; but here the image requires to be magnified, which is done by means of the plano-convex lens S; in other words, the object is seen under the angle *e f d*. In order to accommodate focal distances, the small mirror L can be removed to a greater distance or brought nearer, by the rods and screws communicating from X.

Sir William Herschel got over the difficulty of placing the observer out between the object and the mirror, by a simpler arrangement. He gave the mirror (M) at the bottom of the tube a slight slope, so that



it sends its image to *a*, at the edge of the tube's mouth, where it is viewed by the eye-piece E without bringing the observer's head between the thing viewed and the mirror. On this principle he constructed telescopes of gigantic dimensions and power. His greatest was 40 feet long, and the mirror 4 feet wide. The use of a large mirror is to take in more light, which is apt to fail in using high magnifying powers. With an eye-piece of an inch focus, the power of such a telescope would be 480 each way, which would magnify a surface nearly a quarter of a million of times. The moon would be seen by such a power as if she were brought within 500 miles of us, her real distance being 240,000.

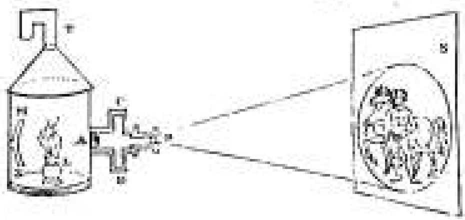
But Lord Rosse has surpassed Herschel in the construction of reflecting telescopes. The chief difficulty in making monster telescopes (apart from the stupendous machinery for supporting and moving them), is the forming of the mirror or speculum, which is of metal, and requires to have a surface of high polish and reflecting power, and at the same time to be ground into a perfectly spherical or rather parabolic form; the mixing of the ingredients to make a good shining metal, and the casting of an immense mass, like a millstone, of an even hardness throughout; and lastly, the grinding, shaping, and polishing of the surface, make a series of operations of the utmost difficulty. After succeeding in the manufacture of the speculum, Lord Rosse has gone on to construct two telescopes of immense power—the one 26 feet long; the other, 'the monster telescope,' 56 feet, the focal length of the mirror being 52 feet. The 56 feet tube is 7 feet wide; the mirror at the bottom is 6 feet wide, with a glittering polish all over the surface, and weighs three tons.

Microscope is a term compounded of two Greek words, signifying *to see what is small*, and denotes that instrument employed to examine minute objects. Those microscopes of greatest power, and termed compound, approach to the telescope in their form. The difference lies in this, that whilst in the telescope the object-glass forms the image of a distant object just as much smaller than itself as the distance of the image from the glass is less, in the microscope, conversely, a small object, placed near the focus of the object-glass, produces a more distant image, as much larger than itself as the image is more distant. In both cases an appropriate eye-glass is employed. The object-glass of a microscope is in general very small, that of a telescope large. An object-glass of a microscope having one-eighth of an inch of focal distance, and so placed as that the image of the object is formed at six inches, the image will be of a diameter forty-eight times as great as the object; and when viewed through an eye-glass of half an inch focus, it will appear magnified twelve times more, or will appear 30,000 times larger than the object. A single or one-lens microscope, magnifies chiefly by allowing the eye to see the object nearer than it could do without the glass.

A *Camera-Obscura*, or *Dark Chamber*, is formed by placing a convex lens in an aperture made in the window-shutter of a darkened room. A glass of proper size and focal distance is chosen, and a screen, or the wall of the chamber, is properly prepared to receive the light, and by this means there is painted on it an accurate picture of all the objects seen from the window, everything bearing an exact resemblance to the reality.

The *Camera-Lucida* is an instrument now frequently used in drawing landscapes, delineating objects of natural history, and copying and reducing drawings. The best form of the instrument consists of a piece of thick parallel glass, at one end of which there is a metallic mirror, having a highly-polished face. The rays from the object are made first to pass through the glass, when they are reflected back upon one of its sides by the mirror, and from that to the eye.

The Magic Lantern.—When a small object is placed close to a lens, and the image reflected upon the wall of a dark chamber, at, say, one hundred times farther from the lens than the object is, there will be a greatly magnified representation of the object. It will only be seen, however, under ordinary illumination; and it is therefore necessary to have a very strong light, concentrated by a suitable mirror or glass, and directed upon the object. When artificial light is employed, as of a lamp, the instrument then becomes a magic lantern. It consists of an argand burner placed in a dark lantern, on one side of which is a concave mirror, the vertex being opposite to the centre of the flame, which is placed in its focus. The lantern is made of tin japanned; and to



carry off the smoke from the flame, it is provided with a tube T at the top. L is the light, and M N a concave mirror to give strength to the light, and send the rays through the tube A B in front. At A in this tube is a hemispherical illuminating lens, and there is a convex lens at B. In the middle of the tube there is a wide part C D, open at the sides, for the reception of *slides*. These slides are slips of glass on which pictures are painted, and the principle of the apparatus consists in forming a representation of the picture, in a magnified size, on a distant white wall or screen S. The slide being placed in one of the conjugate foci of the lens B, the image is consequently enlarged. By bringing the lantern nearer the screen, we diminish the representation, because we cause the rays to strike the screen at a point where they are less divergent. It is an improvement in exhibiting the representations from the magic lantern, to cause the images to fall on a piece of distended and wetted muslin, behind which the spectators are placed. Lately, the mode of representing scenes has been further improved by using two lanterns, placed at equal distances; in this case, while the view in one is being withdrawn, the view in another is coming on, and the eye is charmed with seeing, for example, a scene in winter dissolve and assume the appearance of a similar scene in summer.

ACOUSTICS.

The term ACOUSTICS is derived from two Greek words, which signify *I hear*, and *an art*; and is applied to that branch of natural philosophy which treats of the nature of *sound*, and the laws which determine its production and propagation.

Atmospheric vibration is allowed to be the cause of sound. For instance, a bell is struck by its clapper, the body of the bell consequently vibrates, as we may sensibly assure ourselves by applying our nail lightly to the edge: in its agitation, it beats or makes impulses on the air, which, yielding under the stroke or pressure, is compressed or condensed to a certain distance around. The compressed air instantly expands, and in doing so, repeats the pressure on the air next in contact with it; and thus each one of the original strokes of the vibrating metal sends out a series of *shells* of compressed air, somewhat like the waves dispersed over a lake from the dropping of a stone into its placid bosom, and, like them, always lessening in bulk and force. These *shells* are from two inches to thirty feet in thickness. The air, thus agitated, finally reaches the ear, where it gives a similar impulse to a very fine nervous membrane, and the mind then receives the idea or impression which we call a *sound*.

With regard to the velocity with which the impulse of sound advances, it appears, from the most accurate experiments on the discharge of pieces of ordnance, and marking the interval between the flash and the report, at a distance carefully measured, that when the atmosphere is at the temperature indicated by 62° of Fahrenheit's thermometer, sound travels at the rate of 1125 feet per second, which is nearly equal to the velocity of a cannon-ball the moment it issues from the piece. The ball is very speedily retarded by the resistance of the air, but sound advances with undiminished velocity, though unequal intensity. It will travel a mile in little more than four seconds and a half, or twelve and three-fourth miles per minute. On this depends an easy method of determining in many cases our distance from objects, and which may often prove useful, particularly in thunder-storms. We have only to observe in seconds the interval between the flash and the report, and allow four seconds and a half to every mile, or 1125 feet to every second. It is remarkable, also, that all kinds of sounds, strong or weak, acute or grave, advance with the same velocity; and this arises from the circumstance, that all the oscillatory movements in the air, however minute, or however extended, are performed each in the very same interval of time. For every degree of Fahrenheit above 62°, the velocity of sound is increased one foot and about a seventh (strictly 1 14-100th foot), and for every degree below 62°, it is lessened in the same measure; so that, when the temperature is at the freezing-point, the rate is only 1090 feet per second.

That water is a vehicle of sound as well as the air, is proved by various circumstances, particularly by the fact, that a bell rung under water can be heard above; and if the head of the auditor be also under water, it will be still more distinctly heard. The sound which the sonorous body produces, however, is graver than that which it gives forth in the air. That the atmosphere is necessary for the transmission of sound is evident from the fact, that a bell rung in the exhausted receiver of an air-pump can scarcely be heard. Smooth bodies form favourable channels of sound, as, for example, the surface of ice, snow, water, or the hard ground. Savages, it is well known, are in the habit of putting their ear to the ground, in order to discover the approach of enemies or beasts of prey. Tubes convey sounds with great accuracy, and to great distances, and this property has been applied to various useful purposes. The speaking-trumpet used at sea is a familiar instance; as are also the tubes now generally laid between the galleries and apartments of warehouses, banks, and other public offices, by which the persons in the several apartments can communicate distinctly with each other without rising from their seats. Another valuable application of the tube principle is that of examining the chests of persons supposed to possess pulmonary affections. This is done by means of the *stethoscope*, an instrument invented by Dr Laennec of Paris, and which resembles a small trumpet. The wide end of the instrument is applied to the body, and the other is held to the ear of the physician, who then has a very clear perception of the sounds caused by the action of the lungs, and can judge whether they be healthy or the reverse. A person of skill can exactly describe the condition of the lungs from the nature of the sounds which thus reach his ear.

In consequence of sound requiring a certain length of time to travel, it is impossible for two sounds, at any distance from each other, to be heard at the same moment by persons who are not at equal distances from both. 'If two persons, A and B,' says an American writer, 'are standing at the distance of one mile from each other, and each fires a gun at the same moment, A will not hear B's gun until several seconds after he hears his own, because the sound will require that time to pass through the distance between them. And the same will be the case with B. One might at first suppose that if A should wait and fire at the moment he hears the report from B, the two sounds would then be heard together. A would hear them together, but the time that must elapse after B had fired, before the sound from A would come to *him*, would be greater than if they fired at the same moment: for he must wait till the sound of his own gun had gone to A, and then until the sound of A's discharge should return to him. It is thus evidently impossible for two persons, standing at a distance from each other, to produce a sound which shall be heard by both at the same time.

'It is on account of this principle, that in long ranks of soldiers, where two bands of music are placed at a considerable interval from each other, it is impossible for the two bands to keep time with each other. They may indeed play together, but each soldier will hear the nearest sounds quickest, and thus they will seem to be out of time. It is often noticed, too, that if from an eminence we look upon a long column which is marching to a band of music in front, the various ranks do not step exactly together. Those in the rear are in each step a little later than those before them. This produces a sort of undulation in the whole column, which is difficult to describe, but which all who have noticed it will understand. Each rank steps, not when the sound is *made*, but when, in its progress down the column at the rate of 1125 feet per second, it reaches their ears. Those who are near the music hear it as soon as it is produced, while the others must wait till sufficient time shall have elapsed for it to have passed through the air to them.

'Should a commander stand at the distance of a fifth of a mile from his army, and command them to fire, they might all obey at the moment when the word of command reaches them; but the officer will hear the report of the guns from those at the side nearest him first, then those a little farther off, and so on to the most remote. Thus, though all might obey with equal alacrity, the sounds will not, and cannot, appear simultaneous, for the reports of the distant guns must be delayed long enough for the command to pass from the officer to the men, and then for the sound to return. All attempts, therefore, to make the firing appear exactly simultaneous from a long line must be in vain.'

An *echo*, or duplication of sound, is one of the most interesting phenomena in acoustics. The cause of it is precisely analogous to the reaction of a wave of water. When a wave of water strikes the precipitous bank of a river, it is thrown back in a diagonal direction to the side whence it came, and there again strikes on the bank. In the same manner, the pulses or waves of sound are reflected or thrown back from flat surfaces which interrupt them, and, thus returning, produce what we call an echo. It is evident that the smoother the surface which reflects the sound, the more perfect will be the reverberation. An irregular surface, by throwing back the wave of sound at irregular intervals, will so confound and distract it, that no distinct or audible echo will be reflected. On the contrary, a regular concave surface will reflect sound in such a manner, that at a certain point the reflections from each part of the concave surface will be concentrated into a focus capable of producing a very powerful effect. The velocity with which an echo returns to the spot where the sound originates, depends of course upon the distance of the reflecting surface; and since sound travels at the rate of 1125 feet in a second, a rock situated at half that distance will return an echo in exactly one second. The number of syllables pronounced in a second will in such a case be repeated distinctly, while the end of a long sentence would blend with the commencement of the echo.

An echo may be double, triple, or even quadruple, according to the nature and number of the projecting surfaces from and to which the sound is allowed to play. Distinctly-marked echoes of this combined and planned order may sometimes be heard in the vaults of cathedrals, in which case the waves of sound are driven from side to side of a deeply-groined arch, and reverberate in protracted peals. One of the most interesting echoes of this kind in nature, is that which occurs on the banks of the Rhine at Lurley. If the weather be favourable, the report of a musket, fired on one side, is repeated from crag to crag, on opposite sides of the river alternately, as represented in the fig.

F is considered as the primary point of radiation for the sound, and crossing the river, it strikes at 1, then is sent off to 2, and so on to 3 and subsequent points, stopping, or faintly dying away, opposite E.

There are some remarkable echoes in ecclesiastical structures, arising from peculiarities in the construction. In erecting the baptistry of the church of Pisa, the architect, Giovanni Pisano, disposed the concavity of the cupola in such a manner, that any noise from below is followed with a very loud and long double echo. Two persons whispering, and standing opposite to each other, with their faces near the wall, can converse together without being overheard by the company between. This arises from the elliptical form of the cupola, each person being placed in the focus of the ellipse. In the cathedral church of Gloucester, there is, or was lately, a whispering gallery above the eastern extremity of the choir, which extends from one end of the church to the other. If two persons, placed at considerably distant points, speak to one another in the lowest voice, it is distinctly heard. A similar effect is produced in the vestibule of the Observatory of Paris, and in the cupola of St Paul's in London. A tourist has mentioned that in Italy, on the way to Naples, and two days' journey from Rome, he saw in an inn a square vault, where a whisper could easily be heard at the opposite corner, but not at all on the side corner that was near to you. This property was common to each corner of the room. He saw another on the way from Paris to Lyons, in the porch of an inn which had a round vault. When any one held his mouth to the side of the wall, his whisper could be heard on the opposite side.

The whispering gallery in St Paul's, London, is a great curiosity. It is 140 yards in circumference, and is just below the dome, which is 430 feet in circumference. A stone seat runs round the gallery along the front of the wall. On the side directly opposite the door by which visitors enter, several yards of the seat are covered with matting, on which the visitor being seated, the man who shows the gallery whispers with the mouth near the wall, at the distance of 140 feet from the visitor, who hears his words in a loud voice, seemingly at his ear. The mere shutting of the door produces a sound like a peal of thunder rolling among the mountains. The effect is not so perfect if the visitor sits down half way between the door and matted seat, and much less if he stands near the man who speaks, but on the other side of the door.

It is of great importance that buildings designed for large auditories should be constructed in such a manner, that the voice of the speaker will neither echo from the walls nor be lost to the hearers. The best known form of apartment for the proper distribution of sound, is that in which the length is from a third to a half more than the breadth, the height somewhat greater than the breadth, and having a roof bevelled off all round the sides. This species of ceiling, called technically a coved or *coach roof*, from its being lower at the sides than centre, is in all cases best suited for conveying sounds clearly to the ears of auditors.

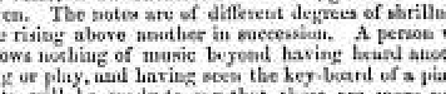
MUSICAL SOUNDS.

There is a peculiar character in sounds, depending on the character of the sounding body. A blow with a hammer, or the report of a pistol, produces only a noise. But if a body be of such a thinness and tightness as to produce a succession of impulses of a sufficient degree of quickness, a *tone* is the result—namely, a sound composed of a great number of noises, all so close upon each other, that they bring but one result to the ear. Wires and strings of metal and catgut, slips of metal, fine membranes, and columns of the air itself enclosed in tubes, are the most familiar means of producing sounds of this kind. Such sounds are said to be musical.

The study of musical sounds, as a branch of natural philosophy, is calculated, perhaps, to give as much pleasure to the man of science as music itself can convey to those who are gifted with what are called good ears. The natural character of these sounds, and their relations to each other, are very remarkable; while the relation of the whole to the human mind must be regarded as one of the most interesting proofs of creative design which the entire circle of nature presents.

The principal sounds of music may be said to be only seven in number. There are other five, which may be produced by the voice with some little difficulty; but the voice, in an untutored condition, gives forth only seven. The notes are of different degrees of shrillness, one rising above another in succession. A person who knows nothing of music beyond having heard another sing or play, and having seen the key-board of a pianoforte, will be ready to say that there are more notes than seven; but there are only seven that are, strictly speaking, various. The voice or an instrument may run up into other notes; but all of these are repetitions of the first seven, and identical respectively with them, in all respects except shrillness. In ordinary pianofortes, there are at least six repetitions of the seven notes, so that the uppermost keys are shriller than the voice of a child, while the lowest rumble like a drum.

The seven notes are named Do, Re, Mi, Fa, Sol, La, Si, or by the first seven letters of the alphabet in a peculiar arrangement—namely, C, D, E, F, G, A, B. They

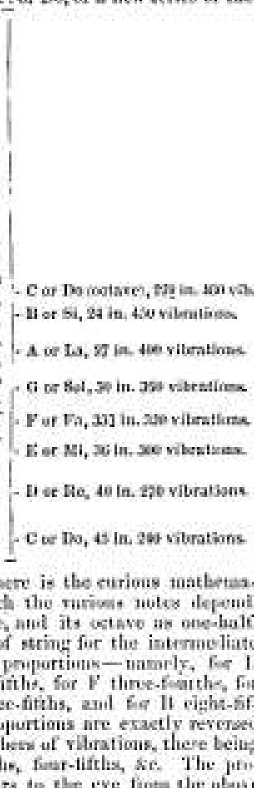


are here represented in the well-known language which musicians present to the eye (using the *treble clef*).

Let an ordinary piece of catgut or violin-string be extended between two points on a board, and screwed up. It may be made, according to its length and degree of tension, to vibrate, when struck, exactly two hundred and forty times in a second. The note which it thus produces is C, or Do; and a man, on trial, will find that this is the note with which he is most apt to begin a song, when he attempts to sing. The note in his voice will be perfectly in unison with the note produced by the string; that is to say, they will melt into and agree with each other, and the effect will be pleasant. This is because the membrane at the top of the singer's windpipe (the instrument of his voice) vibrates exactly the same number of times in a second, producing that note, as the string does. The equality in the number of vibrations is what makes the notes the same, and the effect harmonious and agreeable.

We shall suppose the string to be forty-five inches long that produces the note C of 240 vibrations in a second. Being extended between two pegs near the surface of a board, the experimenter may place his finger upon it right in the centre, and twang or strike either half, when he will find a much shriller note produced, being, in reality, the first C, or Do, of a new series of the seven notes. In this case, the vibrations are exactly double—namely, 480 in a second—these being always the more rapid the shorter the string or the greater its tightness. The second or upper C is called the *octave* of the first, being the eighth note above it.

We shall now suppose that the string is shortened only so far as to leave thirty inches, or two-thirds of its length, free for twanging. This shorter string will sound the note G, or Sol. In this case, as the length of string is two-thirds, so are the vibrations three-halves, or one and a half times those in the former instance; namely, 360. All the other notes are produced by different proportions of string and numbers of vibrations, as shown in the adjoining scale:—



What is remarkable here is the curious mathematical proportions on which the various notes depend. Taking the first C as one, and its octave as one-half, we have various lengths of string for the intermediate notes, in the following proportions—namely, for D eight-ninths, for E four-fifths, for F three-fourths, for G two-thirds, for A three-fifths, and for B eight-fifteenths; all of which proportions are exactly reversed with regard to the numbers of vibrations, there being in succession nine-eighths, four-fifths, &c. The proportions, as clearly appears to the eye from the above scale, are not regular: the string is first shortened five inches, then four, then two and a quarter, next three and three-quarters, and so on. Nevertheless, these are the musical notes which the voice naturally gives forth, and which the mind recognises as beautiful. The string twanged at lengths which would appear in more regular proportion, would give forth musical sounds, but not the seven notes of music—not those peculiar sounds which all nations recognise as such, and which nature has manifestly appointed to serve in that character.

Irregular as the proportions appear, there are some of the seven notes which are more proportioned to each other than the rest. They are said to be more in *harmony* with each other; and the effect when they are struck together is pleasing. It is to be observed in the first place, that a note always harmonises well with its octave, or the eighth or repeating note above it. This is supposed to be because the vibrations of the one note in that case are exactly two for one of the other. The first Do also harmonises well with Sol (G), which is called its *fifth*, being the fifth note above it; and this is, on the same supposition, because the vibrations are in that case as three to two, which is also a symmetrical proportion. Harmony is also produced when some other notes are sounded at the same moment with those which are third above them (their *thirds*); and this may be accounted for in a similar way. Thirds, fifths, and octaves, are therefore pleasing or harmonious sounds; while seconds, fourths, sixths, and sevenths are less so.

Experiments of a very curious nature have been made on this subject. It may readily be observed by the naked eye, that when one of the longer strings of the harp or pianoforte is struck, there is not only a vibration along the whole length, giving it an elliptical appearance, but there are also vibrations of shorter lengths of the same string going on at the same time. It has been found, when light pieces of paper are hung across the string, that they settle at certain places, showing that the principal subordinate vibrations correspond with octaves, fifths, and thirds. A drum, or a sonorous board, over which sand has been strewn, will, if beat, throw the sand into curious figures of a determinate and regularly-recurring character. There are even more curious facts connected with the harmonious notes. The *cries* of a city—that is, the scarcely articulate, but often very musical, sounds uttered by persons selling things on the streets—generally rise on thirds or fifths, sometimes on octaves; and this although few of these poor people have ever been taught music. The cry of oysters by women in Edinburgh is, for example, always on an octave.

With respect to the sounds produced by wind instruments, the effect is caused by the vibrations of a column of air confined at one end, and either open or shut at the other. The length of the sounding column determines the nature of the vibrations; but along with the fundamental tone, there are inferior and subordinate vibrations. The whole column divides itself into regular portions—equal to the half, the third, and so on, of the longitudinal extent—in the same manner as we showed was the case in stringed instruments. We may observe something similar to these vibrations in the contraction and expansion of a long and very elastic string, to one extremity of which a ball is attached. A spiral spring also shows, and perhaps more clearly, the repeated stretching and recoil. If suddenly struck at one end, it will exhibit not only a vibration throughout its whole extent, but likewise partial ones, which wind vermicularly along the chain of elastic rings. If the air be struck with great force, the subordinate vibrations sometimes predominate, and yield the clearest and loudest tones. This may be observed in the dying sounds of a bell, which rise one or two octaves, and expire in the acutest note. Upon the degree of force with which the instrument is blown, depends the performance of the bugle-horn, whose compass is very small, consisting only of the simplest notes. In other wind instruments, the nature of several notes produced depends upon the length and size of the tube, or the positions of the holes in its sides. In the organ, there is a pipe for each note, and wind is admitted from the bellows to the pipes by the action of keys similar to those of a pianoforte. The organ may be played also by a barrel made to turn slowly under the keys, and to lift them in passing, by means of pins projecting at certain determinate intervals from the surface of the barrel. In wind instruments which are furnished with reeds, the tone depends on the stiffness, weight, length, &c. of the vibrating plate or tongue of the reed, as well as on the dimensions of the tube or space with which it is connected.

For further information on the theory and practice of music, see Music and Musical Instruments.

ELECTRICITY—MAGNETISM—ELECTRO-MAGNETISM.

ELECTRICITY.

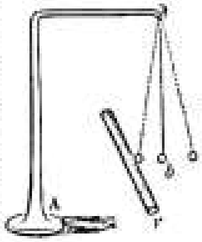
It was observed in ancient times, that when amber was rubbed, it acquired a power of attracting and repelling such light bodies as hair and feathers; and this power afterwards came to be called Electricity, from *electron*, the Greek word for amber. Although the ancients were thus familiar with some of the more obvious phenomena of electricity, they did not investigate the subject methodically, or attempt any generalisation of facts into a scientific theory. It was only in modern times, when close reasoning from truths, established by the evidence of the senses, began to be practised by philosophers, that the phenomena connected with electricity assumed the dignity of a science. Dr Gilbert, an English physician, made the first step towards generalisation in the year 1600. He published a valuable treatise, in which he observed that not only amber, but various other substances, can, by friction, be made to draw light bodies to them. Boyle, Guericke, Newton, and some other philosophers of that period, contributed to extend human knowledge upon this interesting subject; but the real science of electricity took its rise in a later age. About the middle of the eighteenth century, several very remarkable facts were ascertained, particularly by Benjamin Franklin, which identified lightning with electricity; but the extensive relations which connect it with so many other departments of physical science were not discovered until the present century, nor was their importance until then appreciated. In this short era a new science has arisen, founded on that modification of electricity which is known by the name of Voltaic Electricity. The voltaic battery (which will be afterwards described), as an instrument for analysing or decomposing chemical substances, has connected it with chemistry in the most intimate manner. Hence has sprung Electro-Chemistry, one of the connecting branches between remote divisions of the philosophy of nature. Electro-Magnetism is a still more recently-discovered province of science, and which identifies as one two powers which were previously regarded as distinct.

As the best method of conveying a clear, and at the same time philosophical view of this interesting science, we shall, in the first place, independently of all theory, state the most general and remarkable facts connected with it. After these have been enumerated, the reader will be prepared for a review of the theories which have been advanced for the purpose of explaining phenomena, and for connecting the various facts in the mind. The general facts relating to this subject may be classed under two heads—1st, The *Excitation* of Electricity; and, 2d, The *Distribution* of Electricity. Connected with each of these heads are various phenomena, which we shall notice as they occur during the gradual development of the subject.

EXCITATION OF ELECTRICITY.

If a stick of sealing-wax, a bit of amber, the glass of a watch, or any other smooth piece of glass, be rubbed upon dry flannel or woollen cloth, or even the sleeve of a cloth coat, it will be found to have acquired a new and very singular physical property. This property is exhibited by holding the body which has been subjected to friction over small and light substances, such as shreds of paper, gold leaf, feathers, straw, cork, &c. These will be first instantly *attracted* to it, some of them adhering to its surface, others falling back to the place whence they were withdrawn, whilst others are thrown off from the body, as if they were *repelled* from it. Here, then, is a distinct phenomenon—a process of attraction and repulsion at the same instant, which requires careful examination.

The phenomena of attraction and repulsion may be exemplified in a striking manner by a small apparatus, of which we adjoin a representation. A is a stand bent at its upper extremity, and having a hook to which a fine silk thread is attached, with a very small pith ball at its end *b*. Rub a dry rod of glass *r*, and, on presenting it to the ball *b*, the ball will be immediately attracted to the glass, and will remain in contact with it. After they remain in contact for a few seconds, if the glass be withdrawn without being touched by the fingers, and again presented to the ball, the latter will be *repelled*, instead of being attracted, as in the first instance. By being touched with the finger, the ball can be deprived of its electricity; and if, after this has been done, we present a piece of sealing-wax in place of the glass formerly employed, the very same phenomena will take place: on the first application, the ball will be attracted; and, on the second, repelled. It is clear, then, in the first place, that both these electrics—the glass and the wax—have the power of attracting another body before they have communicated to it any of their own electricity; and, secondly, that they repel the body after they have communicated to it a portion of their own electricity.



But a very remarkable circumstance takes place, if we, after having conveyed electricity to the ball *b*, by means of excited glass, which has been for a moment or two in contact with it, should present to it, after the former was withdrawn, excited sealing-wax: the ball, instead of being *repelled*, as it would be were the glass again applied, is *attracted* by the wax. If the experiment be reversed, and the excited wax first presented to the ball, and then the excited glass, the latter will be found to *repel* the ball. 'Hence it follows,' says Sir David Brewster, 'that excited glass *repels* a ball electrified by excited glass. Excited wax *repels* a ball electrified by excited wax. Excited glass *attracts* a ball electrified by excited wax. Excited wax *attracts* a ball electrified by excited glass. From which we conclude that there are two opposite electricities—namely, that produced by excited glass, to which the name of *vitreous* or *positive* electricity has been given; and that produced by excited wax, to which the name of *resinous* or *negative* electricity has been given.

'If, when the pith ball *b* is electrified, either with excited glass or wax, we touch it with a rod of glass, its property of being subsequently attracted or repelled by the excited glass or wax will suffer no change; but if we touch it with a rod of metal, it will lose the electricity which it had received, and will be attracted either by the excited glass or wax, as it was when they were first applied to it. Hence the rod of glass and the rod of metal possess different properties—the former being incapable, and the latter capable, of carrying off the electricity of the pith ball.'

In these experiments, electricity has been produced by *friction*; but there are other methods of obtaining it, which, however, will be afterwards explained.

With regard to attraction and repulsion, a few facts remain to be stated. Some substances remain longer in contact with the electric than others, and two bodies which have both been in contact with the same electric mutually repel each other. If electrics of considerable size are employed, the phenomena of course are better observed; and if the experiment be performed in a darkened chamber, flashes of bluish light will be seen to extend over the surface of the electric submitted to friction, which we shall suppose is a cylinder of sealing-wax, sulphur, or glass. Sparks, accompanied also with a sharp snapping sound, will be seen to dart round it in various directions. If a round body, as a metallic ball, be presented to it, and moved from one end to the other, a succession of sparks will be obtained as the ball passes along the surface; and if the knuckle be presented instead of the metallic ball, each spark will be accompanied by a pricking sensation. If a metallic globe be suspended in the air by silk threads, and in that situation rubbed by an electric, it will also become electrical, and exhibit the same properties as an electric. It is essential to the success of this experiment that it be *insulated;* that is, cut off, by means of a non-conductor, from all communication with any substance, except the air and the electric which sustains it. The instruments employed in experiments similar to those above described are termed *electroscopes.*

DISTRIBUTION AND TRANSFERENCE.

We have noticed that when the excited electric was brought near the pith ball *b*, the latter was first attracted, and then repelled. If we now remove the electric, and present to the ball which has thus touched it a second ball, which has had no previous communication with an electric, we find that these two balls attract one another, and come into contact. The same actions are repeated between this second ball and a third which may be presented to it; and so on in succession, but with a continued diminution of intensity. This diminution plainly indicates a diminished power, in consequence, as it would seem, of its being distributed amongst a number of bodies. It is clear, therefore, that the unknown power which we have called electricity, can, like heat, be transferred or communicated from one body to another, and that its intensity, like that of heat, is weakened by being diffused amongst a number of bodies. An electrified ball can be deprived of its electricity by being touched with a rod of metal of any kind; but if we touch it with glass or wax, it will not be carried off. Hence metals are said to be *conductors*, and glass and wax *non-conductors*, of electricity. Bodies differ greatly in their power of conduction, and many of them owe it to the water which they contain. The following lists show, in a general manner, the kind of substances that possess these properties:—

Conductors.—Silver, copper, lead, gold, brass, zinc, tin, platina, palladium, iron, and the metals in general, charcoal, plumbago, concentrated acids, diluted acids, saline solutions, metallic ores, animal fluids, water, living vegetables and animals, flame, smoke, soluble salts, alcohol, ether, moist earths.

Non-Conductors.—Shell-lac, amber, resins, sulphur, wax, glass, vitrifications, mica, various minerals, silk, wool, hair, feathers, dry paper, leather, air, and all dry gases, baked wood, dry vegetable bodies, porcelain, camphor, caoutchouc, dry chalk, lime, phosphorus, ice, ashes of animal and vegetable bodies, oils.

If electricity is excited on a body, it must either remain on it or pass away; in the former case, the body is a *non-conductor or an insulator;* in the latter case, it is a *conductor.* If the electricity pass along a surface instantaneously and entirely, that surface is a good conductor; if the excitement pass along more slowly, the surface is a conductor of an inferior kind. If the electricity remain altogether stationary at one part of the continuous surface of a body, that body is a perfect insulator; if it remain for a considerable time at one place, but yet have a tendency to move along slowly over the whole body, the insulation is not perfect; there is a degree of conducting power in the substance. Hence a bad conductor is the same as a good insulator, and a bad insulator the same as a good conductor. The metals are the best conductors: the excitement runs along their surface with the speed of light; hence wires and chains, and plates of some metal, such as copper, brass, &c. are used for the purposes of good conduction. Charcoal, in its pure forms, such as plumbago, or that from well-prepared wood, stands next to the metals. Strong acids and alkalies are also good conductors. Water ranks inferior to these, but is still very high; hence all bodies, of whatever material, if they are wet or moist, conduct well; so that to retain the excitement anywhere, dryness is an essential condition. Living animals and vegetables conduct well, in consequence of their containing a great body of water; when dried, both animal and vegetable substances insulate to a very considerable degree, especially the former. Dry silk, wool, feathers, skins, &c. which are all of animal origin, are ranked among insulators. Dry wood, and other vegetable substances, are more nearly allied to conductors than the animal tissues. The resinous bodies are among the best insulators. The most perfect of all insulators are the dry gases, or airs that have no moisture or watery vapour in them. Water, in its liquid state, is a good conductor, but it is an insulator when solidified into ice, or when boiled into steam. The presence of steam, however, is always to be avoided, on account of its liability to be deposited on surfaces, as water or dew; so that although the air were free from visible vapour, yet if it is highly charged with steam or invisible vapour, there is a great danger of the electrical excitement being dispersed by the surfaces of insulators becoming damp. So long, however, as the steam retains its perfectly elastic and gaseous state, like the gases in general, it has no conducting power. Sulphur and phosphorus are among the insulators, and stand perhaps next to wax and the resinous bodies. Some of the insulating solids, such as glass, are rendered conductors by being heated to redness, or to the verge of liquidity: so that the mechanical state of bodies has a great deal to do with their character as conductors or insulators. If all substances were ranked in one table, beginning with the best conductors, and ending with the worst, which are also the best insulators, the metals would be at the top, and the dry gases at the bottom. In the middle would be dry vegetable and animal bodies; between these the line would be drawn where conduction might be said, for all practical purposes, to end, and insulation to begin; but to have good insulation, we would have to descend to glass, sulphur, wax, and shell-lac. Such a table, read from the bottom upwards, would be a table of insulators. When we require strong insulating pillars to support great weight or pressure, glass is commonly used; but where strength is not necessary, wax and shell-lac are preferred. Conducting substances may be rendered non-conducting by being coated with wax or some resinous varnish.

A distinction was formerly made between *electrics* and *non-electrics*, or substances that could be electrified by rubbing, and substances that could not be so electrified; and it was further asserted that non-conductors or insulators were electrics, and that conductors were non-electrics. This was founded on the fact that sealing-wax, amber, and glass, the substances used for exciting electricity, are among the insulators; whereas if we take a good conductor, such as a rod of metal, and rub it ever so much, no excitement seems to be produced. But the whole supposition was founded in a mistake. It is not true that the insulators are the only substances that can be excited by friction; almost every body in nature becomes electric when rubbed with proper precautions. The reason why no electricity appears on a metallic rod or other conductor is, that the excitement is carried off as fast as it is produced; whereas on sealing-wax or glass, it remains stationary, and thus shows itself on the very spot that is rubbed. To electrify a good conductor, it must be carefully insulated. If we take a plate of metal, and attach it to a dry glass handle, and hold it in the hand by the glass, and then rub the surface, a most perceptible excitement is produced, and all the ordinary phenomena of attraction and repulsion can be observed by means of it: so that the metals, and all other conductors, are as good electrics as any of the insulators. In fact, on the electrical machine, a metallic compound is used as one of the rubbing surfaces, and is found preferable to all other rubbers. In this case glass, an insulating substance, is acted on by a conducting substance, showing that, in the actual excitement of the electricity, both kinds may be made available. The distinction of electrics and non-electrics is therefore now abandoned, because non-electrics do not exist, as was supposed. The only substances that have been found incapable of yielding electricity by friction are the gases. There seems to be some feature in the gaseous state of matter that prevents it from acting as an exciting body; probably the same reason that renders gases the most perfect of insulators. But this fact renders still more striking the mistake of calling insulators the only electrics; for the only substances that are absolutely non-electrics are the best insulators that exist. It has been lately proved by Faraday, that a stream of dry air, however violent and intense, rushing through an aperture in a solid body, has no power to excite electricity; although it is demonstrated that the friction, or agitation of the surface of the body, is very strong. But if the stream of air carry along with it particles of powder of any kind, or if it convey liquid drops, a very high excitement may be produced. This discovery was made in consequence of an observation of Mr Armstrong of Newcastle, that steam jets electrified the boiler that they rushed out from. A high *negative* or *resinous* charge is thus given to a metallic boiler, while the jet itself shows *positive* or *vitreous* electricity. The apparent inference from the fact was, that steam could act as a rubber upon metal, and that these two substances could generate electricity by their action, the same as a piece of sealing-wax rubbed with cloth. But when Faraday investigated the phenomenon, he found that what rubbed the cylinder, and created the excitement, was, not the steam, but the water-drops. Dry steam—that is, steam in its perfect invisible elastic state—yields no electricity; and no other dry gas can produce any; but if a certain amount of watery particles be carried out, action arises. And any gas whatever, if it is the medium for sustaining a rush of liquid or solid particles through an aperture, will thereby excite the two electricities—the one kind being made to arise on the body that the stream rushes out from, and the opposite kind appearing in the jet and on everything that it touches. It thus appears that though a stream of water rushing over a surface might evolve electricity, a current of dry air, however powerful, is incapable of the same effect.

THE TWO KINDS OF ELECTRICITY.

It will be understood, from the preceding explanations, that there are two kinds of electricity—namely, a *vitreous* or *positive* electricity, and a *resinous* or *negative* electricity. Although we have thus two electricities, there does not appear to be the smallest difference between them when they are taken individually. The distinction is only observable when brought in contact; they then display so marked a contrariety, or mutually opposive force, that they may be viewed as agents having opposite qualities, which completely neutralise one another by combination, just like an acid and an alkali. It is remarkable that the excitation of one species of electricity is always accompanied by the presence of the other, and both are produced to an equal extent. Thus, when a piece of glass is rubbed by silk, just as much resinous electricity is produced in the silk as there is vitreous electricity produced in the glass; and whatever electrified bodies are repelled by the one, are attracted by the other. Of course these two surfaces, having acquired opposite electricities, invariably attract each other. A white and a black ribbon rubbed against each other between the finger and thumb, exhibit electrical phenomena in a very marked manner. The black is resinously, and the white vitreously electrified; of course they attract each other; and if separated, the one attracts the light bodies which the other repels. When two pieces of the same ribbon of the same length are rubbed, the one being drawn lengthways, and at right angles, over a part of the other, the one which has been subjected to friction in its whole length acquires vitreous, and the other resinous electricity.

To know the species of electricity evolved, it is merely necessary to communicate beforehand, to the slips of gold leaf, a known electricity, either from excited glass, or sealing-wax. If they be divergent with the former, then the approach of a body similarly electrified will augment the divergence, but that of one oppositely electrified will cause their collapse.

There are certain laws that determine, when two substances are rubbed together, which will take the positive, and which the negative electricity. In general, the surface whose particles suffer the greatest agitation or disturbance is the negative surface. Thus if two pieces of the same material are rubbed together, there will be no excitement if the surfaces are perfectly identical; but if one is rough, and the other smooth, the rough one will be negative, and the smooth positive. So if there is a difference in their temperature, the hot surface will be negative, and the cold positive. If we take two bits of ribbon, both from the same piece, and rub the one its whole length across the other, the friction will be most intense on the second, which has sustained, on a narrow surface, the action of the other's whole length; so that the stationary ribbon will be negative, and the other positive. If one ribbon is black, and the other white, the former is negative, and the latter positive; the black dye having the effect, partly of retaining the heat, and raising the temperature more than the white, and partly of bringing in a greater agitation of the atoms under the friction. It will sometimes happen that the same body is negative when rubbed on one kind of material, and positive when rubbed on another.

The metals may be arranged in a certain fixed order, such that each metal will be negative when rubbed on any one that follows it, and positive on any one preceding it. The order is as follows:—bismuth, platinum, lead, tin, copper, gold, silver, zinc, iron, arsenic, antimony. If bismuth is rubbed on antimony, the bismuth will be negative, and the antimony positive. If iron were rubbed on lead, the iron would be positive, and the lead negative. The above series is not an isolated random arrangement of the metals, but is the order of their radiating powers for heat. The worst radiators are at the beginning of the list, the best radiators are at the end; that is, bismuth, platinum, and lead, when once heated, radiate off their heat very slowly; and, on the other hand, when they are exposed to a fire, or any other source of radiant heat, they absorb it very slowly, or they take a long time to acquire the heat. Iron and antimony, however, are good radiators; they give off their heat rapidly, and take it in rapidly. But if two metals be very near one another in such a series, their action might be reversed, if one of the two surfaces were well polished, and the other made very rough. Thus if lead were rubbed on tin, the lead ought to be negative, and the tin positive; but if the surface of the tin were very rough and very hot, while the lead is smooth and cold, the latter might become the positive element. See *Thermo-Electricity*, p. 234.

In rubbing metals to produce electricity, it is necessary to rub with large sweeps, to prevent the two electricities from joining together at the place where they are rubbed. The conducting power of the metals is such, that the excitements produced on the touching surfaces are very apt to run together, and neutralise each other on the spot.

ELECTRICAL INDUCTION.

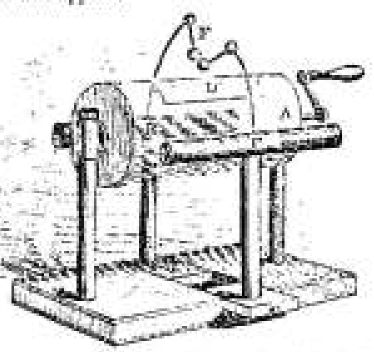
If a body is charged with electricity, and insulated so perfectly as to prevent the escape of the electricity which it contains, it nevertheless tends to produce an electrical state of the opposite kind in all the bodies around it. Thus the vitreous induces the resinous, and the resinous the vitreous, electricity in a body that is situated in the vicinity of either of them, and this to a degree proportioned to the distance which separates the bodies. The electricity is in this case said to be induced, and the phenomenon is called *electrical induction*. The operation of this law is a key to the principal phenomena of electricity. In illustration of it, we shall quote an able writer upon the subject:—'If an electrified body, charged with either species of electricity, be presented to an unelectrified or neutral body, its tendency, in consequence of the law of induction, is to disturb the electrical condition of the different parts of the neutral body. The electrified body induces a state of electricity contrary to its own in that part of the neutral body which is nearest to it; and, consequently, a state of electricity similar to its own in the remote part. Hence the neutrality of the second body is destroyed by the action of the first; and the adjacent parts of the two bodies, having now opposite electricities, will attract each other. It thus appears that the attraction which is observed to take place between electrified bodies, and those that are unelectrified, is merely a consequence of the altered state of those bodies, resulting directly from the law of induction; and that it is by no means itself an original law or primary fact in the science.

'The effect of induction will be in proportion to the facility with which changes in the distribution of electricity among the different parts of a body can be effected, a facility which corresponds with the conducting power of the body. Hence the attraction exerted by an electrified body upon another body previously neutral, will be much more energetic if the latter be a conductor than if it be an electric, in which these changes can take place only to a very small extent. This is confirmed by the following experiment:—Suspend, by fine silk threads of equal length, two small balls of equal dimensions, both made of gum-lac, but one having its surface covered with gold leaf. Place these two pendulums, as they may be called, at a little distance from one another, so as to admit of a comparison of their motions; and then present to them an excited electric, which may be either a tube of glass, or a cylinder of sealing-wax. It will at once be seen that the ball with the metallic covering, which readily admits of the transfer of electricity from one side to the other, will be much more readily and powerfully attracted than the other ball, which allows of no motion in its electricity. The latter ball will, by slow degrees, however, assume electrical states of the same kind as the gilt ball, and will be fully attracted. As this change is very slowly effected, so it is more permanent when once produced; and the plain ball adheres for a considerable time to the electric which has attracted it. The gilt ball, on the contrary, is sooner repelled, by its readily receiving the charge of electricity imparted to it by the electric. A degree of permanent electricity, however, is also induced on this ball, in consequence of its gradual penetration into the substance of the gum-lac.'

Electrical phenomena are generally accounted for by supposing that there is an extremely subtile and highly elastic fluid which pervades all material substances, but is itself devoid of any sensible gravity. It is supposed to move with various degrees of facility through the pores or actual substance of various kinds of matter. Hence, in proportion as they admit of the fluid passing through them with ease or difficulty, bodies have been divided into conductors and non-conductors. According to the doctrine of there being but one species of fluid, it is supposed that the electrical equilibrium which constitutes the natural state of matter is disturbed by friction, and that one of the two bodies brought near to each other attracts to itself a surcharge of the fluid, and is *over-saturated*, whilst the other is left in a deficient state, and is *under-saturated*. For this view of the subject we are indebted to Franklin; and hence the terms of positive or plus, and negative or minus, have arisen. But as some of the appearances cannot easily be reconciled to the hypothesis of a mere excess or deficiency of one fluid, there is another theory which supposes the fluid to be a *compound*, susceptible of decomposition by friction and other means; hence the origin of the terms vitreous and resinous electricities. With respect to the intensity of the electric force, it resembles that of gravitation, by being inversely as the square of the distance. Like gravitation, also, it acts at all distances, and it is not impeded by any intervening body, provided it be not in an active electrical state. But whilst the particles of each fluid repel those of the same kind, they exert, as we have seen, a high attractive power over those of an opposite kind. The intensity of this attraction also, like that of gravitation, increases with a diminution of distance. It is evident, therefore, that from the powerful attraction which they have for each other, they would always flow towards each other, and coalesce, were it not that the non-conducting properties of electrics offer an impediment to their motion.

ELECTRICAL MACHINES.

Rubbing or friction, it will be perceived, is always requisite to produce an artificial display of electrical phenomena. Thus in rubbing the back of a cat, in rapidly drawing off a silk from a woollen stocking, or in performing any similar action with suitable, and in all cases dry, substances, we evolve electric sparks, of lesser or greater intensity. For the purpose of producing powerful electrical results, the aid of mechanism has been found essential. We here offer a representation of the machine most commonly used, in our description of which, the essential parts constituting such instruments will appear:—



A B represents a hollow cylinder of polished glass, which revolves upon a horizontal axis, and is from eight to sixteen inches diameter, and from one to two feet long. For the purpose of insulation, it is supported on two upright pillars of glass, which are fixed in a wooden stand. Two hollow metallic conductors, equal in length to the cylinder, and about one-fourth of its diameter, are placed parallel to it, one on each side, upon two insulating pillars of glass, which are cemented into two separate pieces of wood, that slide across the base, so as to allow of being brought within different distances of the cylinder. To one of these conductors the cushion is attached, which is of the same length with the conductor C. The cushion is usually made of soft chamois leather, stuffed with hair or wool, so as to be as hard as the bottom of a chair, but yet sufficiently yielding to accommodate itself, without much pressure, to the surface of the glass to which it is applied. The prime conductor is a cylindrical tube, each end terminating in a hemisphere. As the electricity is only contained at the surfaces, it is made hollow, generally of thin sheet brass, copper, tin, or pasteboard covered with gold leaf or tinfoil. It must be carefully freed from all points and asperities; and if perforations are made in it for the purpose of attaching wires and other kinds of fixtures, for the purposes of experiment, they should be made about the size of a quill, and should have their edges well rounded and smoothed off. The pressure of the cushion against the cylinder is regulated by an adjusting screw, adapted to the wooden base at E, on which the glass pillar that supports the conductor is fixed. From the upper edge of the cushion there proceeds a flap of thin oiled silk D, which is sewed on the cushion about a quarter of an inch from its upper edge. It extends over the upper surface of the glass cylinder to within an inch of a row of metallic points, proceeding, like the teeth of a rake, from a horizontal rod, which is fixed to the adjacent side of the opposite conductor. The motion of the cylinder, which is given by a single handle, or by a multiplying wheel, must always be given in the direction of the silk flap. That part of the cushion which comes in contact with the glass cylinder should be coated with an amalgam composed of a little tinfoil and mercury, mixed like a paste by means of hogs' lard. The amalgam should be placed uniformly over the cushion, until level with the line formed by the seam which joins the silk flap to the face of the cushion. No amalgam should be placed over this line, nor on the silk flap; and it is even requisite to wipe the silk flap clean whenever the continued motion of the machine shall have soiled it, by depositing dust or amalgam on its surface.

This machine acts in the following manner:—When the cylinder is driven round by the handle, the friction of the cushion upon it produces a transfer of the electric fluid from the latter to the former; that is, the cushion becomes negatively, and the glass positively electrified. By the revolution of the cylinder, the fluid adhering to the glass is carried round, and its escape is at first prevented by the silk flap which covers the cylinder, until it arrives near to the metallic points, which absorb most of the electricity, and convey it to the prime conductor. This being positively electrified, the conductor connected with the cushion being deprived of this electricity, is negatively electrified; so that light balls suspended by threads at F, being oppositely electrified, will attract each other. After the action has gone on for some time, the cushion and its conductor become exhausted of their electricity; so that a new supply must be brought from the earth, the great reservoir of the fluid. This is easily done, by establishing a communication between the cushion and the ground by means of a metallic chain or wire. In this manner a constant stream of positive electricity flows to the prime conductor. Negative electricity is obtained by insulating the conductor to which the cushion is attached, and connecting the prime conductor with the ground, so as to carry off the fluid collected from the cylinder. If the person who works the machine be supported upon a stool having glass legs, and connected with the conductor by means of a metallic rod, or if he touch it with his hand, he is found to be in the same state of electricity; and another person standing upon the ground can draw sparks from him by presenting his knuckles to his body.

By using the electrical machine in the above manner, we are enabled to collect a considerable quantity of electricity, and thus perform experiments upon an ample scale. A pith ball, or a fragment of gold leaf, is very strongly and immediately attracted by the electrified conductor; and the instant after it has come into contact with it, it is repelled; but it is now attracted by the other bodies in its neighbourhood, to which it communicates its own electricity, and then is again in a state to be influenced by the conductor, and to be again attracted; and this alternation of effects will continue as long as the conductor remains charged. This alternation of attractions and repulsions accompanying the transferring electricity by movable conductors, is also illustrated by the motions of a ball suspended by a silk thread, and placed between two bells, of which the one is electrified, and the other communicates with the ground: the alternate motion of the ball between the bells keeps up a continual ringing.

The intensity of the electricity which bodies may contain is measured by a delicate instrument called an *Electrometer*, of which there are several invented by various distinguished individuals. Our limits, however, will not admit of our giving a minute account of them. They all depend upon the repulsive property of electrified bodies; the distance to which the one is repelled by the other being indicated by an index.

We have already observed, that upon the extent of the surface of a body its capacity for receiving electricity principally depends. Electricity is therefore supposed not to spread throughout the whole mass of a body, at least equally, but to remain principally, if not altogether, at the surface. This has been proved by experiments for trying the distance to which the electricity extended beyond the coating of the Leyden jar.

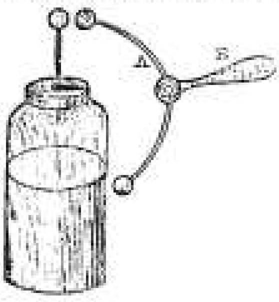
Several remarkable phenomena occur when electricity is drawn off by means of a conductor from those bodies in which the electrical equilibrium has been destroyed. A sharp snapping sound is heard, accompanied by a vivid spark, whilst intense heat is evolved in the path which the electric fluid takes. A perfect conductor offering no impediment to its course, it is unattended with light during its passage through such a body, light only appearing when there are obstacles in its path, such as imperfect conductors. Of the velocity with which it is transmitted we have already spoken. It is so great, that in experiments performed with a chain of considerable length, each link became apparently instantaneously luminous. There are various methods of showing the intensity and colour of electrical light. Conductors having a rounded form give the longest and most vivid sparks, which are sometimes seen to take a zig-zag course, similar to that of a flash of lightning. This deviation in its course is supposed to be occasioned by the fluid darting to minute conducting particles, such as those of moisture floating in the air. Electrical light is similar to light obtained from other sources, and its brilliancy depends upon its intensity. Sir David Brewster found that it was capable of polarisation.

An interesting question arises—Whence comes the light—is it the electric fluid which thus renders itself visible? This was really supposed to be the case by the early electricians, but later philosophers have substituted other theories to account for the phenomena. That of M. Biot, a celebrated French philosopher, is, that electric light has the same origin as the light disengaged from air by mechanical pressure; 'and that it is purely the effect of the compression produced on the air by the explosion of electricity.' This hypothesis has been objected to, however, on the ground that electrical light is produced in the best vacuum that can be formed; and although he has replied to the objection, that no perfect vacuum can exist, yet his arguments, though they carry weight, do not bring conviction.

We have already observed that various sounds accompany the various modes of transference of the electric fluid: a peculiar odour has also sometimes been felt near a machine which has been sharply wrought; but whence its origin, is unknown. All sharp-pointed bodies concentrate most of the electric fluid at their apex, from whence it has a powerful disposition to escape; and every discharge is accompanied by currents of air. Upon this principle many ingenious experiments are founded. An apparatus, consisting of wires terminating in points, and having balls annexed to them to represent the planets, may be constructed so as to revolve when electrified, and thus to imitate the planetary motions. We cannot enter further into this subject, but may state in general terms, that the appearances of the electric spark depend upon the nature of the surface from whence it issues, and towards which it is directed. When it escapes *from* a pointed body, the luminous appearance is that of diverging streams, resembling the filaments of a brush, and forming what is termed a *pencil of light;* but when the fluid goes to a point, the light concentrates at the point itself, and assumes the appearance of a star.

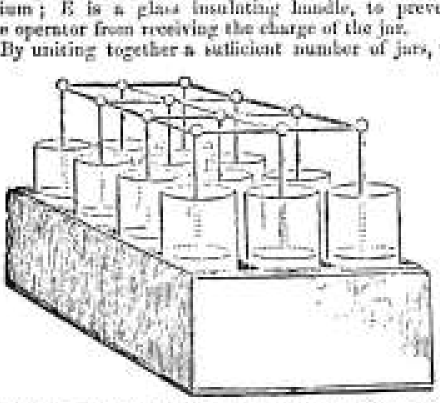
The most convenient mode of obtaining an accumulation of electricity arising from induction, is by the employment of coated glass; that is, of a plate of glass on each side of which is pasted a sheet or coating of tinfoil. Care must be taken to leave a sufficient margin of glass uncovered with the metal, to prevent the transfer of electricity from one coating to the other; and all sharp angles or rugged edges in the coatings should be avoided, as they have a tendency to dissipate the charge.

The form of coated glass best adapted to experiments is that of a cylindric jar; this is coated, within and without, nearly to the top. The cover consists of baked wood, and is inserted with sealing-wax, to exclude moisture and dust. A metallic rod, rising two or three inches above the jar, and terminating at the top in a brass knob, is made to descend through the cover till it touches the interior coating. The name of the *Leyden phial*, or *jar*, is applied to this instrument. It is used in the following manner:—The outer coating being made to communicate with the ground, by holding it in the hand, the knob of the jar is presented to the prime conductor when the machine is in motion; a succession of sparks will pass between them, while at the same time nearly an equal quantity of electricity will be passing out from the exterior coating, through the body of the person who holds it, to the ground. The jar, on being removed, is said to be charged; and if a communication is made between the two coatings, by a metallic wire extending from the external one to the knob, the electric fluid which was accumulated in the positive coating rushes, with a sudden and violent impetus, along the conductor, and passes into the negative coating; thus at once restoring an almost complete equilibrium. This sudden transfer of a large quantity of accumulated electricity is a real explosion; and it gives rise to a vivid flash of light, corresponding in intensity to the magnitude of the charge.



The effect of its transmission is much greater than that of the simple charge of the prime conductor of the machine; and it imparts a sensation, when passing through any part of the body, of a peculiar kind, which is called the *electric shock*. In the foregoing figure, A is a bent *discharging rod*, for establishing a direct communication between the inner and outer coating of the jar, and restoring the electrical equilibrium; E is a glass insulating handle, to prevent the operator from receiving the charge of the jar.

By uniting together a sufficient number of jars, we



are able to accumulate an enormous quantity of electricity. For this purpose, all the interior coatings of the jars must be made to communicate by metallic rods, and a similar union must be established among the exterior coatings, as shown in the annexed engraving. When thus arranged, the whole series may be charged, as if they formed but one jar; and the whole of the accumulated electricity may be transferred from one system of coatings to the other, by a general and simultaneous discharge. Such a combination of jars is called an *electrical battery*.

If we wish to send the whole charge of electricity through any particular substance which may be the subject of experiment, we must so arrange the connecting conductors as that the substance shall form a necessary part of the *circuit of the electricity*, as it is termed. With this view, we must place it between two good conductors, one of which is in communication with the outer coating; and the circuit may then be completed by connecting the other conductor with the inner coating by means of a discharging rod, to one branch of which, if necessary, a flexible chain may be added.

In forming arrangements for directing the passage of accumulated electricity, it should be borne in mind that the electric fluid will, on these occasions, always pass through the best conductors, although they may be more circuitous, in preference to those which are more direct, but have inferior conducting power; and it must also be recollected that when different paths are open for its transmission along conductors of equal power, the electricity will always take that which is the shortest. Thus if a person holding a wire between his hands discharges a jar by means of it, the whole of the fluid will pass through the wire without affecting him; but if a piece of dry wood be substituted for the wire, he will feel a shock; for the wood being a worse conductor than his own body, the charge will pass through the latter, as being easier, although the longer circuit. During its transit through the human body, in like manner, the shock is felt only in the parts situated in the direct line of communication. If the charge be made to pass through a number of persons, who take one another by the hand, for example, and form part of the circuit between the inner and outer coatings of the jar, each will feel the electric shock in the same manner and at the same instant; the sensation reaching from hand to hand, directly across the breast.

By accurate experiments, it appears that the force of the electric shock is weakened, or its effects are diminished, by employing a conductor of great length for making the discharge. A retardation in the passage of electricity also takes place if the conductor is not of a sufficient size; and when this is the case, as well as in those instances where the conductor is not a good one, the discharge will not be effected so instantaneously or so completely. It has also a tendency to diverge from the direct line of its course, being drawn towards conducting bodies which may attract it. The motion of electricity through perfect conductors is attended with no perceptible alteration in the mechanical properties of the conducting bodies, provided they be of sufficient size for the charge of the electric fluid transmitted. On the contrary, very considerable effects are produced when a powerful charge is sent through a wire which is too small to allow the whole quantity to pass with perfect freedom, or through an imperfect conductor, though of large size, as is proved when a tree is struck by lightning.

ELECTRICITY APPLIED TO INORGANIC BODIES AND ANIMALS.

The effects of electricity passing through various substances are both of a mechanical and chemical nature. The former resemble those which would be produced by a material agent driven with great velocity through the substance of the body. But there are many changes induced by electricity, such as cannot be attributed to mechanical agency, and are undoubtedly of a chemical nature. Some of the mechanical effects have already been noticed. Dr Priestley discovered that it expanded bodies. This is proved by passing a stream of the fluid through a capillary or thermometer tube filled with mercury; the latter will be so much expanded, as to break the glass to shivers. The tendency to expand will of course be greater as the conducting power of the body which transmits it is less. Although we know nothing of the nature of electricity, yet it has been found convenient to speak of it as a fluid. Its action upon bodies, which either obstruct its motion, or afford it a ready passage, renders its analogy with a fluid very striking, and the laws of its equilibrium are just those of an imponderable fluid. Solid bodies are capable of being diffused into vapour by passing electricity through them, as is shown by the following experiment:—Take three strips of window-glass, each about three inches long and one wide, and having placed two narrow strips of gold leaf or leaf brass between them, so that the ends of the gold leaf project a little beyond the glass, transmit the charge of a large Leyden jar through the gold leaf. The gold leaf will be found to be melted by the shock, and driven into the pores of the glass. The outer plates of glass are generally broken in this experiment, and the middle one, which frequently remains entire, has an indelible metallic stain upon each of its surfaces.

The metallic colours thus obtained have been employed for impressing ornamental figures upon paper or silk. In order to do this, trace the outline of the figures on thick drawing-paper, and having cut it out as in stencil plates, place it on the silk or paper intended to be ornamented. When a gold leaf is laid upon it, and a card above the gold leaf, the whole is placed in a press, or beneath a weight, and an electrical charge sent through it; the metallic stain is limited to the portion of the drawing-paper that is cut away, and consequently any outline figure may be readily impressed upon the ground employed to receive it.

The effects of electricity as a chemical agent are strikingly displayed in its power of evolving heat, and consequently of inflaming and fusing bodies, and its power of promoting chemical composition and decomposition. Combustible bodies, such as a common candle, can be lighted in various ways, by passing the electric fluid through them. The heat evolved by electricity, like most other of its effects, is in proportion to the resistance opposed to its passage. Nor is its heating power in the smallest degree diminished by its being conducted through any number of freezing mixtures which are rapidly absorbing heat from surrounding bodies. Sparks taken from a piece of ice are as capable of inflaming bodies as those from a piece of red-hot iron. Amongst the more striking chemical effects of electricity, or electro-chemistry, are the decomposition of water, the oxidation of metals, and the restoration of the oxides to their metallic state.

Many experiments have been made for the purpose of ascertaining the changes effected in *phosphorescent* bodies by electricity; and the results are not without importance. It has been discovered, for instance, that substances not naturally phosphorescent, such as statuary marble in its natural or calcined state, were not only rendered phosphorescent by heat after being strongly electrified, but acquired this property with a beauty, a variety, and an intensity of colour, superior to those which occur in specimens that possess natural phosphorescence. It has also very recently been discovered that electricity exercises a curious influence upon odoriferous bodies. When a current of the fluid is made to traverse camphor, the odour gradually disappears. After being withdrawn from electrical influence, it remains odourless for some time, and then slowly resumes its former properties.

There are certain mineral bodies which, from being in a neutral state at ordinary temperatures, acquire electricity simply by being heated or cooled. This property is possessed only by regularly crystallised minerals; and of these the most remarkable is the tourmalin. It is a stone of considerable hardness, and the form of its crystals is generally that of a nine-sided prism, terminated by a three-sided pyramid at one end, and by a six-sided pyramid at the other. When heated to between 100 and 212 degrees, the latter extremity becomes charged with positive electricity, whilst the former remains negative. On cooling, the electric states are generally reversed, that end becoming positive which was formerly negative. Other gems possess similar properties, such as the topaz, some species of diamonds, &c. There are a great many substances which become electrified by passing from the liquid to the solid form, such as sulphur, gum-lac, and in general all resinous bodies. The conversion of a body into the aëriform state is also generally attended by some change in its electrical condition.

There are some bodies which are rendered electrical by pressure. The substance which possesses this property in the most remarkable degree is that variety of the carbonate of lime known by the name of Iceland spar. Cork, bark, hairs, paper, and wood, also possess the property of producing electricity by compression. A number of substances, when reduced to powder, exhibit electricity, if they are made to fall upon an insulated metallic plate. The relation subsisting between electricity and the chemical properties of matter is the most important branch of this inquiry. It is observed by Sir Humphry Davy, that most of the substances that act distinctly upon each other electrically, are also such as act chemically when their particles have freedom of motion; this is the case with the different metals, with sulphur and the metals, with acid and alkaline substances. Of two metals in contact, the one which has the greatest chemical attraction for oxygen acquires positive electricity, and the other the negative. There is little doubt, indeed, that electricity is not only elicited by, but is intimately connected with, all chemical action; and there is every reason to believe that electricity is essentially concerned in the processes carried on in the living system both of animals and vegetables.

The influence of electricity upon the human frame—whether it is administered in small quantities, so as to excite and surprise us, or in the more powerful and awful form of a stroke of lightning—must be well known to every one. When the human frame forms part of the electric circuit, or when the charge of a Leyden phial is made to enter the body at one hand, and pass out of it at the other, a violent concussion or shock is felt along the line of its passage across the breast and through the arms. If the charge is increased, the patient falls down paralysed, suffering a temporary cessation of vital action; and if it be increased to a still greater extent, it produces instantaneous death. This is frequently exemplified in the cases of individuals who are killed by the lightning stroke. It is upon the nervous system that electricity produces the most powerful influence. A strong charge passed through the head gives the sensation of a violent but universal blow, and is followed by a transient loss of memory and indistinctness of vision. If a charge be passed through the spine, the person who receives it loses his power over the muscles to such a degree, that he either drops on his knees, or falls prostrate on the ground. Different persons are affected in very different degrees by electricity, according to their peculiar constitutional susceptibility. Small animals, such as mice and sparrows, are instantly killed by a shock from thirty inches of square glass.

M. Rousseau has suggested a means of 'ascertaining the purity of certain substances, and of detecting any adulterations in them, by measuring their conducting power for electricity. Some years ago, he described a simple apparatus by means of which the purity of olive-oil might be tested on similar principles. He now states that, by these means, any adulterations in chocolate or coffee may be readily detected: he finds that pure chocolate is a non-conductor or insulator of electricity, but that in proportion to the quantity of farina or fecular matter with which it is adulterated, the more easily does it conduct electricity; and in the same way he states that coffee is an insulator, whilst chicory, with which it is often mixed, is an excellent conductor: hence the presence of only a small quantity of that substance is easily detected in coffee by its increased conducting power.'

Electricity is exhibited in a remarkable degree in various living animals; for example, we find in certain fishes a regular system of electrical organs, by which they either defend themselves from the attacks of their enemies, or seize the prey nature has provided for their use. Amongst the most remarkable of these is the *raia torpedo*, which is capable of giving a great many shocks to a number of individuals connected together, in the same manner as in the experiment with the Leyden jar. Another is the electric eel, *Gymnotus electricus*, which, when provoked, discharges its electricity, and the shock is experienced if the hand be dipped in the water containing the fish.

Although many ingenious electrical experiments have been made upon *vegetables*, some of which seem to indicate that the fluid exercises considerable influence over vegetable life, yet the subject is still involved in too great obscurity to admit of its being treated as a branch of electricity.

ELECTRICITY OF THE ATMOSPHERE.

The resemblance between the electric spark, and more especially the explosive discharge of the Leyden jar, and atmospheric lightning and thunder, struck the mind of Franklin with so much force, that he determined, if possible, to verify their identity by experiment. Having constructed a kite, by stretching a large silk handkerchief over two sticks in the form of a cross, on the appearance of an approaching storm he went into a field in the vicinity of Philadelphia, and raised it, taking care to insulate it by a silken cord attached to a key, with which the hempen string terminated. No sooner had a dense cloud, apparently charged with lightning, passed over the spot, than his attention was arrested by the bristling up of some loose fibres on the hempen string: he immediately presented his knuckle to the key, and received an electric spark. The rain now fell in torrents, and wetting the string, rendered it a conductor throughout its whole length, so that electric sparks were now collected from it in great abundance. This discovery soon engaged the attention of the philosophers of Europe; and the truth of the theory, that lightning and electricity are the same fluid, was put beyond all question. In like manner, falling-stars, and other meteoric phenomena, can only be satisfactorily accounted for by regarding them as the results of certain electrical conditions of the atmosphere.

The atmosphere is very generally in an electrical state. This is ascertained by employing a metallic rod, insulated at its lower end, elevated at some height above the ground, and communicating with an electroscope. In order to collect the electricity of the higher regions of the air, a kite may be raised, in the string of which a slender metallic wire should be interwoven. The atmosphere is almost invariably found to be positively electrified; and its electricity is stronger in the winter than in the summer, and during the day than in the night. From the time of sunrise, it increases for two or three hours, and then decreases towards the middle of the day, being generally the weakest between noon and four o'clock. As the sun declines, its intensity is again augmented till about sunset, after which it diminishes, and continues feeble during the night. In cloudy weather, the electrical state of the atmosphere is much more uncertain; and when there are several strata of clouds moving in different directions, it is subject to great and rapid variations, changing backwards and forwards in the course of a very few minutes. On the first appearance of fog, rain, snow, hail, or sleet, the electricity of the air is generally negative, and often highly so; but it afterwards undergoes frequent transitions to opposite states. On the approach of a thunder-storm, these alternations succeed one another with remarkable rapidity.

The protection of buildings from the destructive effects of lightning, is the most important practical application of the theory of electricity. The conductors for this purpose should be formed of metallic rods, pointed at the upper extremity, and placed so as to project a few feet above the highest part of the building they are intended to secure; they should be continued without interruption till they descend into the ground below the foundation of the house. Copper is preferable to iron as the material for their construction, being less liable to destruction by rust or by fusion, and possessing also a greater conducting power. The size of the rods should be from half an inch to an inch in diameter, and the point should be gilt or made of platina, that it may be more effectually preserved from corrosion. An important condition in the protecting conductor is, that no interruption should exist in its continuity from top to bottom; and advantage will result from connecting together by strips of metal all the leaden water-pipes, or other considerable masses of metal in or about the building, so as to form one continuous system of conductors, for carrying the electricity by different channels to the ground. The lower end of the conductor should be carried down into the earth, till it reaches either water, or at least a moist stratum.

For the protection of ships, chains made of a series of iron rods linked together are most convenient, on account of their flexibility. They should extend from the highest point of the mast some way into the sea, and the lower part should be removed from the side of the ship by a wooden spar or outrigger.

VOLTAIC ELECTRICITY, OR GALVANISM.

About the end of last century, an Italian named Galvani discovered that, by arranging two rods of different metals so that they touched one another at one end, and included between their other ends the leg of a recently-killed frog, a convulsive contraction of the limb was produced. It is necessary that one of the metals should touch the nerve, and the other the muscles, in order to produce the effect. The action thus caused by the contact of two metals, or by a triangular circuit formed of two metals and a frog's leg, was found to be the very same as a shock of electricity from the common machine. A new source of electricity, independent altogether of friction, was consequently brought to light. Volta, who followed up the experiments of Galvani, was the first to construct an apparatus for obtaining the excitement in this new principle; hence the kind of electricity so produced is now called *voltaic electricity, or galvanism*.

Although the electricity of Volta is undoubtedly the same natural agency as the electricity of the common machine, it has nevertheless some characteristics that distinguish it from machine electricity, besides its peculiar mode of development. It is found to be of feeble *strength* or *intensity*; that is to say, it can never be excited to such a stretch as to inflict the severe blows upon animate or inanimate things that the other can give. The most powerful voltaic machine that has ever been constructed could not strike a man dead, or shatter a resisting obstacle. On the other hand, the voltaic electricity can be produced in much greater *quantity* or amount than we can obtain from friction. The distinction between *intensity* and *quantity*, which is of great importance in reference to the whole of the present subject, may be familiarly illustrated by the case of heat. The *intensity* of heat is its temperature; the *quantity* depends partly on the temperature, but chiefly on the extent of the heated substance. A red-hot poker is of a very high temperature or intensity; but it does not contain so great an amount of warmth as the water of a single hot bath. The quantity of heat is measured by the amount of coal necessary to produce it; and it may be expended either in heating a small body to a very high temperature, or a larger extent of material to a moderate temperature. The electricity of friction may be compared to a red-hot iron, that of Volta to a vast volume of warm water.

Now there are certain purposes that are best served by the high intensity; and others that require merely a great quantity, no matter how feeble the intensity. The chemical and magnetical effects of electricity are dependent on quantity alone; hence these were not produced in a very high degree till after the discoveries of Volta.

The term *current electricity* has also been given to the present branch of the subject, because the excitement arises in a constant stream, and can hardly be said to exist if it is not continually evolved. A Leyden jar may be charged, and may remain in that state, without requiring a continual supply to be poured into it; hence the common electricity has been called *statical*, or reposing electricity, or electricity in equilibrium. But the other kind must be kept in constant motion, in order to appear at all. This is owing to its feebleness, or its inability to give a high charge. If it is insulated, it soon ceases; because it cannot go on adding to the intensity of a limited surface: hence the voltaic machine must always be formed into a circle of conductors, where the electricity may flow round and round without interruption; in which case it is produced without ceasing.

It was supposed by Volta that the electricity arose from the simple fact of two different metals touching each other; or that there is a virtue in mere contact similar to the active rubbing of two surfaces. A crown-piece laid on a copper penny would, according to him, evolve electricity; and the one would be positively, and the other negatively charged. But there is no sufficient reason for believing that the simple contact of two bodies, apart from all other influences, is able to disengage electricity. There may be circumstances attending the contact that will render it a source of excitement; the one substance may have a strong chemical affinity for the other, as when a piece of soda is dipped into an acid; or the one may be much hotter than the other, and cause a rapid communication of heat to arise; or they may be unequally susceptible to some common influence, as when the flame of a lamp is applied to the joining; but in all these cases a power is present over and above contact, which may serve to give forth electricity.

The more common belief as to the source of voltaic electricity is, that it is due to *chemical combination*, or the union of two substances having a chemical affinity for each other. Such unions commonly produce heat in great abundance; for it is well known that the warmth of a fire proceeds from the union of coal with the oxygen of the air. When two substances combine together to produce a third substance different in its qualities from both, there is always a disengagement of heat, and the action is of the kind called *chemical*. A quantity of brimstone united in this way with a mass of copper filings, results in a new material, different in every respect from either brimstone or copper; they are yellow; it is black: it is neither a combustible like the one, nor a metal like the other. The production of this new substance is an act of chemical combination; and while the union is going on, an intense heat is given forth.

Now the prevailing theory is, that the kind of action that transforms two substances into a third substance having new and distinct properties, which takes place in uniform and fixed proportions, and which causes sensible heat, is the action that gives birth to the electricity of Volta. It can be proved that in most cases of chemical action electricity is always developed. When an acid combines with an alkali, the acid acquires positive, and the alkali negative excitement. So when an acid acts on a metal—as when zinc is plunged into oil of vitriol—the acid is positive, and the metal negative. The action of water in rusting metal would also render the metal negative.

Dissolutions without chemical action bring forth the electrical excitement. When acids are dissolved in water, they become positive, and make the water negative. When alkalies are dissolved in water, they become negative, and make the water positive. When acids are mixed with one another, there is no action beyond mere solution; electricity, nevertheless, arises. If nitric and muriatic acid are mixed, at the moment of mixture excitement may be detected—the nitric acid being the positive ingredient.

The action of the machinery that is used for producing voltaic electricity may now be understood without much difficulty. This machinery generally consists of two metals, and a liquid capable of acting upon metallic bodies by chemical affinity. One of the metals should be acted on as strongly as possible, and the other as weakly as possible. The liquid is commonly an acid, or a corroding salt dissolved in water. Water alone will serve the purpose; but its chemical affinity for metals being faint, compared with acids, it produces feeble effects.

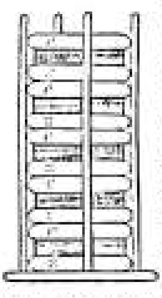
Let the adjoining fig. represent a vessel containing an acid, or other corrosive liquor. Immerse in the liquid a plate of zinc (Z): a chemical action will immediately arise; the surface of the zinc will be attacked, and gradually converted into a new substance, which will be some compound of zinc. In the meantime the zinc will be acquiring a charge of negative electricity, and the liquid an equal charge of positive electricity; which could be made apparent by the instruments adapted to show this kind of electricity, or by what is called a voltaic electrometer. But let us next immerse a copper plate (C), face to face with the zinc plate. Copper is much less readily acted on than zinc, but it is still liable to be corroded by an active liquor.

Accordingly, the copper surface would be gradually combined with the liquid, and a coating would be formed on it which would consist of a compound of copper. Thus, then, we should have two metallic plates—one undergoing a quick, and the other a slower corrosive action or chemical combination. Electricity would arise in both cases; the metals would be negative, and the liquid positive. But take now a wire (W), and solder it to the edges of the two plates that are outside the liquid; a circle is then formed, containing four portions—namely, a plate of zinc, a mass of corrosive liquor, a plate of copper, and a wire bridging from the copper to the zinc. The actions formerly described are now greatly modified. The action upon the zinc plate, which is the more corrosive of the two, is very much quickened; the compound formed on its surface is deposited more rapidly. But *the corrosion of the copper entirely ceases.* The production of electricity is therefore now confined to the surface of the zinc; and this electricity is found to circulate steadily round and round the fourfold circle of zinc, liquid, copper, and wire: it may be easily detected at any place in this circle. In other words, a permanent electrical excitement is maintained in every point of four connected substances. If all the excitement existing in the apparatus were taken off and discharged at any one instant, it would be found renewed again the next; hence the reason for speaking of this excitement as a *current*, or as being in a current state. The principle already laid down for determining the kinds of electricity that arise when an acid acts on a metal, informs us of the directions taken by the positive and negative currents. Thus the zinc (Z) is negative, while the liquor adjoining, or intervening between the plates, is positive; and as the action goes on, more and more negative electricity passes upon the zinc, and more and more positive electricity upon the liquid. Accordingly, the negative charge of the zinc, being driven away from the surface of contact of zinc and liquor, can go in only one direction. It cannot pass to the liquid, and thence to the copper; it must therefore pass upon the wire, and round to the copper by the outside portion of the circuit. So the positive electricity, originating at the surface of corrosion, and passing thence upon the intercepted liquor, must make its way through the liquor to the copper plate, and from that to the outside wire, and round to the zinc in this direction. That is to say, the negative charge is conducted from the zinc by the outside wire to the copper, and through the liquid to the zinc again; while the positive charge is conducted in the opposite course, or through the liquid to the copper, and thence by the wire to the zinc. All the four portions of the circle are conducting substances, so that the charge will readily pass round and round. We have thus two opposite currents—a positive current circulating in one direction, a negative current circulating in the contrary direction. The two currents are always of equal intensity and quantity, and they always move in the directions now described. The zinc plate is called the negative pole of the circle, and the copper plate the positive pole; because a body touching the one would take on a negative charge, and a body touching the other, or the copper, would be made positive.

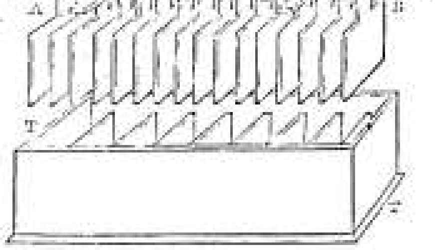
It appears, therefore, that chemical action is the origin of the electricity; and, on the other hand, that the electricity produced has some control over the chemical action; for one of the two affinities—namely, that between the liquid and the copper, is entirely suspended by it, and the other is made more intense. How this happens, we shall have to explain when we come to speak of the theory of the voltaic circuit, after describing the most usual forms of its construction.

VOLTAIC PILES AND BATTERIES.

The first form of the apparatus for evolving chemical electricity was called the *pile of Volta;* because it was constructed by Volta from a great number of round pieces of metal, like crown pieces, piled up in a column. If a round piece of zinc is taken, and a similar piece of copper, and if a moist cloth is laid between them, a voltaic circle will be formed when an outside conductor is carried from one plate to the other. All the four elements of the circle will be present—the zinc; a corrosive liquor in contact with it, and extending to the copper; the copper; and the outside conductor from the copper to the zinc. The cloth merely serves the purpose of containing the liquid. Thus, let an upright stand be formed, with glass or wooden rods fixed into a piece of wood for a bottom. Place on the bottom a disk of zinc, Z; above that a piece of woollen rag, soaked with corrosive liquor, of the same size as the zinc, and upon the cloth a disk of copper. On the copper lay another piece of zinc, a wet cloth, and another piece of copper; and repeat the same process until the pile is built up to a sufficient height, being careful to observe the same order throughout. The pile will terminate in a disk of copper above, and in a disk of zinc below; and when a conducting communication, such as a piece of wire, is carried from one end to the other, a circle will be formed, and a pair of currents will be carried round and round in opposite courses, exactly as in a single circle. Commencing at the lowest zinc plate, there will be a chemical action between its surface and the liquor touching it; electricity will be developed, the negative charge will pass upon the zinc plate, and the positive will be conducted through the liquid to the first copper disk, and from it to the zinc lying upon it, and thence to the place of action between the second zinc and the second cloth, where it will be reinforced by the excitement produced at this contact, and a double charge will pass through the second cloth to the second copper, and thence to the third zinc, to be reinforced again, and pass on as before. In this way all the actions of the pieces of zinc upon their adjoining liquid will conspire into one great positive current, passing from the bottom upwards; and at the same time the negative charges arising on the zinc plates will join together in one great negative current passing downwards, and going off at the lowest plate by the outside conductor, and proceeding by it to the top, to move downwards again. The general course of the process will be the very same as in a single circle: the zinc end will be the positive, and the copper end the negative pole of the pile. The intensity of the pile increases with the number of plates. If these are few, but large, the intensity is not great, but the quantity is considerable. That is to say, such a pile would not give severe shocks, but it would have powerful magnetic and chemical effects, which, as stated, depend upon quantity, without regard to intensity.

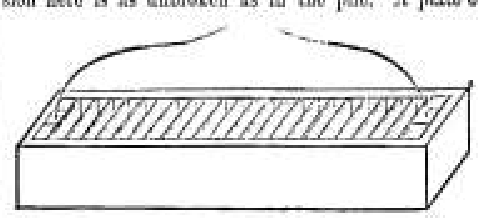


The pieces of cloth employed in the pile being of no use but to contain the liquid, they may be dispensed with, and instead of them, vessels may be used to contain both the liquid and the plates. Volta himself made an arrangement of this sort; and all the usual forms of the voltaic battery are constructed on the principle of immersing the plates in the corroding liquor. The *trough battery* is a porcelain trough (TT), divided by partitions into separate compartments or cells, each compartment being intended to receive a pair of plates



and contain the acting liquor. The plates are suspended from a piece of wood (AB), at the proper distances for being immersed in the separate cells, and they are connected with one another by metallic slips; it being necessary that each plate of copper should have a conducting connection with the next plate of zinc, in order to complete the circle. No communication of any kind is allowed to take place between one cell and another; with this view the partitions are made not only water-tight, but of an insulating material, like porcelain. The battery of the Royal Institution, by which Sir Humphry Davy effected the decomposition of the alkalies and earths, was of this construction, and consisted of 2000 pairs of plates, with an acting surface amounting to 128,000 sq. inches.

Another kind of trough battery is represented below, where the partitions themselves are the acting plates; each partition being made up of a plate of zinc and a plate of copper soldered together. The succession here is as unbroken as in the pile. A plate of

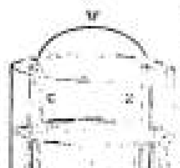


zinc, a portion of liquor, and a plate of copper, follow each other, and are repeated from one end to the other. The liquid is of course poured into the cells. A wire is soldered to the last zinc plate at one end, and another wire to the last copper plate at the other end; and when these wires are brought together, or connected by any conductor, the circle is completed, and the currents pass into active circulation.

THEORY OF THE VOLTAIC CIRCUIT.

Various imperfections of a practical kind occur in the working of the piles and batteries above described, the most serious of which is, that the action, although ever so strong at first, becomes rapidly weaker and weaker, and in no very long time entirely ceases. The materials formed by the chemical action of the liquid and the zinc gradually accumulate, and stand between the fresh zinc and fresh liquor, and thus prevent the process from going on. But to remedy this and the other imperfections of the battery, it is necessary to understand clearly what the circumstances are that add to its strength, and what causes contribute to weaken and obstruct it.

Let us consider again a single pair of copper and zinc plates, immersed in a vessel containing liquid: and in the first place, let the liquid be pure water, which, though feeble in its effects, is an exciting substance. Let Z and C be the two plates, supposed to be seen edgeways, and to face one another, and connected outside by the wire W. It has been known for the last seventy years that water is not a simple, but a compound body, formed by the chemical union of other two elements—oxygen and hydrogen. Each ultimate particle of water must therefore be supposed to be a compound particle, or an atom of oxygen adhering firmly to an atom of hydrogen. It is as a compound body that water acts in the voltaic circle, and as such we have to look upon it.



Let the double circles 1, 2, 3, 4, stand for atoms of water, or compounds of oxygen and hydrogen; the oxygen atom being marked *o*, and the hydrogen atom *h*. An oxygen atom is supposed to be in contact with the zinc plate; and the process pursued is the following. The zinc has, from its nature, a strong affinity for oxygen; this affinity is more powerful than the affinity of hydrogen for oxygen; and in such an arrangement as the present, the superior affinity of the zinc draws the oxygen atom to itself, dissolves the attraction between it and its hydrogen atom, sets the hydrogen free, and makes a new compound atom called oxide of zinc. Along with this transference of the oxygen particle, there is a quantity of free electricity evolved: the oxide of zinc has a negative charge, and the disengaged hydrogen atom a positive charge. But this charge possessed by the hydrogen increases its affinity for oxygen, or makes it more powerful than a particle that has no such extra excitement. Accordingly, it approaches the oxygen end of the second particle of water, overpowers the affinity of the two atoms, combines with the oxygen, and sets the hydrogen free, charged in like manner with positive electricity. This free and charged hydrogen comes up to the third atom of water, and decomposes it in the same way; and a series of decompositions goes on till the copper plate is reached, and the action interrupted. Thus the free hydrogen appears at the copper plate, and communicates to it by contact its positive charge, rendering the copper positive, and enabling it to transmit positive electricity round the outside wire towards the zinc. The particles of free hydrogen rise up to the surface from the copper plate. The reason why the copper is not acted on in the closed circuit is, that the currents derived from the zinc overpower its own attraction for the oxygen of the water. The copper would of itself attract water particles by their oxygen end, and decompose them; but the zinc being much more powerful in its attraction, it begins a series of decompositions that end in presenting hydrogen instead of oxygen to the copper, and in suspending its power to decompose the water. The transmission of electricity is thus effected by loosening the bonds of every compound atom that stands in its way, and by making up new combinations, where different atoms are brought together. The carrying round of the currents to the place of action, quickens the energy of the combination at the surface of the zinc.

Such a circle formed out of zinc, copper, and pure water, would in a short time entirely cease, owing to the zinc becoming coated with oxide, which stands between the water and the particles of metallic zinc. But if a small portion of oil of vitriol, called also sulphuric acid, is poured into the water, it combines with and carries off the coating of oxide from the zinc plate, and leaves a clean surface; the action then goes on again with renewed energy. The acid continues to take up the oxide as fast as it is formed, and the circle is thereby rendered much more active.

When sulphuric acid combines with oxide of zinc, it forms a new substance, called sulphate of zinc, which remains dissolved through the liquid. But this new substance acquires, like the hydrogen, a positive excitement, and goes in consequence towards the copper, and is apt to form a deposit that mars the conducting power of the plate. Moreover, the hydrogen itself, by its attraction for the copper, is apt to remain stagnant in the surface, and prevent the evolution of new particles, in which the continuance of the action depends. This is remedied by pouring nitric acid into the cells, which has the power of absorbing the hydrogen as fast as it is formed at the copper; and to prevent the sulphate of zinc from going on to the copper conductor, a porous or permeable partition is interposed between the plates. This partition is called the *diaphragm*.

The power of a battery is increased by substituting for the copper a metal still less corrosive, such as silver, gold, or platinum. Platinum is, of all metals, the least acted on by acids; hence it is well adapted for the positive plate of the battery. A further improvement is made by amalgamating the zinc plates, that is, coating them with mercury, which, from a cause not well understood, serves to diminish their waste.

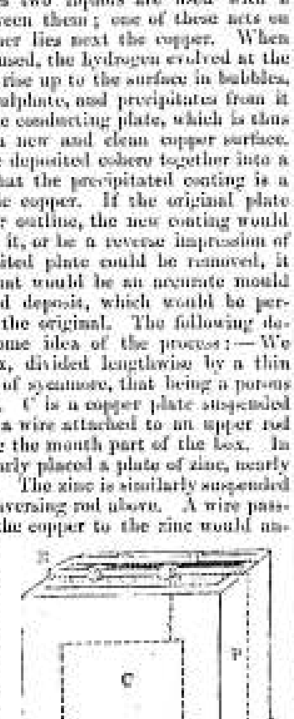
The voltaic battery produces effects similar to those of common electricity. It has the power of decomposing chemical compounds; it evolves heat sufficient to burn combustibles and heat metallic wires to redness. Its magnetical effects will be described afterwards. With respect to its physiological effects, it may be observed that the shock received by the human body from the voltaic pile is similar to that resulting from a large electrical battery very weakly charged. Twenty pair of plates are generally sufficient to give a shock which is felt in the arms. With a hundred pair, it extends to the shoulders. A continued flow of the current through the body is accompanied by a continued aching pain. The impression made upon some of the nerves of the face when they form part of the circuit, is accompanied by the sensation of a vivid flash of light. When the current is made to pass along a nerve distributed to any of the muscles of voluntary motion, they are thrown into violent convulsive contractions. The susceptibility of some animals is very great; and if the battery be powerful, small ones (birds, mice, &c.) may be easily killed by the shock. Striking effects are produced by galvanism in the muscles of an animal after death, as long as they retain their contractility.

APPLICATIONS OF VOLTAIC ELECTRICITY.

The first practical application of voltaic electricity to the arts, was the protection of the copper bottoms of ships from the destructive action of sea-water. Sir Humphry Davy suggested that nails or wires of zinc should be fastened, at intervals, on the copper plates, which would cause a circuit to be formed of copper, zinc, and salt water. In this case the copper would cease to be acted on by the water, and would serve as a conducting plate to the zinc, which would be the substance wasted. Thus a small expenditure of zinc would come in place of a great expenditure of copper. A piece of zinc equal to the head of a small nail was found sufficient to protect between forty and fifty square inches of the ship's bottom.

The value of the device was, however, neutralised by a consequence that had not been foreseen: the protected copper bottom rapidly acquired a coating of sea-weeds and shell-fish, whose friction on the water became a serious resistance to the motion of the ship; and it was discovered that the bitter poisonous taste of the copper surface, when corroded, acted in preventing the adhesion of living objects. The principle, however, has been applied with success to protect the iron pans used in evaporating sea-water.

The greatest application of the voltaic circuit is the *electrotype*, or the process of multiplying impressions of medals, coins, engraved plates, busts, &c. which was invented about the same time by M. Jacobi of Petersburg and Mr Spencer of Liverpool. It is founded on the action of the circuit upon sulphate of copper, commonly called blue vitriol, when this is dissolved in the liquor adjoining the copper plate. We have seen that in improved batteries two liquors are used with a porous partition between them; one of these acts on the zinc, and the other lies next the copper. When sulphate of copper is used, the hydrogen evolved at the copper plate does not rise up to the surface in bubbles, but decomposes the sulphate, and precipitates from it metallic copper on the conducting plate, which is thus constantly receiving a new and clean copper surface. The particles that are deposited cohere together into a firm solid mass, so that the precipitated coating is a plate of good metallic copper. If the original plate had a certain shape or outline, the new coating would exactly correspond to it, or be a reverse impression of it; and if the deposited plate could be removed, it would have a face that would be an accurate mould for receiving a second deposit, which would be perfectly identical with the original. The following description will give some idea of the process:—We take a trough or box, divided lengthwise by a thin partition P, composed of sycamore, that being a porous and durable material. C is a copper plate suspended in one of the cells by a wire attached to an upper rod of metal R, traversing the mouth part of the box. In the other cell is similarly placed a plate of zinc, nearly the size of the copper. The zinc is similarly suspended by a wire from the traversing rod above. A wire passing over direct from the copper to the zinc would answer the same purpose of communication; but the plan of an intervening rod with attaching screws is found to be more convenient. Into the cell containing the copper we put as much water as will about four-fifths fill it; then into this we place crystals of sul-



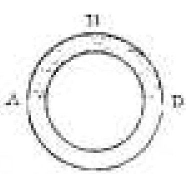
phate of copper, which soon dissolve and form a solution. Into the other cell, containing the piece of zinc, we place a similar quantity of water, into which pulverised sal ammoniac is put, so as to form a solution likewise. The preparatory process may now be said to be complete; but unless the copper has been previously prepared to receive the deposition on one part only, the deposition would take place all over it. To guard against this, the copper, before being placed in the trough, must have been coated on the back and edges with a moderately thick varnish of sealing-wax dissolved in spirits of wine, and which must be allowed to harden before it is put into the trough. The wire of the copper must likewise be varnished; but no varnishing is necessary on the zinc.

We have now described all that requires to be done in the first instance; and the trough may be put aside to allow the process time to operate. This operation will consist of voltaic currents, commencing with the action of the sal ammoniac upon the zinc, and going round the circuit. As the action proceeds, it will be observed that an effervescence is going on in the zinc cell; and this indicates that the deposition of metal from the sulphate of copper is taking effect on the plate. The length of time occupied in perfecting the process will vary from four to six days; but during this interval it will be necessary to add fresh material, both sulphate of copper and sal ammoniac. In some boxes a small shelf is put, to contain the sulphate of copper during its dissolution. The copper plate may be occasionally examined, to ascertain the extent of the deposition; and when this deposition is as thick as a shilling, it may be separated from the plate. We have now procured a fac simile of the engraved copper plate *in relief*—in point of fact, a substantial piece of copper formed from a solution. The copy in relief is of no value in the arts; and to be of use, it must be subjected to a fresh process, in which *it* receives the deposition. This second deposited cake of metal is a *fac simile* or duplicate of the original plate; and by thus using the relief plate again and again, we may obtain any number of engraved copper plates of the same subject that we may think proper.

In this way a deposition may be made on any metallic surface whatsoever, and an exact copy in reverse of that surface taken. But the process is not confined to metallic surfaces. A coating can be precipitated on wood, sealing-wax, plaster of Paris, or any other plastic material, by first covering it over with a film of black lead. The black lead renders the surface a conductor of electricity, and, as such, it may form part of the voltaic circle, and cause a metallic deposit to take place. Copies may be taken in silver, gold, and platinum, as well as in copper, by using solutions of the salts of these metals. So the processes of plating, gilding, and platinising can be performed by electrical deposition—that is, an article made of iron, copper, or any cheap metal, can receive a coating of silver, gold, or platinum, to whatever thickness may be desired. Even baskets and wickerwork may be enveloped in a metallic surface.

THERMO-ELECTRICITY.

In the voltaic circuit, chemical combination is the source of the electricity, and this electricity produces a great many different effects, the most prominent being—chemical decomposition, *heat*, and magnetism. Now, as electricity can produce heat, so, on the other hand, heat can produce electricity, as we formerly had occasion to mention. But it was only in 1822 that the method was devised of procuring a permanent current by the application of heat, in the same way as a current is maintained by chemical combination in the voltaic circle. The discovery was made by Professor Seebeck of Berlin. Hence arose a new branch of the subject, termed *thermo-electricity*, or *heat-derived* electricity. A thermo-electric circle is formed by choosing two metals, whose power of radiating heat is unequal, and soldering them together; then if the joining is heated by a lamp, currents of electricity are evolved, which will pass round and round when a metallic circle is completed. Thus in the figure; if ABCD be a metallic circle, the one-half ABD being bismuth, and the other half copper; and if a lamp is applied at A, one of the joinings, it will heat both metals, and cause electric currents to flow round the circle. A positive current will pass from the bismuth to the copper, or round in the direction ACDB, the negative taking the opposite direction; so that when two metals differently disposed in regard to the reception of heat are heated together, the discrepancy shows itself in rendering the metals electric.



If, instead of bismuth and copper, bismuth and antimony are soldered together, the effect will be greater, the disparity of the metals being greater. The following table exhibits the order of the principal metals in regard to thermo-electric combinations:—

Bismuth	Lead	Gold
Mercury	Tin	Zinc
Nickel	Copper	Iron
Platinum	Silver	Antimony.

The metals at the top of the table—bismuth, mercury, &c.—are the worst radiators of heat; that is, if they are raised to a high temperature, they give off their heat slowly; and on the other hand, they take in radiant heat slowly. If exposed to a fire at the same distance as metals at the lower end of the table—such as iron and antimony—they would be much longer in being heated to a given pitch than these would be. Accordingly, antimony, iron, and zinc, are good radiators of heat, and good at taking in radiant heat. The farther asunder two metals are in the list, the greater the difference of their radiating power, and the better they answer as a thermo-electric couple. Hence bismuth and antimony surpass all others; next to these would be bismuth and iron. Each metal causes a positive current to pass upon any metal beneath it, and a negative upon any metal above it; that is, the bad radiating and receiving metal is rendered negative, and the good radiator positive, by the application of heat to their junctions.

Compound thermo-electric circles, or batteries, are formed by soldering any number of rods, end to end, in a line; in this case the heat will have to be applied to every second joining. Thus we must take first a bar of bismuth, and solder it to a bar of antimony; then to the free end of the antimony we solder a second bar of bismuth; and so on as long as we please. Then if the first, third, fifth, &c. joinings are heated, currents will be produced all in the same direction, and augmenting each other. If, while these joinings are heated, the other joinings—that is, the second, fourth, sixth, &c.—are cooled, by being laid in ice, the effect will be increased. Cooling has the same action as heating; but the currents arising from it are in opposite directions. Such a line of bars as we have described may be so doubled up into a bundle, as that the odd joinings shall be at one end (the first, third, fifth, &c.), and the even joinings (the second, fourth, sixth, &c.) at the other end. Such is the usual form of the thermo-electric battery. A wire connected with the last rod of bismuth makes the negative pole; a wire attached to the last rod of antimony is the positive pole. If either end of the bundle is heated, currents will be produced; if both are equally heated at the same time, there would be no excitement; if one were heated, and the other cooled, the excitement would be doubled. The thermo-electric battery is found to be a very delicate measure of radiant heat; and it is therefore adopted as a new kind of thermometer.

MAGNETISM.

Anciently, there was found in Magnesia, in Asia, a certain kind of iron ore, in which the remarkable property was discovered of attracting other kinds of iron or steel; this ore afterwards received the name of *loadstone;* but from Magnesia, the place in which it was originally found, we derive the terms *magnet* and *magnetism.* Latterly, loadstone ore has been discovered in Siberia, Sweden, Piedmont, the kingdom of Naples, and various places in North America. This magnetic iron ore, which is of an excellent quality for making steel, is of a dark colour, and generally occurs crystallised in the form of regular octahedrons; its attractive quality is strengthened by exposure to the air. It has likewise been found that meteoric stones, which are composed of iron and nickel, possess a strong magnetic virtue resembling the loadstone of the earth.

Besides attracting iron, the loadstone is found to have the remarkable property named *polarity;* that is to say, if a loadstone is freely suspended by a string, or lies on a pivot, it will not rest till it has settled in one position, which is a nearly north and south direction; or one end points to the north, the other to the south. If it is moved out of this position, it returns to it again. The term *polarity,* which has now such a wide usage in the sciences, originated in this fact. The end of the loadstone that pointed to the north pole of the earth was called its north pole, and the other end its south pole; and the loadstone was thus said to be *polar* in a new sense; for the old meaning of poles, as when we speak of the earth's poles, was the ends of the axis of revolution.

But the loadstone, besides attracting iron, and pointing to the north and south poles of the earth, has the power of communicating its virtue to steel. If a bar of steel is repeatedly rubbed from end to end by a loadstone, the steel is permanently endowed with all the magnetic properties; that is, it is able to attract iron, and it arranges itself in the north and south direction. A piece of steel thus acted on is called an *artificial magnet,* the loadstone being designated the *natural magnet.* A magnet will attract iron in all its forms; but it is only iron made into steel that can take on the power of magnetising upon itself.

If we suspend a magnet till it come to rest in its north and south position, the north end is always reckoned its north pole; and this is a test for discriminating the poles. If, now, we take two magnets whose poles are known in this way, and if we present the north pole of the one to the north pole of the other, we will find that they repel one another; if the first magnet is held in the hand, and the second suspended on a string, the north end of the second will fly away the moment the north end of the first comes near it. And if we present south pole to south pole, the very same repulsion will take place. But if we bring the *north* pole of the first near the *south* pole of the second, they attract each other, and clink together, end to end, and the one will draw the other after it. So if the south pole of the first is placed near the north pole of the second, a like attraction ensues. Hence are deduced the two general facts, or general laws of magnetic polarity—namely, *like poles repel each other; unlike poles attract each other.* We have seen that electrical attractions follow the same laws. Had we been able to go into the detail of chemical decomposition by the voltaic battery, we should have found it also to be governed by these laws. The negative atom of a chemical compound goes to the positive pole of the circuit, or to the wire issuing from the copper; while the positive atoms gather around the negative wire, which proceeds from the zinc. Wherever polarity occurs—that is, whenever bodies have opposite forces residing in their opposite sides—it is on these principles that the attractions and repulsions take place. All electric and magnetic forces have this character; chemical affinities are of the same nature; and cohesion, when it causes the particles of bodies to assume the forms of crystals, is a polar cohesion.

Another property of the loadstone, and of the magnets formed from it, is that termed *magnetic induction;* which means that magnets have the power of communicating a temporary polarity to soft iron. When a magnet attracts a piece of iron wire, it renders the wire a magnet for the time, or so long as the two touch each other. This is proved by the fact, that the bit of wire, while it hangs by the magnet, is able to attract another piece of iron to itself; but the moment that the connection with the magnet is broken, the second attraction ceases. Such a power is called *induction.* The magnet is said to *induce* polarity upon the iron that it attracts. This induction, however, is ruled by the law of opposites; that is, the north pole of the magnet renders the end of the iron, touching it a south pole, while the other, or free end of the iron, is a north pole. So the south end of the magnet attracting the end of an iron rod makes it north, and the far-off end south.

South joins north, and north south, in all cases of attraction. In fact the reason why a magnet attracts soft iron at all is, that it has the power of making it for the time a magnet, and of attracting it as it would another magnet. It is a general rule that a polar body can act only upon a polar body; and if a body destitute of polarity is acted on, it is in consequence of its first receiving a temporary polarity by induction.

If one piece of iron in contact with a magnet attract a second piece, it will render this also magnetic, and enable it to attract a third, and the third a fourth, and so on till the strength of the magnet can bear no more. Each new piece has its two invariable poles, and each of these poles always joins the opposite pole of the next piece. On this principle a magnet can sustain a long string of iron filings, each particle being attached to another by its temporary magnetic power. This action is exactly analogous in its nature to what takes place in common electricity; so that the principle of induction also pervades more or less all polar phenomena.

A straight bar of steel, magnetised by rubbing, is called a bar magnet. But it is more convenient to twist magnets into the form of a horse-shoe, as in the annexed figure. M is the magnet, R the ring for suspending it, and K a piece of soft iron lying across the two poles, and called the *keeper*, and sometimes the *armature*, or arming of the magnet. It is also called the *lifter*, because when the magnet is made to show its attractive power by supporting weights, they are suspended from it. In the horse-shoe, the two poles of the magnet are brought so near, that they can be joined in this manner by a single piece of iron; and they attract it by their combined force. The keeper is itself made a magnet by induction, with its opposite poles lying to the opposite poles of the horse-shoe. The closing of the magnet by the keeper preserves its strength; and if a scale is suspended by it, and weights added by little and little, the power may be very much increased.

The earth itself is found to be a huge magnet, having its two opposite poles, which, however, are not situated in its proper poles, or the ends of its axis of rotation, but at a considerable distance from these. Still the magnetic poles are in the neighbourhood of the poles of revolution; and the one is called the north, and the other the south, *magnetic pole*. This is the reason why magnets and magnetised needles point in a north and south direction. These magnetic poles are gradually shifting; and seem to be describing a circle, which it takes hundreds of years to accomplish.

The *mariner's compass*, which shows the direction that a ship is sailing at sea, when all other landmarks are wanting, is a small magnetic bar resting on a pivot in the centre of a card, and acted on by the earth's magnetism, so as always to point to the north and south magnetic poles. Allowance is made for the deviation of these poles from the true north and south points, and thus the mariner can always tell in what direction he should steer.

In order to observe the state of the earth's magnetism for scientific purposes, as, for instance, to determine the precise shifting of the poles, other instruments are used. The *dipping needle* is a magnet that shows the direction of the pole downwards in the depths of the earth. The *intensity needle* is an apparatus to show if the earth's polarity has always the same strength. Observation has shown that there are daily and yearly variations in the state of terrestrial magnetism; besides sudden changes, called *magnetic storms*. These storms always appear along with earthquakes; they also accompany the *aurora borealis*, rendering it likely that the northern lights have a magnetic origin.

ELECTRO-MAGNETISM.

This branch of electricity was created in 1820, when Professor Oersted of Copenhagen discovered that a voltaic current has the power of magnetising an iron bar, so as to give to it all the properties of the loadstone. This discovery, taken along with thermo-electricity, completes the proof of the identity of the various natural agencies known by the names of chemical affinity, heat, electricity, and magnetism. All these influences are nothing more than modifications of one grand power pervading material bodies, and most probably derived from the sun. It is not necessary that they should be supplied separately to the earth; for out of any one of them all the others can be produced. Supposing that the sun's ray contained nothing but heat alone (in addition to light), electricity, magnetism, and chemical force could all be obtained from it by making the proper arrangements. The sun's heat causes electric currents to circulate round the earth, and these electric currents are sufficient to make it a magnet exactly as we find it to be. But it is to be carefully observed, that although chemical power, electricity, magnetism, and mechanical force (as derived from heat), are all so far identical with one another, and with the sun's heat, that out of any one all the rest can be formed, yet from all that appears, the other portion of the solar ray—namely, *light*—is perfectly distinct from these, although often appearing in their company, and dependent upon them for its manifestation. It is something more refined and subtile than the other ethereal powers, being, as it were, an agency superadded to these, with laws and functions of its own. When heat is converted into electricity, it disappears as heat: a certain measure of the one is consumed in producing a certain measure of the other. But when heat makes a body luminous, it loses nothing of its heating power; there is no expenditure of substance in yielding the light. So, on the other hand, if pure light were taken in ever so great quantity, it could not yield the smallest portion of heat. Light and heat, therefore, are not *convertible*. Hence they can never be considered to stand in the same relation to each other as the five agencies of chemistry, electricity, magnetism, heat, and mechanical force.

It had been long observed that electricity was capable of producing magnetical effects. The needles of ships' compasses, when struck with lightning, always underwent a change in their magnetic character: on some occasions their poles have been reversed—what was the north before becoming the south. Disturbances of needles have also been caused by shocks from Leyden batteries. But the exact way that the electricity acted in such cases was difficult to discover, and very singular when actually discovered.

If we take the conducting wire of an active voltaic battery—that is, when the electric currents are moving along it—and bring a magnetised needle, or small bar, near the wire, the needle will be affected in such a way, that it will tend to lay itself right across the wire. In other words, the electric wire has an attraction for a magnet; but this attraction is not in the direction of its length, but in the direction of its breadth, or at right angles to the line of the currents. The conductor is electric along its length, and magnetic across. If the needle is held in all positions, close by the wire, we shall find that the magnetic tendency circulates round and round, there being two magnetic currents moving in opposite circles, corresponding to the two electric currents passing along the conductor. If a needle is pointed to the side of the wire, the end will either dip or rise, according to the pole presented; supposing it to dip, the opposite end, when pointed in the same way, would rise. So that while the electricity passes from particle to particle of the copper wire, each particle is made a magnet, with its poles lying across the electric poles, having electricity at its two ends, and magnetic currents moving round its middle, or round what would be called its *equator*.

The conducting wires of two active voltaic circuits, laid side by side, and free to move, attract or repel each other like two magnets. If the directions of the currents are the same in both—that is, if the positive currents both move one way—they will repel each other, by the law of like repelling like. If the currents are opposite, or if the positive of the one moves in the same course as the negative of the other, they will attract each other.

A piece of soft iron laid across the wire of a battery is made a magnet by induction, just as if suspended from the loadstone. If the wire is taken and coiled round and round the soft bar, the action will be very much increased, from the contiguity of a greater amount of electric and magnetic matter. Hence, for showing the magnetism of electricity in its highest energy, the method of coiling is always adopted. Such a coil, spiral or cork-screw, is technically called a *helix*. Sometimes it is formed of thick wire, with few turns, in the exact resemblance of the cork-screw; in other arrangements small wire is used, covered with silk thread, and coiled as close as it can lie, and in a great number of layers, one above the other. The silk covering is necessary to insulate the wires, or prevent the electricity from passing from one to another by the contact of their sides, which would confuse and destroy the whole action. If a bar of soft iron is inserted into one of these coils, connected with a voltaic battery in full operation, it is made for the time a magnet, and receives the name of the *electro-magnet*. When it is taken out, its magnetism disappears. And when the connection of the wire with the battery is cut off, or when the circle is broken, the magnetic action ceases. Such a bar lying in a coil, where electricity is circulating, can be made to show all the effects of the loadstone magnet. By employing a powerful voltaic battery, or a series of circles producing the currents in *large quantity*, very powerful attractions are developed. The *quantity battery*, as distinguished from an intensity battery, is formed of a few very large single circles; that is, of pairs of large plates, or large cylinders, according to the shape employed. Electro-magnets can easily be made to support a hundredweight; and with a compound battery of six or eight large cylinders, the keeper could not be dragged off by the whole strength of a draught horse. The electro-magnet, like the common magnet, is often made in the horse-shoe form, and the wire coiled all along both legs.

The *voltaic electrometer*, or the instrument for showing the existence of a voltaic current, and measuring its quantity, is an electro-magnetic coil or helix, with a magnetised needle attached to it, which moves across the direction of the wires when a current is passed along their length. A wire from each end of the coil is made to connect with the apparatus that is producing the electricity to be tested, and thus a circle is completed; and if any excitement is present, it will pass in a double current through the whole length of the coiled wire, and render it magnetic in its cross direction, and thereby act on the needle, and thus make evident to the eye the presence of what excitement (however feeble) there happens to be.

MAGNETO-ELECTRICITY.

The relation of magnetism to electricity was finally established in the most triumphant manner when Faraday succeeded in causing the loadstone, or common magnet, to produce a current of electricity of exactly the same kind as that produced by the chemical actions of the voltaic circle; so that a magnet could, as it were, take the place of the apparatus of zinc, copper, and corrosive liquid. This discovery is analogous to the thermo-electric pile, in so far as it shows that what formerly appeared as an effect of electricity, is also a cause of it. The current had always been known to have a heating power; but it was not till 1822 that heat could be made to produce an electric current; so whereas Oersted showed that electricity could yield magnetism, Faraday pointed out the means of making magnetism yield electricity. This, with some other researches of Faraday, completed the proof of the convertibility of any one kind of the polar agencies here treated of into any other kind.

It was from believing in the likelihood of deriving electricity from a magnet, after a magnet had been formed by electricity, that Faraday made the attempt, by placing a powerful permanent magnet, in all conceivable ways, in contact with a circle of wire connected with the electro-magnetic electrometer. For a long time, however, no effect could be traced. But at last the circumstance was discovered that was essential to the transference sought for—*the magnet must be in motion* across the wire, or, what is the same thing, the conductor must be in motion across the magnet. This condition being complied with, the electric currents are actually manifested, or a circle of wire can be made alive with electricity the same as if an active pile of volta were in its course: so that the magnet does really contain within itself both the magnetic and the electric virtues; or it possesses a power that can show itself either as a magnet, or as an electric current, according to the circumstances it is placed in. If iron is in the neighbourhood, it appears as a magnet, and draws the iron to itself: if a wire formed into a complete circle is in the neighbourhood, and is moved in the direction of its length across the bar, the magnet puts forth the very same energy as a voltaic circle. The magnet at rest lying by the wire at rest has no influence; but any movement of the transverse kind, corresponding to the difference of direction previously discovered to belong to the two powers, makes the wire an active circle. On this principle machines have been constructed for showing electrical effects, called

ELECTRO-MAGNETIC MACHINES.

The discovery of electro-magnetism showed how electricity might be employed as a mechanical agency, or a prime mover of machinery. When powerful currents circulate around the wire enveloping the body of an electro-magnet, it can draw any piece of iron to itself with very great force. This attractive energy may be turned to account in machinery as well as the expansive force of steam. Hence many persons have occupied themselves in devising electro-magnets with the view of maintaining by their means a constant motion. It is essential that every motive power should be able to turn a wheel, in order that it may be serviceable in the mechanical arts: and if once a wheel motion is produced, every other kind of motion can be derived from it. Electro-magnetic attraction acts in a straight line, and for a short way; and its strength increases as the keeper approaches the end of the magnet, where the motion ceases. The character of the action, therefore, is a straight movement of limited range and increasing power. The attempts which have been made to produce a wheel motion out of such a power have been in part successful. Mr Davidson of Aberdeen has succeeded in moving a turning-lathe, and in propelling a wheel carriage, which was carried forward like a locomotive; and of course any other whirling machinery could be moved by the same means. The principle of his apparatus was to have four magnets arranged so as to act upon the four iron spokes of a wheel, and to have only two acting at a time. When two spokes came up opposite the ends of two of the bars, their magnetism was suspended, and the other two rendered magnetic. These carried forward the wheel another stage, and were then suspended, and the others again brought into action. The defect of the machine was, that the whole power of the magnets was not brought into play. Until the machinery employed be such as to give effect to the total energy of the attraction, we cannot expect that an electro-magnet will be made an economical prime mover.

The electric telegraph is the most successful application of electro-magnetism that has yet been made. Proceeding upon the principle that an electric current can pass along a conducting wire to a great distance, and can move a magnetic needle at any point of its course, the contrivers of this astonishing machine have been able to convey signals from one end of the country to the other with the speed of lightning; and these signals being sufficiently varied in their appearance to stand for all the letters of the alphabet and the ten figures, verbal communications can be made from one place to another hundreds of miles distant.

The machinery of the telegraph consists, in the first place, of a *line of conducting wire*, suspended on poles, and reaching from station to station. A single wire serves for one circle of electric currents, it being found that the earth is a conductor of electricity; and if a current pass along a wire above ground, it will return again under ground, provided the wire at each end is carried to the earth and attached to a mass of metal buried there; so that every wire will make a separate circle, and carry a distinct set of signals. The wire is formed of iron coated with zinc, called galvanised iron wire. It rests on the poles in earthenware tubes, which serve to insulate the passing electricity.

The second part of the telegraph is the *battery*, which maintains the electric current that moves along the wire and returns by the earth. The form of battery that answers best is the partitioned trough battery, with a pair of copper and zinc plates in each cell. The cells are filled first with dry sand, and into this is dropped dilute sulphuric acid, in sufficient quantity to moisten the sand all through, and form both a corrosive agent and a liquid conductor of the electricity from the zinc to the copper. The bottom of the battery is porous, and the liquor gradually oozes through, and carries away with it the sulphate of zinc formed by the action, and new liquor is constantly dropped in above. The battery is thus constant. It requires to be large or small in proportion to the distance between the extreme stations. A line of a hundred miles must have a much stronger current than a line of twenty.

The third portion of the telegraph machinery is the *needles*. These are what the signals are made by. If a magnetised needle lie side by side with a portion of conducting wire, when the circle is closed, and the currents set on, the needle is deflected, or lies across the wire, so that the circle cannot be completed without the fact being known along the line, wherever we attach properly a needle to the conductor. In the same way, when the circuit is broken, the return of the needle will indicate the change. Or if there be such an arrangement as to reverse the current, or connect with the copper pole the end of the wire that formerly joined the zinc pole, a deviation of the needles will again take place, but in an opposite direction. This reversing of the current is easily produced by a piece of simple machinery. Thus, then, each wire can make two distinct signals; and by using several wires at the same time, a great variety of signals can be given. Thus, for example, if there were two wires, four signals could be made by using one needle at a time. Then by using both in all possible combinations, other twelve signals would be produced. By repeating the deviations of the needles two or three times, the variety can be still further extended. Thus one letter may be signalled by moving both needles once to the right; another by moving one to the right and the other to the left; another by moving one twice to the right; and so on. The needles stand over a coil, in order to receive the strength of a concentrated or multiplied current. But the needle system is not the only signalling apparatus that has been contrived, although it is the most extensively used at present. Its defect is the slowness of the working. The most expert operator can signal only fifty or sixty letters in a minute, which is very much slower than ordinary speaking. It being desirable to communicate intelligence with as little loss of time as possible, other schemes have been proposed of quicker operation than the needles.

The fourth part of the machinery is the apparatus for making and breaking the metallic contact that completes the circle, and for passing the currents either way. The external instrument for this purpose is a handle that may be moved to one side or the other, and in so doing closes the circuit. When it stands in an up and down direction, the circuit is broken, and no action is manifested; the needle corresponding is then seen to hang likewise in a perpendicular direction. When the handle is moved to one side, the circuit is closed, and one end of the needle deviates to the same side. When the handle is moved to the other side, the current is arrested, and put on in the reverse direction, and the needle moves to the other side. See No. 26.

The galvanic principle has also been applied to the movement and regulation of clocks, as will be explained under TIME AND TIME MEASURERS.

ANIMAL ELECTRICITY.

This branch of the subject refers to the production of electricity by living bodies. It includes also what is known of the effects of electricity on the animal system.

We have already adverted to the production of electricity by the torpedo and gymnotus. In these animals the electrical organ is something superadded to the ordinary structure of fishes, and is quite independent of the other vital organs, except in so far that it requires to be supplied with nerves and blood-vessels. But apart from the possession of special apparatus, the operations of the animal body are such as to evolve electricity in many ways. The chemical processes of digestion and respiration, the constant passage of heat to and fro, the mechanical movements, may all generate electricity. It is probable, however, that a large portion of what is thus produced is expended or consumed in other operations. Observation seems to show that in the whole the state of the body, when healthy and vigorous, is *positive*, or that a surplus of positive electricity tends always to appear on the surface, from the actions of the vital organs. But after severe labour, hard exercise, and exhaustion, the state of the free electricity generally changes to *negative*.

This observation, when connected with the electrical states of the atmosphere, has an important bearing upon human health and vigour. If the positive state of the body is its natural state when sound and strong, a positive atmosphere, and the contact with positive surfaces, will be favourable, and a negative atmosphere unfavourable, to its wellbeing. Now it is found that the regular and ordinary state of the atmosphere is positive, and the state of the earth negative. In clear, dry, steady weather, this is the uniform character of the atmospheric and terrestrial charges. The contact of the air will therefore be healthy, and the contact with the earth, by a good conducting substance, unhealthy—that is, to stand upon an iron floor, or in water, with the naked feet, even in a fine day, must tend to carry off the body's positive electricity, and communicate to it the charge, associated with weariness and exhaustion. In foggy weather, the air is generally negative, and envelopes the body with a charge hostile to its own; it is therefore inevitable that such weather should have a depressing effect on the system. Even within doors, where the air is rendered dry and warm by fires, the absence of the congenial electricity must be felt. During rain and storms, the state of the atmosphere often fluctuates, and passes in a few minutes from positive to negative, and from negative to positive. Such changes are very distressing to many people. The sensibility to alternations of the electrical state of the atmosphere enables us to feel the approach of storms, or changes from dry to moist weather.

When the actions of electricity on the animal system are better understood, it may be possible to use artificial methods of maintaining, under all circumstances, the charge that is identical with health and activity. We have acquired, by means of our houses, clothing, and fires, an almost perfect command of the element of heat; and it is to be hoped that we may some day attain an equal command over the element of electricity, and keep at a distance the deleterious negative charge, as effectually as we defy the winter cold.

CHRONOLOGY—HOROLOGY.

THE general relation of events and successive existences to each other we denominate *Time*—a thing of duration, involving the past, the present, and the future. It is evident that for the measurement of time we can have no standard of the same tangible nature with a pound, a yard, or a pint measure. We must have recourse to the space or duration involved in some continued or reiterated motion, as to which we have all the proof possible in the nature of the thing, that it requires the same period for its recurrence on one occasion as on every other. The motions of the heavenly bodies are of such a nature, and present the surest standard of reckoning time on a large and comprehensive scale. For periods, however, less in duration than a single day, or day and night, there are no explicit natural standards; hence the utility and necessity of mechanism of human invention, the motions of which, mathematically adjusted and numbered, shall measure and record more brief and arbitrary divisions.

In accordance, therefore, with what is the common practice of mankind in applying such a scale of time to the general routine and business of life, especially in its more civilised condition, we purpose to treat—*first*, of the measurement of time by days, months, years, and cycles, considered with special reference to their respective natural and artificial subdivisions and accumulations; and *secondly*, of those instruments and machines which have been invented for dividing the leading astronomical unit, or day, into seconds, minutes, and hours. The former of these departments may be termed *Chronology*, or the science of time in general; the latter *Horology*, or an explanation of the various contrivances which have been devised for marking and measuring its arbitrary subdivisions.

CHRONOLOGY.

Chronology—from *chronos*, time, and *logos*, discourse—is literally the doctrine of time—the science which treats of its various divisions, and of the order and succession of events. The chronologist has thus a threefold duty to perform—namely, to assign a measure to the interval which elapses between the recurrence of any natural event; to determine certain points or epochs from which to date occurrences, whether preceding or succeeding that epoch; and lastly, dating from any given epoch, to arrange in due order all facts and phenomena which may be considered of importance. Adopting this course, we shall treat in the first place of the division of time into

DAYS AND HOURS.

The day is that portion of time which elapses while the earth turns once completely round on its axis—one half of its surface being exposed, alternately, to the light of the sun on the one hand, and to the darkness of the starry heavens on the other—thus producing to those carried round with it the succession of day and night, and the apparent phenomenon of a diurnal revolution of the sun from one point in the illuminated atmosphere back again to the same point, or nearly so, as explained under ASTRONOMY.

The succession of day and night would undoubtedly constitute the first great natural period reckoned by the human race—involving, as it does, not only the most familiar and most strikingly-contrasted phenomena within the bounds of man's experience, but phenomena peculiarly adapted to the great necessities of his nature—those of vigilance and sleep. Yet the precise point at which the day should be held to begin and terminate, must have been a matter much less easily settled; and accordingly we find, that while, amongst ancient nations—the Babylonians, Persians, Syrians, Greeks, and almost all the nations of Asia—the day began at sunrise, and was held to last throughout the whole of the ensuing daylight and darkness (an arrangement better adapted to countries near the tropics than elsewhere, as the sun there rises more nearly about the same time throughout the year), the Jews, Turks, Austrians, and others, with some of the Italians and Germans, have begun their day about sunset; the Arabians theirs at noon, as do astronomers and navigators of all nations; the ancient Egyptians, and most of the modern Europeans and Americans, on the other hand, as well as the modern Chinese, beginning theirs at midnight, which is evidently the most convenient method, since it throws all the waking and active portion of the day under one date.

The subdivision of the day into morning, forenoon, mid-day, afternoon, evening, and night, is natural, though somewhat indefinite, and may be conceived to have always been more or less marked by man, even in his rudest state. At all events, the ancient Chaldeans, Syrians, Persians, Indians, Jews, and Romans, divided the day and the night into four parts; but there is nothing obvious in the natural changes or motions of the sun, moon, earth, or stars, which could point out the division of days into hours, hours into minutes, or minutes into seconds. These divisions are entirely artificial and arbitrary, unless, indeed, we conceive the second to represent that minutest portion of time which, to the human mind, constitutes its natural unit or rudiment, as particles constitute the units of a mass; but even seconds have been subdivided into thirds; and still it is evident that, after all, these are no more the minutest elements of time than are molecules the minutest elements of masses.

In the civilised part of the world, it is now customary to divide the day, and reckon the minuter portions of time, by instruments to be afterwards described, in seconds, sixty of which constitute a minute; in minutes, sixty of which constitute an hour; and in hours, twenty-four of which constitute a day. Most nations have these instruments marked for only twelve hours, the computation being twofold, like the day itself; but the Italians, Bohemians, and Poles, run them on from the first to the twenty-fourth—from one o'clock to twenty-four o'clock. The Chinese, on the other hand, divide the day into twelve hours only, each being, therefore, twice the length of ours. When the decimal system was adopted by the French, the day was necessarily divided into ten hours.

The length of time which elapses while any given point on the earth's surface passes from a similar point in the starry firmament, and returns to the same point, is called the *sidereal* day, and is found, when measured by the motions of the ordinary instruments invented for the purpose of pointing out its subdivisions—namely, time-keepers—to consist of, or be equal to, 23 hours 56 minutes 3 seconds, and (to be still more exact, as astronomers require to be) 4 thirds—a third being the sixtieth part of a second. But although the distance of any fixed star in the firmament is so immense, that the whole orbit of the earth is but, as it were, a point itself in comparison, and the motion of the earth in that orbit, therefore, cannot alter or affect the length of the sidereal day to any appreciable extent, it is otherwise with the *solar* or natural day, which is that portion of time elapsing between the arrival of the sun at the meridian, or mid-day, on two consecutive days. The mean length of this period of time is 24 hours; nearly 3 minutes 56 seconds on the average being required, in consequence of the earth's motion in its orbit, to bring the sun up to the same meridian on every successive day. The present inclination of the plane of the earth's equator to the plane of its orbit, however, which is diminishing, though with extreme slowness, and the unequal rapidity of the motion of the earth in its orbit, which is also diminishing as slowly, with the diminution of the eccentricity of the orbit, really cause the solar or natural days to be of unequal length; so that, though averaging 24 hours each, they sometimes fall short, and sometimes exceed that average.* It is the former of these causes, too, which gives rise to the difference in the relative length of night and day, according to the seasons of the year. This average of twenty-four hours is what we denominate a *civil* or mean solar day, and is the time employed by the earth in revolving on its axis, as compared with the sun, supposed to move at a mean rate in its orbit, and to make 365.2425 revolutions in a mean Gregorian year.

We have thus three species of day—the sidereal, or that time which elapses between two successive culminations of the same star, and which is now universally adopted by astronomers in their observatories; the solar, natural, or apparent day, being the time that elapses between two consecutive returns of the same terrestrial meridian to the centre of the sun, and which consequently commences at noon; and the civil or mean solar day, which is the mean or average of these meridional returns, and which most modern nations have adopted, placing the commencement and termination at mean midnight.

It is here necessary to observe, that as the earth rotates from west to east, every meridian has its own natural day; and any place east or west of that meridian has a corresponding earlier or later sunrise. The earth, of 360 degrees of longitude, turns in twenty-four hours; consequently every hour is equal to 15 degrees; and every degree equal to four minutes of time. Thus, taking Greenwich as the normal meridian, Alexandria being 30 degrees E., is two hours earlier, or 12 o'clock when 10 at Greenwich; Bengal is 90 E., and it is there 12 at noon when only 6 in the morning at Greenwich. So New York is 74 degrees W., or four hours fifty-six minutes; and consequently, when noon at Greenwich, it is only 4 minutes past 7 in the morning at New York. As with these large distances, so with every other difference of longitude, however minute; and it is thus that we speak of our clocks being earlier or later than Greenwich time, according as we are situated east or west of that meridian. Ipswich, for example, being east of Greenwich, is about 5 minutes before, or earlier; Edinburgh being west, is about 12½ minutes behind; and Dublin being still farther west, is about 25 minutes late. Hence the necessity, in these days of rapid transit, of keeping by one uniform standard of time, or at least of having a table of differences for the principal stations throughout the country. In most cases, it would be preferable to have our clocks furnished with two minute-hands — one to indicate Greenwich time, and the other the natural time of the locality.

MONTHS AND WEEKS.

After the day, the next distinct natural measure or division of time marked out by the heavenly bodies in their time-keeping revolutions is the month. The lunar month is the period during which the moon revolves once round the earth, and is equal to 29 days 12 hours 44 minutes 3 seconds. The solar month is the period during which the sun appears to pass through a twelfth part of his annual course, or through one of the twelve arbitrary signs of the zodiac, and is equal to 30 days 10 hours 30 minutes: it is not so distinctly pointed out by nature as the lunar month. The month came ultimately to be disconnected from the lunar and terrestrial revolutions, as will be afterwards more particularly noticed, and civil or calendar months, accommodated to the year, were substituted; these also, as well as the names given to them in their annual order, will fall to be noticed while treating of the year itself and its subdivisions.

The subdivision of the month into weeks of seven days is very ancient, having, from the most remote period of history, been in use among the Hindoos and other nations in the East, including the Chaldeans and Jews. The week did not enter into the calendar of the Greeks, who divided the civil month into three periods, of ten days each; and it was not introduced at Rome till the time of the Emperor Theodosius. The Roman month was anciently divided into three periods—*Calends*, *Nones*, and *Ides*. The calends were invariably placed at the beginning of the month; the ides at the middle of the month, on the 13th or 15th; and the nones (*novem*, nine) were the ninth day before the ides, counting inclusively. From these three terms the days were counted backwards in the following manner:—Those days comprised between the calends and the nones were denominated *days before the nones*; those between the nones and ides, *days before the ides*; and those from the ides to the end of the month, *days before the calends*. The Greeks had no calends; hence the Roman phrase 'Græcæ calendæ,' or 'never,' corresponding to the English 'Latter Lammas,' and the Scotch 'Morn come never.'

The use of weeks is supposed by some to be a remnant of the tradition of creation; by others, as suggested by the phases of the moon; while a third class refer its origin to the seven planets known in ancient times. The latter hypothesis explains the circumstance, that the days of the week have been universally named after the planets in a particular order. Thus the French, at the present day, following the practice of the ancients, name the days from Mercury, Jupiter, Venus, &c.; while the English adopt Saxon appellations, derived from the deities of northern Europe, and from the Sun and Moon. Hence our term Sunday is from the *Sun*; Monday, the *Moon*; Tuesday, *Tuesco*; Wednesday, *Woden*; Thursday, *Thor*; Friday, *Friga*; and Saturday, *Seater*. (See SUPERSTITIONS.) In England, the Latin names of the days are still retained in legislative and judiciary acts. The Quakers, or Society of Friends, do not use the name of the week-day, but call each day, as they do the months, by its proper number—reckoning Sunday the 1st, Monday the 2d; and so on.

YEARS AND SEASONS.

The year, properly so called, or the solar or astronomical year, is that portion of time which elapses while the sun passes through the twelve signs of the zodiac, or rather while the earth revolves once completely round the sun in its orbit; and while, from the parallelism of the axis of the earth's rotation to itself, combined with its inclination to the axis of the orbit, each hemisphere is turned alternately, once toward, and once from the sun; thus constituting, at least in the extra-tropical regions, the distinction between summer and winter. (See ASTRONOMY.)

It would undoubtedly be this marked alternating distinction which would first lead the attention of every rude but progressing nation not inhabiting tropical countries to calculate their time by years, for in these would even the most savage nation feel an interest, analogous to that with which they had come to contemplate the alternating distinction between day and night. The spring and autumn, too, would soon be stamped with the impress of their sensibilities as natural periods, respectively, of hope and fruition. But it is rather remarkable that the only distinctions in the seasons made by the most ancient nations known, were those of summer and winter; as if these had been so extreme, as to absorb all other distinctions.

The distinction of the seasons would soon be found to depend upon the alternate approach and departure,

* A combination of both causes renders necessary an equation of time (see ASTRONOMY, p. 14), by which clocks ought to be kept earlier or later than the meridian sun or sun-dial. A clock so adjusted is said to keep *true* or mean time, in contradistinction to solar or *apparent* time. Equation tables are given in most almanacs, along with the hours of sunrise and sunset.

or elevation and depression, of the sun in the heavens at stated and regularly-recurring intervals; but the exact division of time into solar years could not have been effected till astronomy had made some progress; when it would immediately appear, in the endeavours at length made to measure the year by revolutions of the moon, that as an exact number of days, or times of the earth's rotation, is not contained in 'a moon,' or lunar month, so an exact number of moons, or even of days, is not contained in a year, or revolution of the seasons. Such observations as these led to methods of accommodating the one period to the other; or in other words, to the

ADJUSTMENT OF THE CALENDAR.

The Chaldeans, Egyptians, and Indians, and indeed almost all the nations of antiquity, originally estimated the year, or the periodical return of summer and winter, by 12 lunations; a period equal to 354 days 8 hours 48 minutes 36 seconds. But the solar year is equal to 365 days 5 hours 48 minutes 49 seconds; or 10 days 21 hours 13 seconds longer than the lunar year, an excess named the *epact*; and accordingly the seasons were found rapidly to deviate from the particular months to which they at first corresponded; so that, in 34 years, the summer months would have become the winter ones, had not this enormous aberration been corrected by the addition or intercalation of a few odd days at certain intervals. Thus was the calendar first adjusted, and the solar year estimated to consist of 12 months, comprehending 365 days. But no account was taken of the odd hours, until their accumulation forced them into notice; and a nearer approximation to the exact measurement of a year was made about 45 years before the birth of Christ, when Julius Cæsar, being led by Sosigenes, an astronomer of his time, to believe the error to consist of exactly 6 hours in the year, ordained that these should be set aside, and accumulated for four years, when of course they would amount to a day of 24 hours, to be accordingly added to every fourth year. This was done by doubling or repeating the 24th of February; and in order to commence aright, he ordained the first to be a 'year of confusion,' made up of 15 months, so as to cover the 90 days which had been then lost. The 'Julian style' and the 'Julian era' were then commenced; and so practically useful and comparatively perfect was this mode of time-reckoning, that it prevailed generally amongst Christian nations, and remained undisturbed till the renewed accumulation of the remaining error, of 11 minutes or so, had amounted, in 1582 years after the birth of Christ, to 10 complete days; the vernal equinox falling on the 11th instead of the 21st of March, as it did at the time of the Council of Nice, 325 years after the birth of Christ.

This shifting of days had caused great disturbances, by unfixing the times of the celebration of Easter, and hence of all the other movable feasts. And accordingly, Pope Gregory XIII., after deep study and calculation, ordained that 10 days should be deducted from the year 1582, by calling what, according to the old calendar, would have been reckoned the 5th of October, the 15th of October 1582. In Spain, Portugal, and part of Italy, the pope was exactly obeyed. In France, the change took place in the same year, by calling the 10th the 20th of December. In the Low Countries, the change was from the 15th December to the 25th, but was resisted by the Protestant part of the community till the year 1700. The Catholic nations, in general, adopted the *style* ordained by their sovereign pontiff; but the Protestants were then too much inflamed against Catholicism in all its relations, to receive even a purely scientific improvement from such hands. The Lutherans of Germany, Switzerland, and, as already mentioned, of the Low Countries, at length gave way in 1700, when it had become necessary to omit *eleven* instead of ten days. A bill to this effect had been brought before the parliament of England in 1585, but does not appear to have gone beyond a second reading in the House of Lords. It was not till 1751, and after great inconvenience had been experienced for nearly two centuries, from the difference of the reckoning, that an act was passed (24 Geo. II., 1751) for equalising the style in Great Britain and Ireland with that used in other countries of Europe. It was enacted, in the first place, that eleven days should be omitted after the 2d of September 1752, so that the ensuing day should be the 14th; and in order to counteract a certain minute overplus of time, that 'the years 1800, 1900, 2100, 2200, 2300, or any other hundredth year of our Lord which shall happen in time to come, except only every fourth hundredth year of our Lord whereof the year 2000 shall be the first, shall not be considered as leap-years.' A similar change was about the same time made in Sweden and Tuscany; and Russia is now the only country which adheres to the *old style*; an adherence which renders it necessary, when a letter is thence addressed to a person in another country, that the date should be given thus:—April $\frac{1}{13}$ or $\frac{\text{June 26}}{\text{July 9}}$; for it will be observed, the year 1800 not being considered by us as a leap-year, has interjected another (or twelfth) day between old and new style.

The twelve calendar or civil months were so arranged by Julius Cæsar, while reforming the calendar, that the odd months—the first, third, fifth, and so on, should contain 31 days, and the even numbers 30 days, except in the case of February, which was to have 30 only in what has been improperly termed leap-year, while on other years it was assigned 29 days only; a number which it retained till Augustus Cæsar deprived it of another day. The names of the twelve months are strictly Roman;—Thus *January* is said to be derived from Janus, a divinity who presided over the commencement of all undertakings, whence his name was appropriately applied to the first month in the year; *February* from *februo*, 'I purify,' because in that month funeral lustrations were performed at Rome; *March* from Mars, the reputed father of Romulus; *April* probably from *aperire*, 'to open,' in allusion to the opening or budding of vegetation; *May* from Maia, the mother of Mercury, to whom sacrifices were offered on the first day; *June*, according to some, either from Junius, Juno, or Juniores; *July*, in honour of Julius Cæsar; *August*, in honour of Augustus; *September*, *October*, *November*, and *December*, signifying respectively seventh, eighth, ninth, and tenth, are the names which were employed when the Roman year consisted only of ten months, and began with March.

The commencement of the year, till a comparatively very recent period, was the subject of no general rule. The Athenians commenced it in June, the Macedonians in September, the Romans first in March, and afterwards in January, the Persians on 11th August, the Mexicans on 23d February, the Mohammedans in July, and astronomers at the vernal equinox. Amongst Christians, Christmas day, the day of the Circumcision, the 1st of January, the day of the Conception, the 15th of March, and Easter day, have all been used at various times, and by various nations, as the initial day of the year. Christmas day was the ecclesiastical beginning of the year, till Pope Gregory XIII., on reforming the calendar, ordered it, in 1582, to begin thenceforward on the 1st of January. In France and England, the same practice commenced about the same time; but in the latter country, it was not till 1752 that legal writs and instruments ceased to consider the 25th of March as the beginning of the year. In Scotland, New-Year's Day was altered, both for historical and legal purposes, from the 25th of March to the 1st of January, by a proclamation of King James VI., in the year 1600. The English plan was found exceedingly inconvenient; for when it was necessary to express a date between the 1st of January, which was the commencement of the historical year, and the 25th of March, which opened the legal one, error and confusion were sure to occur, unless it were given in the following awkward fashion—January 30, 1648-9, or 164 8/9. Even this was apt to lead to mistakes; and it is perhaps even to this day a matter of doubt with some intelligent persons whether the execution of Charles I., of which the above is the usual appearance of the date, occurred in the year 1648 or 1649: it in reality occurred in the year which, by our present uniform mode of reckoning, would be called 1649.

The present mode of reckoning time has experienced no interruption in its leading features for many years, except under the French Republic. In September 1793, the French nation having resolved that the foundation of their new system of government should form their era, instead of the birth of Christ, whose religion they had in a great measure shaken off, resolved also that a calendar should be adopted on what was termed philosophical principles. The Convention, therefore, having decreed, on the 24th November 1793, that the common era should be abolished in all civil affairs, and that the new French era should commence from the foundation of the Republic—namely, on the 22d September 1792, on the day of the true autumnal equinox—ordained that each year henceforth should begin at the midnight of the day on which the true autumnal equinox falls. This year they divided into twelve months of thirty days each, to which they gave descriptive names, as follow:—From the 22d of September to the 21st of October was *Vendémaire* (Vintage Month); to the 20th November was *Brumaire* (Foggy Month); to the 20th December was *Frimaire* (Sleety Month); this completed the autumn quarter: to the 19th January was *Nivose* (Snowy Month); to the 18th February was *Pluviose* (Rainy Month); to the 20th March was *Ventose* (Windy Month), which completed the winter quarter: to the 19th April was *Germinal* (Budding Month); to the 19th May was *Floréal* (Flowery Month); to the 18th June was *Prairial* (Pasture Month); here ended the spring quarter: to the 18th July was *Messidor* (Harvest Month); to the 17th August was *Fervidor* or *Thermidor* (Hot Month); to the 16th September was *Fructidor* (Fruit Month), which terminated the period of summer. In ordinary years there are five extra days—namely, from the 17th to the 21st of our September, inclusive: these the French called *Jours Complementaires*, or *Sans-culottides*, and held as festivals; the first being dedicated to Virtue, the second to Genius, the third to Labour, the fourth to Opinion, and the fifth to Rewards. At the end of every four years, forming what they called a Franciade, occurred a leap-year, which gave a sixth complementary day, styled *Le Jour de la Revolution*, and employed in renewing the national oath to live free or die.

The *week*, though not exclusively a Christian or Jewish period of time, they also abjured. The thirty days of the month were divided into three parts, of ten days each, called *Decades*; of which the first nine (called Primidi, Duodi, Tridi, Quartidi, Quintidi, Sextidi, Septidi, Octidi, Nonidi) were working or common days, while the tenth, styled Decadi, was observed as a kind of Sabbath, though not exactly in the Jewish sense of the word. The French, however, in indicating any particular day, either by word or writing, generally mentioned only the number of the day of the month. The Republican Calendar was first used on the 26th of November 1793, and was discontinued on the 31st of December 1805, when the calendar used throughout the rest of Europe was resumed.

CYCLES.

A cycle, from a Greek word signifying *circle*, is a perpetual round or circulating period of time, on the completion of which, certain phenomena return in the same order; the end being thus, as it were, brought back to the beginning. Under such a definition, the common practice of accumulating years into centuries has of course no title to be classed: it is merely an arithmetical computation, like the equally common mode of counting by tens—forming, indeed, part of the same system.

The *Solar Cycle* is a period of 28 years, during which the day of the month, in every succeeding year, falls on a different day of the week, from the first, till the cycle is completed; when the days of the month and week meet as at first, one cycle corresponding to another. By this cycle, which has no relation to the sun's course, we find 'the Dominical letters,' or those letters amongst the first seven in the alphabet (used to represent the days of the week) which point out the days of the month on which the Sundays fall during each year of the cycle. If there were 364 days in the year, the Sundays would happen every year on the same days of the month; if 365 exactly, every 7th year; but because the additional fractional period contained in the year makes an alteration of a day in every 4th year, the cycle extends to four times seven, or 28 years.

The first solar cycle in the Christian era having begun 9 years before the commencement of that era, to discover what year of the cycle the year 1848 forms, we must add 9, and divide the sum 1857 by 28, the period of the cycle, and the quotient 66 is the number of solar cycles that have passed during that era, the remaining 9 being the year of the cycle corresponding to 1848.

The *Lunar Cycle*, also called the 'Golden Number,' from its having been written in letters of gold by the Greeks, and the 'Metonic Cycle,' from its having been discovered by Meton, an Athenian astronomer, is a period of 19 years, at the end of which the phases of the moon occur on the same days of the civil month as in a previous lunar cycle, and within an hour and a half of the same precise moment of time.

The first lunar cycle in the Christian era having begun one year before the commencement of that era, to discover what year of the cycle 1848 forms, we must add 1, and divide the sum 1849 by 19, the period of the cycle, and the quotient 97 is the number of lunar cycles that have passed during that era: the remainder, 6, corresponding with 1848, being the sixth year of the next lunar cycle.

The *Dionysian Period* is a combination of the solar and lunar cycles, forming, by the multiplication of 28 by 19, a period of 532 years, at the expiration of which it is again new moon on the same days of the week and month as before: chronological events are compared and tested by such a calculation.

The *Indiction* may here also be noticed; though, were it not for severing it from the other cycles with which it is connected in the Julian period, it might perhaps more properly appear under the head of epochs and eras. This was a Roman period of 15 years, the first of which commenced in the year 312 after the birth of Christ. It was appointed merely for the regulation of certain payments by the subjects of the empire; but it came to be observed by the Greek church and the Venetian senate, as well as the court of Rome.

The *Julian Period* is a combination of the solar and lunar cycles with the Indiction; the respective periods of 28, 19, and 15 years being multiplied by each other, and the product, 7980 years, being what is called the Julian period, during which there cannot be two years having the same numbers for the three cycles; but at the termination of this period they return in the former order.

The year 1848 is the 6561st of the Julian period: hence it began about 709 years previous to the date vulgarly assigned to the creation of the world, and has been used instead of that era, to obviate the disputes of chronologers, and to reconcile their systems; for all agree as to the year in which the Julian period began.

The *Precession of the Equinoxes*, on the supposition that the motion on which it depends is uniform, is a cycle of 25,920 years, during which the points whereat the sun crosses the equator at the equinoxes retrograde along the whole circle of the ecliptic, and return to their former position. The present rate of this motion, which depends on the solar and lunar attraction of the quantity of matter heaped up along the region of the equator, is 50 seconds of a degree yearly, or a whole degree in 76 years. (See ASTRONOMY.)

Sir Isaac Newton endeavoured to fix the period of the Argonautic expedition by this cycle, and it has given rise to some curious and interesting speculations regarding the period when the signs of the zodiac were invented.

The *Ecliptical Cycle* is an unknown period of time, during which the angle between the ecliptic and the equator, or the obliquity of the ecliptic, has completed all its changes. The present rate of the diminution of the obliquity is estimated at about 48 seconds of a degree every century. The extent of this change on either hand, like the length of the period in which it is accomplished, is at present unknown, though astronomers, founding on elements with regard to which there admittedly exists 'great uncertainty,' suppose the extent of the 'oscillation' to be very limited. The degrees of ecliptical obliquity at present existing in the *different* planets, however, so far as known, vary from a state in which it almost vanishes in the entire coincidence of the ecliptic with the equator, as in Jupiter, to one in which it is almost 'wide as the poles asunder,' as in Uranus. The ascertainment of the extent of this movement, in the case of the earth, is of great practical importance, especially in geological chronology. The changes of the seasons are occasioned by the obliquity of the ecliptic, being more or less extreme, according to the greater or lesser degree or extent of that obliquity; and, from certain recent discoveries in geology, which seem to imply the former increase of these extremes, coincidently with the former increase of the obliquity of the ecliptic, it appears highly probable that the hitherto hopeless problem of *a geological chronology*, in its most comprehensive sense, by a 'conversion of astronomical into geological periods'—a problem proposed some years since as the subject of a prize essay by the Royal Society of London—will receive its complete solution from the movements of this great ecliptical pendulum.

EPOCHS AND ERAS.

The principal difficulty which must have presented itself to nations desirous of preserving the memory of events, as they might occur, in their annals, from day to day, from month to month, and from year to year, and for long periods of years, would be to obtain a starting-point from which to number these days, months, years, and periods of years; and as no very marked astronomical event (unless, perhaps, eclipses) could render one of these starting-points preferable to another, such starting-points came practically and generally to consist, in early times, when nations had little mutual intercourse, of some event, important or known, perhaps, only to the nation dating from it. This event would form *an epoch*, so named from a Greek word signifying to stop. The enumeration and series of years computed from an epoch is called *an era*; and accordingly of epochs and eras there have been almost as many as there have been of nations. As the eras of ancient nations, however, have become obsolete, it would be useless, as it is here impossible, to enumerate all that we know of, or even any great number of them. But we shall notice a few of the most important in the meantime, reserving the names of all the other principal eras to be afterwards presented together in a tabular form.

The *Era of the Olympiads* is the first on record, and it also became the most celebrated of the ancient methods of computing lengthened periods of time. It took its rise amongst the Greeks 776 years before the birth of Christ. Public games had been instituted at Olympia, a city in Elis, which took place every fifth year, at the recurrence of the full moon after the summer solstice—namely, about the beginning of our July. As this festival made a great impression on the public mind, the people began to reckon by Olympiads, or recurrences of the Olympic games, an Olympiad comprising four years. The computation by Olympiads ceased after the 364th Olympiad, in the 440th year after the birth of Christ, as usually computed, though the epoch of the birth of Christ is not a point of time exactly fixed. The Greeks latterly adopted a new era, called

The *Era of Seleucus*, or the *Seleucidæ*, sometimes also called the era of Alexandria. This era commenced twelve years after the death of Alexander the Great, at the first conquest, by Seleucus Nicator, of that part of the west which afterwards formed the immense empire of Syria. This era has also prevailed, and still exists, amongst the people inhabiting the Levant. The Jews reckoned by it till the fifteenth century of the Christian era, when they substituted the supposed era of the Creation, to be afterwards noticed; and they still begin their year according to it, in the months of September or October.

The *Roman Era* was reckoned by the Romans from the epoch of the foundation of their famous city Rome, an epoch now precisely ascertained to have corresponded to the 753d year before the birth of Christ. The computation of time by the Roman era ceased in the sixth century of the Christian era.

The *Christian Era*, of which we now live in the eighteen hundred and forty-eighth year, was not adopted as a mode of time-reckoning immediately after the commencement of Christianity. That religion existed long in a very obscure way; and the date of the birth of its founder did not, for several centuries, become a sufficiently important event in the eyes of enlightened nations to cause them to make it an era. The era of the Olympiads, the Roman era, the era of Seleucus, and the dates of ecclesiastical councils, and other events then considered of importance, were the common modes of reckoning, and continued partially to be so till a period less remote than many people suppose. Even in Italy, and its celebrated capital, Rome, which became the chief seat of Christianity at a very early period, this era was not used till the sixth century. It was introduced into France in the seventh, but not fully established till the eighth century. In Spain, though occasionally adopted in the eleventh, it was not uniformly used in public instruments till after the middle of the fourteenth century, nor in Portugal till about the year 1415. Now, however, all nations professing Christianity have abandoned other eras, and confined themselves to this; using the Latin words *Anno Domini*, 'the year of our Lord,' or their initial letters, A. D., to distinguish it; while for all dates previous to the generally-received epoch of the era, the words *Anno ante Christum*, 'the year before Christ,' their abbreviation A. A. C., or even more usually the letters B. C., signifying 'before Christ,' are used.

The *Era of the Hegira* commences at the epoch of the flight of Mohammed from Mecca to Medina, which took place on the 16th day of July, A. D. 622. The Mohammedan year is regulated by this event; hence it is used by the Turks, Arabs, and other Mohammedans, comprising a large portion of the modern population of the world.

The *Mundane Era*, or era of the creation of the world, has been the subject of much controversy. As many as 300 different opinions, according to Kennedy, in his 'Scriptural Chronology,' have been entertained regarding the period which elapsed between the creation and the incarnation. Some have made it 3616 years; others 6484. From the creation to the deluge, the computation of the Hebrew text makes a lapse of 1656 years; the Samaritan version only 1307; the Septuagint 2262. No ancient chronologist attempted to fix the epoch of the creation: some conceived it impious to do so. In modern times, the impiety has been supposed to lie all the other way. But some enlightened commentators have been bold enough to return to the ancient orthodox idea, so far at least as to maintain that the Scriptural epoch of the creation is indefinite, being merely cursorily alluded to in the words, 'In the beginning God created the heavens and the earth.' Geologists, in general, also adopt this wide interpretation. In the authorised version of the Bible, however, the chronology usually given places the epoch of the creation in the year 4004 B. C. Thus, A. D. 1 is A. M. 4004; the letters A. M. being used as an abbreviation of *Anno Mundi*—'year of the world.'

Years of Principal Eras Correspondent to 1848.

		YEARS.	ABBREV.
Era of Creation (Constantinopolitan account),		7356	A. M. Const.
Era of Creation (Alexandrian account),		7340	A. M. Alex.
Era of Creation (Jewish account),	7th Tisri,	5608	A. M.
Julian period,		6561	Jul. Per.
Caliyug (Hindoo),	Poos or Margaly,	4949	Cal.
Era of Abraham,	4th month of	3863	Ær. Abr.
Olympiads,	7th month 1st year of	660	Olymp.
Era of Rome,		2600	A. U. C.
Era of Nabonassar,	8th month of	2596	Ær. Nab.
Egyptian era,	24th Cohiac,	2301	A. Æg.
Era of Death of Alexander,	3d month,	2171	A. Mort. Alex.
Spanish, or era of the Cæsars,		1886	A. Cæs.
Diocletian, or era of Martyrs,	24th Cohiac,	1564	Ær. Diocl.
Hegira,	7th Regeb.	1264	A. H.
Chinese year,	45th year of 71st cycle of 60 years.		

MISCELLANEOUS PERIODS.

Besides these major periods, we have others of less significance, but still useful to be known, as they are frequently alluded to in works of a historical nature. Thus a *lustre* (Lat. *Lustrum*) is a period of five years; or, more properly, the completion of fifty months, at the end of which term a census was taken of the Roman population. A *generation* is the interval of time elapsed between the birth of a father and the birth of his son, and is generally used in computing considerable periods of time both in sacred and profane history. The interval of a generation is consequently of uncertain length, and depends on the standard of human life, and whether the generations are reckoned by eldest, middle, or youngest sons. Thirty years are usually allowed as the mean length of a generation, or three generations for every hundred years. A *reign* is the interval that elapses between the accession and demise of a monarch or supreme governor, and is a term in frequent use by historians. It is a period, however, of very uncertain duration, and differs in different countries, according as the sovereign may be liable to assassination, deposition, and the like. Dr Hales has, however, shown that the average standard of reigns is about twenty-three years, reckoning from a series of 454 kings in 10,105 years. A *century* (*centum*, a hundred) is a period of one hundred years, reckoning from the commencement of the first year in any given century; thus the current century is the nineteenth of the Christian era.

TABULAR CHRONOLOGY.

Under this head the leading events, phenomena, or facts recorded in history are arranged in the order of time in which they have occurred—that is, in chronological order. When we look back, however, over the lapse of three or four thousand years, and consider the imperfect modes of record, the changes and transcriptions through which these records have passed—or even the absence of all record, save undated monuments and vague tradition—it will not be surprising that the tabular arrangements of chronologists should be so frequently inaccurate and contradictory. A perfect tabular chronology is what mankind can now never hope to attain: a full record—even reckoning only such events as are of medium general interest—would be too vast either for compilation or perusal. All that we can reasonably hope to attain, is an approximation to the leading facts in the early history of our race, and a brief indication of the more important occurrences in later times. Referring the reader to the systematic chronologies of Newton, Blair, Playfair, Sir Harris Nicolas, and others, we shall merely remark, that the best mode of tabulating events is that which exhibits the dates in bold characters, and endeavours to arrange in juxtaposition the leading occurrences in the principal countries of the world. By these means reference is greatly facilitated, and a notion of civil progress more intelligibly conveyed. Particular chronologies, as of meteorology, agriculture, ecclesiastical history, and the like, are most advantageously constructed in separate tables; that is, by tabulating, in consecutive order, the leading incidents in the progress of the individual science or subject. The language of tabular chronology should always be concise, elliptical rather than expletive—a mere indication rather than an account of the event recorded.

HOROLOGY.

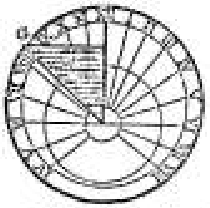
Reference has already been made to the heavenly bodies and their motions as the most primitive and natural, as well as most perfect time-keepers. Our attention here, therefore, must be confined to those artificial machines which have been invented chiefly for the purpose of adding to the convenience of these, by dividing the unit of astronomical time-keeping—namely, the day—into fractional parts, such as hours, minutes, and seconds; there being no such convenient and desirable measurement obvious in nature. The science which explains the methods of so measuring and marking the fractional parts of the day is termed *horology*, from two Greek words, signifying *hour* and *discourse*—a term comprehensive of every time-keeping contrivance, from the simplest sand-glass to the most perfect chronometer. The instruments to which we shall here advert are dials, depending upon the shifting shadow of an object illuminated by the sun; clepsydræ, depending upon the equable flow of a liquid; and clocks and watches,* whose movements are determined by weights and springs.

SUN-DIALS.

Long before the invention of any artificial time-keeper, the interval between sunrise and sunset was really divided, with no little accuracy, even amongst the rudest nations, simply by the shortening, turning, and lengthening of the shadows of trees, rocks, and mountains; and it was this primitive mode of dividing the day which no doubt naturally suggested the first idea of sun-dials. The earliest time-measurer of this description of which we have any historical notice is the dial of King Ahaz, who lived about 742 years before the birth of Christ. According to Herodotus, the Greeks learned the use of them from the Chaldeans, probably through the Babylonian priest and astronomer Berosus, who taught and expounded in Athens about 540 years before Christ. Mention is made of the hemisphere or dial of this philosopher; and the octagonal Temple of the Winds, which is still standing, shows on each side the lines of a vertical dial, and the centres where the gnomons were placed. In Rome, sun-dials were not known till B. C. 293, when one was erected near the temple of Quirinus—the rising and setting of the great luminary being the only standards of reckoning previous to this period. The Romans at this time were not aware that a dial made for Rome is not suited to other places. The ancients used hemi-

* Although modern machines for measuring time are designated by the general appellation of clocks and watches, they are also distinguished by peculiar names arising from certain modifications in their construction, or from certain particular purposes they are intended to serve. By the term *clock* is understood an instrument which not only shows, but also strikes the hours; a *time-piece* is one which shows the hours without striking them; a *quarter-clock* is one which strikes the quarters as well as the hours; an *astronomical clock* is one which shows sidereal time; a *watch* is a portable or pocket time-piece; a *repeater* is one having a contrivance, by means of which it can be made to repeat the hours; a *chronometer* is a watch of the best kind, or one fit to be employed for astronomical purposes.—*Brande's Dictionary of Science.*

spherical dial-plates, and placed the radius, which throws the shade, in the direction of the north polar star. Subsequently, vertical plane dials came to be the usual form, as may be seen on the fronts and gables of many of our old mansions. At present, the most common construction is the horizontal dial, or that in which the plane of the dial-plate is parallel to the horizon. In this form the style or gnomon G, the edge of the shadow of which determines the hour-line, runs in the plane of the meridian—that is, due north and south; while its sloping edge forms an angle with the horizon, or plane of the dial, equal to the latitude of the place in which the instrument is situated, and hence parallel to the earth's axis.



Although a sun-dial may certainly be adjusted so as to point out the time of day within a few minutes, it is needless here to dwell further on the details of an instrument now of little use. The most perfect of sun-dials being only available in sunshine, and not at all through the night (in which, by the way, moon-dials were sometimes used), they were partly superseded, even at a very remote period, by

CLEPSYDRÆ AND SAND-GLASSES.

It has been thought that the regular motion of the dropping of water, and the simpler forms of clepsydræ, or water-clocks, were used for the measurement of time even previous to the invention of sun-dials. They certainly were known in very remote antiquity, and were then used in various parts of Asia and Europe; in China, India, Chaldea, Egypt, Italy, and Greece; into the last of which countries they were introduced by Plato. Julius Cæsar found them even in Britain. It was by them that he discovered some of the nights to be shorter or longer in this country than in Italy, which is nearer the equator, or line of equal days and nights. The Romans themselves had clepsydræ 100 years before Cæsar's invasion; and it is supposed that the Phœnicians had introduced them into Britain through Cornwall, where they traded for tin. The clepsydra, invented by Ctesibius of Alexandria, B. C. 145, consisted of a jar containing water, which slowly escaped by a hole at the bottom, while the oar of a miniature boat on the surface, as it sank with the fall of the water, pointed out the hours, which were marked on the side of the jar. It is even alleged that toothed wheels were applied to clepsydræ by Ctesibius. Such instruments, however, though brought to great perfection in the ninth and tenth centuries, and indeed still used in India, have never been made to measure time with great accuracy. The principal defect is the unequal dropping of the water, caused by the varying depth or weight of the liquid in the containing vessel, the increase or decrease of temperature, or change of barometric pressure. Very ingenious attempts have been made to remedy this defect, but the greater complexity and delicacy thereby occasioned, render the instruments of very little practical value. As time-keepers, clepsydræ may therefore be considered as superseded by ordinary clocks and watches.

In one instance, however, the revival of their principle has been proposed—namely, for the accurate measurement of very short intervals of time by the flowing of mercury from a small orifice in the bottom of a vessel kept constantly filled to a fixed height. 'In this case,' says Brande, 'the stream is intercepted at the moment of noting an event, and diverted aside into a receiver, into which it continues to run till the moment of noting any other event, when the intercepting cause is suddenly removed. The stream then flows into its original course, and ceases to run into the receiver. The weight of mercury received, compared with the weight of that which passes through the orifice in a given time, observed by the clock, gives the interval between the events.' This ingenious application of the principle of the old clepsydræ is due to the late Captain Kater.

The running of fine well-dried sand through a tube, or from an orifice in a containing vessel, was another obvious species of regular motion, very analogous to the flowing or dropping of water. Accordingly, sand-glasses, still in use in this and other countries, were of very early invention. We have evidence of their employment in the East about a couple of centuries before the Christian era. Though now used only for rude and trivial purposes—the half-minute glass being still employed on ship-board, and the two and a half or three minute egg-glass by the housemaid—some centuries ago, in western Europe, they were the almost universal measurers of brief intervals; and hence the numerous allusions of our poets, and the symbolical representations on our monuments and sculptures.

PLANETARIUMS OR ORRERIES.

It is rather a curious circumstance, that, long before the invention of clocks or watches, artificial machines were constructed, imitative of the motions of the sun, moon, and planets—the natural time-keepers.

Of the planetariums of modern times, the first in England was one made for Lord Orrery, whose name has since been given to such machines. The talented and self-taught astronomer, Ferguson, who was originally a poor Scottish herd-boy, made several orreries, and used chronometers to keep them in motion. But though the accuracy with which wheels and pinions can be made to represent different revolutions is beautifully illustrated by the best of these machines, they can give no just conception of the relative size, distance, or velocity of the planets, or hence of the periods of their revolution. 'As to getting correct notions on this subject (the magnitude and distances of the planets),' says Sir John Herschel, 'by drawing circles on paper, or still worse, from those very childish toys called orreries, it is out of the question.' A verdict so decided, and from such a source, renders any attempt at description or illustration unmeaning and superfluous.

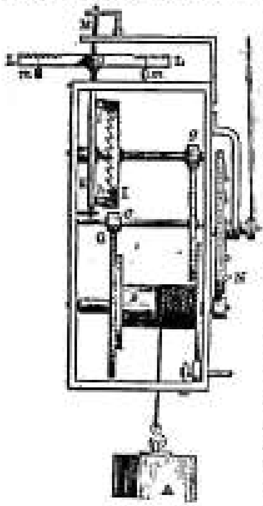
CLOCKS.

The strong hold which the planetary motions appear to have taken on the minds of our forefathers, as the great antitypes of all true time-keepers, is also curiously manifested in the fact, that even when a more detailed measurement of time became necessary, in the intellectual progress of nations, these motions still continued to be represented, so that the very first clock of which we have any perfectly authentic account—that, namely, invented by Wallingford, abbot of St Albans, in 1326—not only showed the hours, but the apparent motion of the sun, the changes of the moon, the ebb and flow of the tides, &c. This, however, was by no means the first clock ever constructed; instruments with weights, wheels, pinions, and a balance, for the measurement of time, having been long previously known, though by whom invented, appears to be a subject of much controversy. Doubtless they required more than the intellect of a single mind. Be this as it may, the most ancient clock of which we have any description, is that of Henry Vic, or De Wyck, a German, erected in the tower of the palace of Charles V., king of France, in 1379; and rude and imperfect as it was, the analogy of modern invention, especially in watches, would lead us to think that it must have been the fruit of several centuries of thought and improvement.

A portrait of this parent of modern time-keepers may be interesting to our readers; and, from its comparative simplicity, will be well adapted as a groundwork for further explanation of the mechanism of clocks and watches in their more complex and intricate forms. It will, moreover, show the general mode of construction adopted in the fourteenth century, including the balance with weights, by which the motion was then regulated, instead of as now by a pendulum.

General Movement and Regulation of Clockwork.

Without requiring to enter into any very minute detail of the manner in which motion in a clock or watch is successively communicated from one toothed wheel G or I, or pinion *e* or *g*, to another, which, indeed, would in some instances only tend to perplex the mind of the general reader, it will be readily understood that the weight A below the clockwork, wound up by a cord on the cylinder B, in its constant tendency to fall to the ground, will cause the cylinder to turn round on its axis as it falls, and as the cord uncoils; and thus one toothed wheel or pinion will set another in motion, till the movement be communicated to the crown wheel, escapement wheel, or wheel of rencounter (I), the teeth of which so act on the two small levers or pallets (*i h*) projecting from, and forming part of, the suspended upright spindle or vertical axis (K M), on which is fixed the regulator or balance (L L), that an alternating or vibratory instead of a circular motion of the balance itself will be the result. The rotatory motion of the wheelwork, in short, will be converted into a vibratory motion by the alternate catching of the levers by the teeth of the crown or escapement wheel, and their alternate escape from them.



De Wyck's Clock.

Now, it will at once appear manifest that a heavy weight, such as that here represented, operating on a few wheels thus arranged, unless it have some counteractive weight, or other check, to modify and balance its operation, will rapidly run down even to the ground, if the height of the clockwork, and the length of the cord attached to the cylinder, permit it, causing the wheels to rotate, the balance to vibrate, and the hands to revolve on the face of the clock, with similar rapidity, increasing every moment, till the weight be fairly run down. It is this rapid motion of the wheelwork which begins in a *modern* clock whenever the *pendulum* is taken away, while the weights are still attached to the cylinders; and the rapid ticking then heard is the uncounteracted operation of the crown wheel, moved by the falling weight upon a piece of mechanism similar in purpose to the levers and spindle in the above figure. To prevent this rapid unwinding of the clockwork, then, and to adjust it to the more deliberate measurement of time, we have, in De Wyck's clock, the balance, *loaded with two weights* (*m m*); and the farther these are removed from the axis or spindle (K M), the more heavily will they resist and counteract the escapement of the levers, and the rapidity of the rotation of the escapement wheel, till the clock be brought to go neither too quick nor too slow; when, of course, it would be improper to remove them further towards the ends of the balance, as the clock would then go too slow for correct time-keeping.

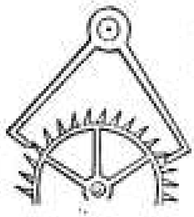
Pendulum and Escapement.

What the balance and the weights attached to it in De Wyck's clock were to clocks of an ancient date, the pendulum is, in general, to modern clocks; the oscillations of the pendulum, and the vibrations of the balance, being completely analogous in purpose and effect, both being kept up or sustained by the 'escapement,' while both require, or, as it were, demand, by the law of gravity, a certain time for their performance; and thus, by reaction, check and equalise the exercise of those very powers and movements by which they are kept in play. The measurement of time being thus regulated by the oscillations of the balance or the pendulum, this part of the mechanism of a clock, including the escapement, is of primary interest and importance; and we shall find this also to be the case in the numerous contrivances, chiefly by English artists, to effect the same object to the best advantage in the still more delicate and ingenious mechanism of watches. We may here also remark, that so invaluable is the principle of *regulation*, whether by oscillation or rotation, and so generally and extensively useful in other respects, that, from the smoke-jack to the steam-engine, it has, in one form or other, been called into practical operation.

Galileo, the great astronomer, when a student at Pisa, happened to discover, while engaged in the cathedral there—not in meditating on the imposing ceremonial of the Catholic church, which was then in progress, but in what, to many a good Catholic, would undoubtedly have seemed the vacant, idle, and profane contemplation of the lamps which swung from the roof—that the oscillations of a pendulum, whether great or small, are performed in equal times in each pendulum—an important fact, the truth of which he tested, not by the beats of his watch (for no such instrument then existed), but by the beats of a natural time-keeper to which we have not yet alluded—namely, the pulse. He afterwards discovered, what was ultimately demonstrated by Newton—that 'the shorter the pendulum, the less is the time of its vibration;' or, in other words, that the number of oscillations performed by a pendulum in a given time depends on its length—four times the length producing twice the number of oscillations. A pendulum, the length of which, from the point of suspension to the centre of the weight attached to its lower extremity, is 39 inches 2 tenths, will oscillate once precisely every second in the latitude of London; not in any other latitude, however, as has been found by experience; the number of oscillations with the same length of pendulum diminishing towards the equator, where oscillations equal in length to 2 minutes 15 seconds a day will be lost; while, on the other hand, they will increase towards the poles, where a proportional number of oscillations will be gained. Thus, as already explained under the Laws of Matter, the pendulum of a clock, made and adjusted to time in London, requires to be lengthened if taken nearer to the poles, or shortened if taken towards the equator. The greatest possible nicety, indeed, is required in the adjustment of the length; for a difference, if in extent amounting to the 1000th part of an inch, would cause an error of about one second a day; therefore, to make a pendulum *go slower* by one second a day, it must be lengthened by the 1000th part of an inch; and to make it go quicker, it must be shortened in the same proportion. The following are the result of some measurements of the seconds' pendulum at different latitudes in the northern hemisphere:—

Spitzbergen,	79°	49′	58″	N. Lat.,	39·2146	inches.
Edinburgh,	55	58	40	...	39·1554	...
London,	51	31	08	...	39·1390	...
Jamaica,	17	56	07	...	39·0350	...
Sierra Leone,	8	29	28	...	39·0195	...

The first use which Galileo, then a medical student, made of his valuable discovery, was to ascertain the rate and variations of the pulse; and its application to clockwork was an afterthought. It is even denied that he did more than suggest such an application; or, as has been also alleged, that at all events his son put his suggestion into execution; and accordingly the merit of the invention of pendulum clocks is very generally attributed to Huygens, a learned Dutchman, about 1657. This celebrated philosopher, in adapting the pendulum to the mechanism previously invented, had little more to do than simply to add a new wheel to the movement, so as to enable him to place the crown wheel and spindle in a horizontal instead of a perpendicular position, that the lower arm of the balance—then of course perpendicular, instead of horizontal, as in De Wyck's clock—might be extended, as it were, downwards, and thus, in fact, be converted into a pendulum. The principle thus adopted, however, from the peculiar action of the levers and spindle, required a light pendulum and great arcs of oscillation; and the consequence was, as Mr Thomson, a recent popular author, tritely remarks, that 'Huygens's clock governed the pendulum, whereas the pendulum ought to govern the clock.' About ten years afterwards, the celebrated Dr Hooke invented a better method, which was introduced by Clement, a London clockmaker, in 1680, and enabled a less maintaining power to carry a heavier pendulum, which also making smaller swings or arcs, was less resisted by the air, and therefore performed its motion with greater regularity. This was called the *anchor escapement*, and it is still in use, together with the practice to which it gave rise of suspending the pendulum by a thin flexible spring instead of a cord, which was liable to change its length



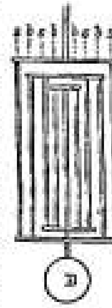
by moisture; an evil, however, perhaps fully equalled by the variation of the elasticity of the spring by heat and cold. The seconds' pendulum, with the anchor escapement, was called the *royal* pendulum. As this plan, however, was found to cause a reaction or retrograde movement of the wheels, and has hence been called the *recoil* escapement, a further improvement was made about the beginning of the eighteenth century by George Graham, another English artist, who invented the repose or *dead* escapement.

The wheels are kept by this escapement in a state of repose or rest during the whole oscillation of the pendulum, except at the moment when it receives its impulse from the crown-wheel. Requiring smaller arcs, too, even than before, the oscillations are made in more equal times. A still more perfect modification of the escapement is the free or *detached*, but it is more difficult to execute. The *half-dead* escapement, also, has been introduced as a mean between the dead escapement—an increase of power with which causes a clock to lose time—and the recoil escapement, with which a similar increase of power causes one to gain. For the purposes of ordinary clocks, this mode of escapement has been found to answer very well.

Compensation Pendulums.

Pendulum rods, which are usually made of metal, though sometimes of wood, especially in church clocks, were next found to vary in length by variations of temperature, according to that law of nature by which every body increases in volume or in actual size by heat, and diminishes or contracts by cold. The inevitable consequence of the influence of such variations on the length of the pendulum will at once be seen, from what has been already said, to be an increase of the number of its oscillations in a given time while in cold temperatures, and hence shorter than its mean length, as in winter, or even at night, or in cold situations; and a diminution of them while in warm temperatures, and hence longer, as in summer, or even during the day, or in warm situations: and a pendulum with a metal rod will cause a clock to vary several seconds in a day from such changes alone. To insure, therefore, a still greater accuracy and uniformity in the measurement of time than had previously been obtained, various ingenious but simple devices have been put into practice, wherein the very cause of the inaccuracy has been made subservient to the end desired. And here the talent of the artist Graham again displayed itself, and led the way to every other modification of the primitive *idea*, however dissimilar in detail, and whether applicable to pendulums or balances, to clocks or watches. Indeed the first method of 'compensation' adopted for pendulums has, with some little improvement, ultimately superseded all its more recent modifications. This method Graham called the *mercurial compensation*, and it consists simply of a tube or cylindrical glass jar containing quicksilver or mercury, and attached to the lower end of a steel rod in the arc of its oscillation. As the steel rod lengthens by heat, the mercury expands in volume, and rises in the tube; while, as the rod shortens by cold, it contracts, and sinks or falls. Thus the arc of oscillation remains ever at the same distance from the point of suspension, or upper extremity of the pendulum; or, in other words, the pendulum, in fact, remains ever of the same length.

Graham also conceived the notion of another compound pendulum, composed of different metals, so arranged, as to compensate each other by their *difference* of expansion or contraction. This modification of the idea of a compensating pendulum was more fully developed by John Harrison, another celebrated artist, who in 1726 invented the gridiron pendulum, composed of five rods of steel and four of brass, so arranged, that the rods which expand the most raise the weight or bob as much as the rods which expand the least depress it. In the annexed fig., the bars marked *a* are of steel, those marked *b* are of brass; the centre rod of steel is fixed at the top to the cross-bar connecting the two middle brass rods, but slides freely through the two lower bars, and bears the bob B. The remaining rods are fastened to the cross-pieces at both ends, and the uppermost cross-piece is attached to the axis of suspension. It is easy to see that the expansion of the steel rods tends to lengthen the pendulum, while that of the brass rods tends to shorten it; consequently, if the two expansions exactly counteract each other, the length of the pendulum will remain



unchanged. The relative lengths of the brass and steel bars are determined by the expansions of the two metals, which are found by experiment to be, in general, nearly as 100 to 61. If, then, the lengths of all the five steel bars added together be 100 inches, the sum of the lengths of the four brass bars ought to be 61 inches. When the compensation is found on trial not to be perfect, an adjustment is made by shifting one or more of the cross-pieces higher on the bars. This pendulum has been greatly improved by Troughton, who substituted for the two pairs of brass rods two cylinders of brass, sliding the one within the other, to which the steel rods are attached.

Unfortunately, however, this compensation changes, as all metals do, not continuously and gradually, under the influence of heat or cold, but by jerks. The mercurial pendulum, therefore, under certain improvements by Thomas Reid, a talented Edinburgh artist, and by others, has of late been frequently resumed; and it has been found that time-keepers provided with this pendulum and a dead escapement do not vary, on the average, more than a quarter of a second daily—a degree of accuracy wonderful, indeed, when contrasted with the fact, that down to the middle of the sixteenth century clocks were incapable of going nearer to accurate time than about 40 minutes within the 24 hours, and were nevertheless held to be precision itself compared with all other methods of measuring time then known.*

* Before quitting the subject of pendulums, it is worthy of remark that their mutual action or sympathy, while oscillating near each other on the same wall, so long as they are mutually connected by a rail or shelf common to both, or so long as the cases of the clocks to which they belong are either fixed to each other or standing on the same flooring plank, is a very singular phenomenon, observed by Huygens, Elliot, De Luc, Reid, and many other artists. One pendulum will even stop another, it is said, in such circumstances, and will again cause it to resume its

Other Improvements.

While improvements were effecting in the escapement and pendulum of clocks, the ingenuity of artists was not confined to these alone. Till the beginning of the sixteenth century, clocks were of great bulk, and only fit for turrets or large buildings; and although after this period they were made small enough to be introduced into apartments, there could be no such thing as a really portable clock, far less a watch, till weights and pendulums were got rid of altogether. The substitution of a mainspring for a weight, therefore, constituted a great era in horology, or the science of time-keeping; and this took place about the middle of the sixteenth century, and was shortly afterwards followed by the invention of the *fusee*, a very necessary appendage to the mainspring. But as these inventions completely altered the form and principles of horological machines, and, together with that of the spiral escapement spring, and other improvements, which soon followed that of the pendulum, rather constitute peculiar features of the watch than of the clock (although they were mostly applied at first only to portable timepieces of the nature of clocks, in which they are, indeed, still used), we shall reserve the explanation of these ingenious pieces of mechanism till we come to treat of watches. Meantime, there is another part of the works which requires to be here noticed; namely, the

Mechanism for Striking the Hours.

It is not known when the alarum or when the striking mechanism of the clock was first applied. The alarum was adopted for the use of the Romish priesthood, to arouse them to their morning devotions. The first striking clock probably announced the hour by a single blow, as they still do, to avoid noise, in most, if not all, of the Scottish churches. In De Wyck's clock, the wheel N, with its projecting pins, served to discharge the striking part, which it has not been thought necessary to illustrate. Like other old clocks, it locked against an interrupted hoop, fixed on what was called the *hoop-wheel*; and the eleven notches on the edge of the plate-wheel determined the hours, or particular number of blows which the hammer should give. During the seventeenth century, there existed a great taste for striking clocks, and hence a great variety of them. Several of Tompion's clocks not only struck the quarters on eight bells, but also the hour after each quarter; at twelve o'clock, 44 blows were struck; and between twelve and one, no less than 113! Many struck the hour twice, like that of St Clement Danes, in the Strand, London, first on a large bell and then on a small one. Others, again, were invented so as to tell the hours with the least possible noise, also by the aid of two bells, each blow on the small one indicating five hours.

vibrations till it stop, alternately, itself. It has also been found that two clocks with pendulums of nearly equal length and power, or weight, though differing in their measurement of time while apart, will so vibrate in unison when thus connected, as to keep time together with the most surprising accuracy, till they are again separated, or till the plank connecting them be sawn asunder. This singular but not altogether unaccountable influence appears to be not unlike that sympathy of sound between two musical instruments tuned in unison, wherein, when a chord of one is struck, the other, placed in a proper situation, though untouched, responds or echoes back the sounds at first called forth. And as in the combinations of certain medical substances, or in various other combinations, the general result of all the elements is obtained as a steady mean to be depended on, without the special failure, fault, or disadvantage of any one element in the combination, accuracy of time-keeping, of a remarkable kind, might readily be obtained by this singular mode of bringing out, by a combination of pendulum clocks, an average rate of motion. 'It is the opinion of an eminent foreign artist,' says Reid, the author of a standard article on clock and watch-making in the Encyclopædia Britannica, 'that a few clocks placed in this way would communicate the motion of their pendulums to each other, till they came all at last to beat at the same instant;' an opinion in which Reid himself expresses his entire concurrence.

The striking part of a clock is rather a peculiar and intricate piece of mechanism. In ordinary clocks, the impelling power is a weight similar to that which moves the time-measuring mechanism itself; but the pressure of this weight on the striking machinery is only permitted to come into play at stated periods in course of the workings of the time-keeping apparatus—namely, at the completion of every hour; when the minute-wheel, which revolves once in an hour, and carries the minute-hand of the clock along with it, brings it into action by the temporary release of a catch or detent, permitting the weight wound up on the cylinder of the striking apparatus to run down for a little, in doing which, the hammer is forced into action, so as to strike the bell. Whether the strokes shall be one or many, is determined principally by two pieces of mechanism, one called a *snail*, from its form or outline, with twelve steps, and the other a *rack*, with twelve teeth; but the intricate action of the whole it would be in vain here to attempt to explain. Suffice it to say, that the time during which the striking weight is *allowed* to descend, varies according to the turning of the twelve steps of the snail on its axis, and the position of the twelve teeth of the rack, at different hours of the day; being sometimes only long enough to permit one blow to be given by the hammer on the bell, and at another time long enough for twelve such blows.

The lifting piece of the rack-hook, in some clocks, may be raised by pulling a string attached to a small additional piece of mechanism, and thus the clock is made to repeat the hour last struck at any time required—an addition useful through the night, or to the blind. The modes, however, by which clocks as well as watches have been made repeaters, have been very various. Repeating-clocks were first invented by Barlow, an English clergyman, and executed by Tompion in 1676. Some have been made to repeat both hours and quarters at any time, and to indicate the time by blows which might be felt but not heard.

The bells connected with clocks, especially those of churches and other public buildings, are often worthy of notice, either on account of their gigantic size, or on account of the arrangements by which they are made to perform a variety of musical chimes. If cast to the proper size and shape, and of the right metal, the latter conditions are easily obtained, by applying the necessary striking apparatus; but to produce gigantic as well as perfect dimensions, and then to elevate the mass several hundred feet in some tower or spire, is a feat of no ordinary character. The size and weight of some of our British bells are enormous. Thus the celebrated Tom of Oxford, which is 22 feet in circumference, weighs 9894 pounds; the great bell of St Paul's, London, 11,470 pounds; Peter of Exeter Cathedral, 12,500; Old Tom of Christ-church, Oxford, 17,000; and the recently erected Peter of York Minster, 21,000. Enormous as these weights are, they are insignificant compared with some which have been produced in continental Europe and in China. Thus the brass bell of Strasburg is 22,400 pounds weight; that of Rouen Cathedral 36,000; the seven great bells of Pekin, according to Le Compte, weigh 12,000 pounds a-piece; while the monster bell of Moscow, which now lies unemployed, is about 67 feet in circumference, 21 feet high, and has been calculated to weigh not less than 443,000 pounds! The metal of which bells are made is generally an alloy of 80 parts copper and 20 tin. An English *bell-metal*, analysed by Dr Thomson, yielded 800 copper, 101 tin, 56 zinc, and 43 lead.

The illumination of clocks was a favourite idea in the seventeenth and eighteenth centuries, and is equally useful in a public way as the striking of hours or the ringing of bells. It was only during the current century, however, that any plan was adopted for public clocks; the first notion being to light them from without, by reflecting the light of a common lamp or gas jet on their dials. This simple method is still employed, but is vastly inferior to the employment of a translucent dial, with a strongly-reflected light from behind. Recently, the pure brilliancy of the Bude-light has greatly contributed to the improvement of this very useful practice.

Curious Clocks.

Various and ingenious, as well as often highly curious, have been the forms and purposes displayed in the construction of clocks, even from their earlier epochs down to the present day. We have already instanced some of an ancient date which pointed out the motions of the sun and moon, the ebb and flow of the tides, &c. Others of a more fanciful description followed. The famous astronomical clock of Strasburg, completed by Isaac Habrecht about the end of the sixteenth century, deserves a prominent place in our catalogue. It has been recently renovated by a M. Schwilgue, after four years' labour; but its original movements are thus described in Morrison's Itinerary:—'Before the clock stands a globe on the ground, showing the motions of the heavens, stars, and planets. The heavens are carried about by the first mover in twenty-four hours. Saturn, by his proper motion, is carried about in thirty years; Jupiter in twelve; Mars in two; the Sun, Mercury, and Venus in one year; and the Moon in one month. In the clock itself, there are two tables on the right and left hand, showing the eclipses of the sun and moon from the year 1573 to the year 1624. The third table, in the middle, is divided into three parts. In the first part, the statues of Apollo and Diana show the course of the year, and the day thereof, being carried about in one year; the second part shows the year of our Lord, and the equinoctial days, the hours of each day, the minutes of each hour, Easter day, and all other feasts, and the Dominical letter; and the third part hath the geographical description of all Germany, and particularly of Strasburg, and the names of the inventor and all the workmen. In the middle frame of the clock is an astrolabe, showing the sign in which each planet is every day; and there are the statues of the seven planets upon a circular plate of iron; so that every day the planet that rules the day comes forth, the rest being hid within the frames, till they come out of course at their day—as the sun upon Sunday; and so for all the week. There is also a terrestrial globe, which shows the quarter, the half hour, and the minutes. There is also the figure of a human skull, and the statues of two boys, whereof one turns the hour-glass, when the clock hath struck, and the other puts forth the rod in his hand at each stroke of the clock. Moreover, there are the statues of Spring, Summer, Autumn, and Winter, and many observations of the moon. In the upper part of the clock are four old men's statues, which strike the quarters of the hour. The statue of Death comes out at each quarter to strike, but is driven back by the statue of Christ, with a spear in his hand, for three quarters; but in the fourth quarter that of Christ goes back, and that of Death strikes the hour with a bone in his hand, and then the chimes sound. On the top of the clock is an image of a cock, which twice in the day crows aloud, and claps his wings. Besides, this clock is decked with many rare pictures; and being on the inside of the church, carries another frame to the outside of the walls, whereon the hours of the sun, the courses of the moon, the length of the day, and such other things, are set out with great art.'

Other ancient clocks displayed processions of saints, with obeisance to the Virgin and Child, &c.; and scarcely a town of any importance was without some curiosity of this sort peculiar to itself. Many curious specimens were invented in the seventeenth century, amongst which were a variety measuring time, or at least moved, by balls running down inclined planes, swallowed up by, and traversing the bodies of, brazen serpents, or descending in metallic grooves, to be again thrown up by Archimedean screws; some were made to go by their own weight, descending inclined planes, and thus avoiding the casualties to which mainsprings and weight lines are liable; others, by means of springs, were even made to ascend such planes. One was simply and ingeniously hung like a lamp from the ceiling, and was kept going by its own descent, the winding up consisting merely of pushing it again towards the ceiling. In another, the dial formed the brim of a plate, filled with water, in which swam a tortoise, turning marvellously with the hour, and ever pointing towards it—by magnetic attraction, as every one would now readily conceive; and this favourite idea was varied by many other simple contrivances. Within the last few years, not a little wonder of a similar kind, we recollect, was excited by a puzzle-clock, with an hour hand proceeding from the centre of a crystal dial-plate, perfectly transparent, and moving without any visible connection with mechanism. In this case a piece of glass itself, rotating in the interior of the dial, constituted the requisite mechanism.

More interesting, perhaps, than any of these, and yet of the simplest construction, and of the most common material, are the *electric*, or rather *electro-magnetic clocks*, lately invented by Mr Bain of Edinburgh. The prime mover of these machines is the electric currents of the earth, brought to bear upon the machinery, as thus described by a party for whom one of the earliest was constructed. 'On the 28th of August 1844, Mr Bain set up a small clock in my drawing-room, the pendulum of which is in the hall, and both instruments in a voltaic circle as follow:—On the north-east side of my house, two zinc plates, a foot square, are sunk in a hole, and suspended by a wire, which is passed through the house to the pendulum first, and then to the clock. On the south side of the house, at a distance of about forty yards, a hole was dug four feet deep, and two sacks of common coke buried in it; among the coke another wire was secured, and passed in at the drawing-room window, and joined to the former wire at the clock. The ball of the pendulum weighs nine pounds; but it was moved energetically, and has ever since continued to do so with the self-same energy. The time is to perfection; and the cost of the motive powers was only seven shillings and sixpence. There are but three little wheels in the clock, and neither weights nor spring; so there is nothing to be wound up.' The electric clock, as now patented and employed by the Electric Telegraph Company, is somewhat differently constructed. A plate of copper, and another of zinc, buried in the ground to the depth of nine feet, so as to be kept constantly moist, are the generators of the electric current, which is conveyed directly to the pendulum by wires. The pendulum is made of wood, suspended by a steel spring, and furnished, as usual, with a regulating bob; the current is conveyed down the wooden rod by wires, to a magnetic coil a little above the bob, and placed in juxtaposition to two permanent magnets, which maintain the oscillation; and about the middle of the pendulum rod an apparatus is placed on either side, for the purpose of alternately making and breaking the circuit. With the exception of the *break* apparatus, the whole machine is of extreme simplicity, and little liable to disarrangement. Many of these ingenious clocks have been since constructed, and an illuminated one, projected from the front of Mr Bain's workshop in Edinburgh, moves, as the inhabitants can testify, with the utmost regularity. One great advantage of this invention is, that supposing every house in a city provided with the simple apparatus before referred to, one electric current could keep the whole in motion, and thus preserve the most perfect uniformity of time. It is not too much to expect, therefore, that as we have now a common supply and diffusion of gas and water, so we may shortly have a common diffusion of time. In a highly-civilised and business country, the one is almost as necessary as the other.

Miscellaneous Clockwork.

The applications of clockwork to other purposes than that of measuring time, are numerous and important. In all of them, however, the principle is the same—namely, the indication of space, or, what is equivalent, the indication of time or number by mechanical motion. Thus, according to the unit we assume, any amount of space may be indicated either in a regular series, or in a decreasing or increasing series—the increment or decrement taking place progressively, or at intervals, as may be wanted. What can be done with space, can be equally accomplished with regard to time or number, and that with an accuracy and precision that no human powers can rival. It was by springs, and weights, and clockwork, that the *automata* which amused our forefathers were moved and directed. Whether they danced or made music, or in whatever way they simulated the conduct of living creatures, it was mechanism that governed their actions—mechanism which would have commanded our admiration the more, that it had been applied to useful purposes. All our *meters*, by which the discharge of gases and liquids are now measured, are but combinations of clockwork; as are also those numerous inventions for *registering* events connected with atmospheric temperature, rise and fall of barometric pressure, direction and force of wind, vigilance of sentinels, and the like.

Thus by a properly-constructed *anemometer* (literally, wind-measurer), not only may the force and direction of the wind be ascertained at any given moment, but the instrument may be made to trace or register the direction from which, and the force with which, the aërial current has swept during every minute of the day—all that is necessary being, to place under the tracing pencils a clean sheet of paper every twenty-four hours. In like manner, clocks are made for registering the daily fluctuations of the barometer, by means of a pencil floating on the surface of the mercury, and made to traverse a circular card, divided into 365 parts by radii lines, and turned on its centre by the clock once a-year. A curious time-keeping method of insuring the presence and attention of night-watchmen has been successfully tried of late years. It consists of a clock with pins projecting round the dial, which can only be pushed inwards at a certain interval, when the watchman's presence and attention are required to unlock the case, and do so, otherwise his neglect, and the exact quarter of an hour at which he was absent, is shown by the *tell-tale*. Amongst other recent inventions may be noticed a *lock-clock*, to prevent bankers' safes, &c. from being opened except at stated intervals. So also *odometers* (road-meters), or instruments for measuring the space travelled over, whether by pedestrians or wheel-carriages—motion being communicated by the moving body to the clockwork, which is fitted with indices and alarums to indicate any unit of distance required. The same principles have been applied to machines for graduating scales, for engraving tints, and other analogous processes, in which delicacy of line and accuracy of distance are the objects in view.

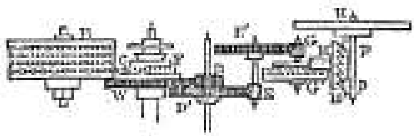
Closely allied to these varieties of clockwork, but evincing a greater degree of scientific skill, are the various machines which have from time to time been invented to lessen the drudgery of long and continuous calculation. The principles upon which the increase and decrease of numbers depend are as fixed as nature herself; and these once known, wheel machinery of determinate proportions may be constructed to perform every operation in arithmetic with the utmost facility and accuracy. It is well known that in calculations involving the powers and roots of numbers, progression, equations, logarithms, and the like, it not only requires great expertness, but accuracy—an accuracy which is scarcely attainable under the strictest human attention. Such calculations are of indispensable utility in astronomy, navigation, and geography, as well as in general mathematics; and for application, are usually printed in tabular forms, embracing many hundred pages of thick-set figures. To complete such tables with perfect accuracy would require the life-work of several calculators; and yet, by well-arranged machinery, it has been demonstrated that they can be calculated and printed, free from errors, in the course of a few weeks.

The most extensive and ingenious of *calculating machines* are undoubtedly those invented, and so far perfected, by Mr Babbage. That constructed at the expense of government for the calculation of astronomical and nautical tables, is, we believe, not yet completed, in consequence of some misunderstanding, which caused a suspension of its progress in 1833. This employed 120 figures in its calculation. At a later period, Mr Babbage began another on his own account, intended to compute with 4000 figures! Of the former invention, Sir David Brewster, in 1832, speaks in the following terms:—'Of all the machines which have been constructed in modern times, the calculating machine is doubtless the most extraordinary. Pieces of mechanism for performing particular arithmetical operations have been long ago constructed; but these bear no comparison, either in ingenuity or in magnitude, to the grand design conceived, and nearly executed, by Mr Babbage.' Somewhat later, we find a writer in Lardner's Cyclopædia stating that the principle on which this machine was founded was one of a perfectly general nature, and that it was therefore applicable to numerical tables of every kind, and that it was capable not only of computing and printing, with perfect accuracy, an unlimited number of copies of every numerical table which has ever hitherto been wanted, but also that it was capable of printing every table that can ever be required. It appears that the front elevation of the calculating machinery presents seven upright columns, each consisting of eighteen cages of wheelwork, the mechanism of each cage being identically the same, and consisting of two parts, one capable of transmitting addition from the left to the right, and the other capable of transmitting the process of carrying upwards; for it seems that all calculations are by this machinery reduced to the process of addition. There will therefore be one hundred and thirty-six repetitions of the same train of wheelwork, each acting upon the other; and the process of addition with which the pen would be going on successively from figure to figure, will here be performed simultaneously, and—as the mechanism cannot err—with unfailing accuracy. The results of the calculating section are transferred by mechanical means to the printing machinery, and the types are moved by wheelwork, and brought successively into the proper position to leave their impressions on a plate of copper; this copper serving as a mould from which stereotyped plates without limit may be taken.

WATCHES.

Clocks and watches are certainly amongst the most perfect, as, in the civilised world, they are the most indispensable, machines ever produced by human ingenuity. 'To become a good watchmaker,' says Berthoud, 'it is necessary to be an arithmetician, in order to find the revolutions of each wheel; a geometrician, to determine the curve of the teeth; a mechanician, to find the forces that must be applied; and an artist, to be able to put into execution the principles and rules which these sciences prescribe. He must know how fluids resist bodies in motion; the effects of heat and cold on different metals; and, in addition to these acquirements, he must be endowed by nature with a happy genius.' No one who has not closely attended to the matter, can conceive the difficulty which has been experienced even in dividing circles for the wheels of a watch into the requisite number of rigorously equal parts, and in 'pitching' them in, or adjusting them one with another. All the resources of art shown by Ramsden, Troughton, and other eminent mathematical instrument makers, have been here called into requisition. And as to the delicacy of touch and adjustment necessary in the mere regulation of the mechanism, after being thus accurately made and 'pitched in,' some slight idea may be formed from the fact, which we give in the words of Mr Thomson, that 'a second (a mere pulsation) is divided into four or five parts, marked by the vibrations of a watch-balance, and each of these divisions is frequently required to be lessened an exact 2880th part of its momentary duration!' England has great honour in having advanced the art of watch-making to its present high condition.

Before entering upon a description of the various parts, we here present the general arrangement of the wheelwork of a common vertical watch—the frame-plates being omitted, and the dial being supposed to be turned downwards:—B is the *barrel* or drum, containing the spring which produces the motion. F is the *fusee*, connected with the barrel by the chain *c*. W is the *fusee-wheel*, called also the first or great wheel, which turns with the fusee, and works into the pinion



D, called the *centre-wheel pinion:* this centre pinion, with the centre wheel or second wheel D′, turns *once* in an hour. The centre wheel D′ works into the *third-wheel pinion* E; and on the same arbor is E′, the *third wheel*, which gives motion to the fourth or *centrate-wheel pinion* G, and along with it the centrate wheel G′. The teeth of this wheel are placed at right angles to its plane, and act on the pinion H, called the *balance-wheel pinion;* H′ being the balance wheel, or scape wheel, or crown wheel, attached to the same arbor. The balance wheel acts on the two *pallets p, p*, attached to the *verge* or arbor of the *balance* K; and these being placed at a distance from each other, equal to the diameter of the balance wheel, and in different places, receive alternately from the scape wheel an impetus in opposite directions, which keeps up the vibratory motion of the balance. Such is the general arrangement of the powers and motions; we shall now proceed to the analysis:—

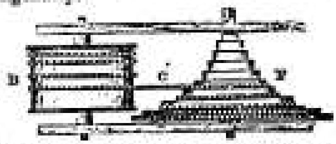
Mainspring and Fusee.

The invention of the mainspring in place of the weight, was the first pre-requisite to the formation of the watch. But although the mainspring was applied as the maintaining power to time-pieces of a very imperfect description, called watches, about the middle of the sixteenth century, and although the balance had, in such instruments as these, assumed its present form of a vibrating ring, with the greatest weight of course accumulated round a circumference, it was not until the spiral hair-spring was applied to the balance, some time after the invention of the pendulum, as a substitute in clocks for the balance itself, that a comparatively useless machine was converted into a time-measurer nearly as accurate, even in its ordinary form, as the pendulum clock. Though the invention of the balance-spring, however, was comparatively an early improvement, and the greatest the watch has ever received, we must pass it over in the meantime, till we briefly describe those parts of the mechanism which first rendered the existence of the watch possible at all.

The *mainspring* consists of a coil of thin elastic steel ribbon, enclosed in a miniature barrel or 'drum,' to the inner side of which the outer end of the coil is fixed, while the inner is fixed to an axis at the centre of the drum, and round which it may be wound or twisted, so as, by its elasticity and recoil, to cause the drum to make as many revolutions as it makes turns itself while it unwinds. Here, then, we have the main power which sets the whole mechanism of the watch in motion. But it is evident that this power, if thus at once applied to the wheels, would cause them to move with less and less rapidity as it became uncoiled, and as its springing power of course became exhausted; so that unless the wheels were so constructed that only the middle turns were required to be in action,

and not those in which it is at its greatest or its least power, a force sufficiently equal even for ordinary purposes could not be thus obtained. French spring-clocks, strange to say, are still, in general, made on this defective principle; but English watches and spring-clocks are supplied with a 'fusee,' which corrects the inequalities of the mainspring with a simplicity only equalled by its ingenuity.

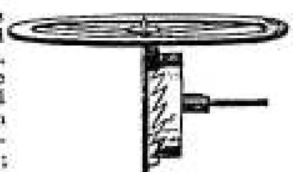
The *fusee* is a cone with a spiral groove, attached to the side of the first wheel of the watch, and connected with the barrel or drum containing the mainspring by a chain, hooked, at its ends, to both. The figure to the right, in the above cut, is the fusee; that to the left is the barrel.



In winding a watch, the key is placed on the axis of the fusee, and the chain is wound off the barrel on to the cone of the fusee. When fully so wound, the spring is at its greatest power of recoil; but the chain being then round the smallest part of the cone, the influence of the spring on the wheels is at its least amount; while, just as the power of the spring relaxes and diminishes, the cone enlarges, and its lever influence hence increases. The fusee, in short, is a variable lever, worked by the mainspring, with more purchase when it has less power, and with less purchase when it has more power. It is a very beautiful contrivance, completely answering the intended purpose, when properly made. By means of a spring contained in the interior of the fusee-wheel, the watch is maintained in motion, while the fusee itself is turned by the watch-key in winding up the mainspring. This is called the *going fusee.* When the watch or spring-clock has no fusee at all (and in very flat watches no fusee *can* be introduced), the barrel is immediately attached to the first wheel. In every case, however, the power of the spring is conveyed through the wheels, by nearly the same arrangement in all watches and clocks, to

The Escapement.

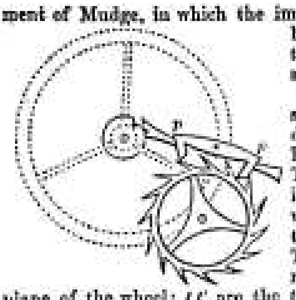
On the peculiar construction of this part of the mechanism, so as best to keep up the vibrations of the balance, the superiority of one watch over another principally depends; though much of course also depends on the skill of the workman, and the quality of his materials, in the construction of *every* part of so delicate a machine. The escapement, however, according to its peculiar form, is that by which the watch is chiefly distinguished:—



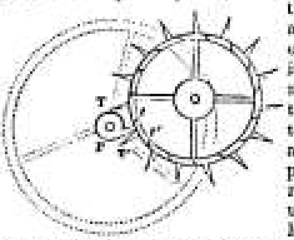
The *vertical watch* is so named from its old vertical escapement. This particular mode of escapement is still made in common watches, where it answers sufficiently well; but when applied to clocks regulated by pendulums, is found to be exceedingly defective. The mechanism of this—the *crown-wheel escapement*, as it is technically called—will be readily understood by reference to the preceding figure.

The *horizontal* or *cylinder watch* is so named from the horizontal escapement of Graham, introduced about the beginning of last century. In this mode of escapement, the impulse is given to a hollow cut in the cylindrical axis of the balance, by teeth of a peculiar form, projecting from a horizontal crown wheel.

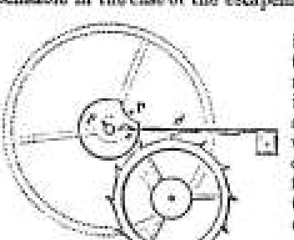
The *lever watch* is so named from the lever escapement of Mudge, in which the impulse is given to the balance by a lever attached to crutch or anchor pallets, *p*, *p*.



The *duplex watch* is so named from the duplex escapement of Hooke, perfected by Tyrer, in which the impulse is given by a wheel furnished with two sets of teeth. T T' are the teeth of repose, lying in the plane of the wheel; *t t'* are the teeth of impulse, and stand perpendicular to the plane of the wheel; P is the impulse pallet, fixed upon the arbor of the balance, immediately above the plane of the wheel, so that its extremity or claw may be caught by the teeth *t t'*, and receive the impulse from them as they successively pass. A small ruby roller is also placed upon the arbor, 'behind the pallet, having a notch in one side of it for receiving the teeth T T'. When the tooth *t* has passed the claw of the pallet, the tooth T falls upon the ruby roller, where it rests, until, by the returning vibration of the balance, the notch is brought to the point of the tooth. The tooth then falls into the notch, and thus passes the roller, and the next impulse tooth *t'* comes up to the pallet, where it acts with great advantage, in consequence of the long lever. As the successive impulses are given in the same direction, the balance necessarily makes two vibrations for each impulse given by the upright tooth. The main advantage of this construction consists in there being only one pallet, and in the action being independent of great accuracy in the execution of the teeth of the 'scape-wheel, which is indispensable in the case of the escapements above described.



The *detached watch* is so named from the detached escapement of Berthoud, improved by Arnold and Earnshaw, in which the vibrations of the balance are free, or detached from the influence of the crown-wheel, unless at the instant when it receives its impulse and unlocking; the wheels standing still till then. In the diagram, P is the main pallet, projecting from the arbor of the balance-wheel, concentric with which is another small pallet *p*, called the *lifting pallet*, which, when the balance is vibrating, lifts a slender spring *s*, so as to set at liberty the tooth held or locked by the detent *d*, which projects from the spring. As in the case of the duplex, the balance here makes two vibrations for each impulse. This mode of escapement, which requires no oil, forms a peculiar feature of the chronometer or marine time-keeper.



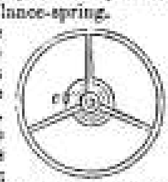
On the respective merits of these different kinds of watches, a few useful hints will be afterwards given. There are many other escapements, but those only now pointed out are in general use.

Balance and Balance-Spring.

These are the only other parts of the mechanism of the watch of which it is necessary here to treat.

The balance, as may be seen from the representations of it in connection with the different escapements just noticed, is a wheel finely poised on its axis; the pivot-holes in which it turns being frequently—in chronometers and clocks, as well as in watches—jewelled, or made of small rubies, diamonds, &c. as those of other of the wheels also are, for the sake of durability. The natural effect of an impulse given to such a wheel would be a complete rotation on its axis. This, however, as we have already seen, is convertible, by various escapements, into a vibratory motion. But as in clocks the pendulum was found to be a most invaluable adjunct, absorbing, as it were, in its own more or less extended oscillation every inequality in the rotation of the wheelwork, or the vibration of the balance, something of precisely the same nature for watch escapements was the great desideratum, when the balance-spring or hair-spring was invented; and, from this analogy, it even acquired the name of the pendulum-spring—improperly so, however, as Reid remarks, especially as there is a pendulum-spring of another description altogether.*

Simple and obvious as the suggestion of the regulative influence of a spring, applied to the vibrating mechanism of the watch-balance, in place of either weight or pendulum, may now appear, especially after the idea of the mainspring, as a substitute for the maintaining weight, had been suggested, this has been held to be a crowning invention in the mechanism of the watch; and the honour of its first suggestion has been claimed by no less than three very eminent men—by Dr Hooke, by Abbé Hautefeuille, a Frenchman, and by Hüygens, the Dutch astronomer. It was ultimately proved, that although Hüygens had applied for a patent at Paris in 1674, Hautefeuille had done so several years before; while Hooke had made a similar application in England in 1658. To Hooke, therefore, must be attributed the first idea of the balance-spring.

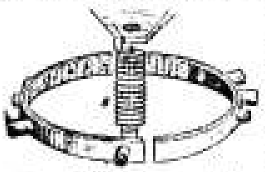


In its application to the balance of a watch, one of the extremities (*c*) of the spring is fastened to a point independent of the balance, while the other is attached near its axis. When the balance is at rest, the spring is inclined neither way, this position being called the point of rest; but when the impulse is given to the balance by the crown wheel of the escapement, it is clear that now a rotatory motion of the balance cannot take place, even though there should be nothing in the form of the escapement to prevent it; the balance will now only move round so far as the impulse given is able to overcome the elastic resistance of the spring; and when that resistance becomes equal to the impulse given, the balance will stop for a moment, and then be driven back by the elastic recoil of the spring, continuing thus to vibrate so long as the impulse is repeated or the watch is in motion.

The recoil of the spring is sufficient to drive back the balance to a distance nearly double the length of its first motion; this is therefore called the long arc of vibration. But when the motion of the balance is free, with a certain length of spring, the *long* arc of vibration is made in less time than the short one, to which the impulse is given: with a spring of greater length this principle is reversed; whence it was concluded by Le Roy and Berthoud, that equality of time, or *isochronism*, in unequal vibrations, could be more easily obtained by lengthening the spring than by tapering it. In principle, too, the stronger and shorter the spring,

* This little instrument, the hair-spring, is no less remarkable for the extreme delicacy of its construction, than for the great value which it shows the possibility of giving to a piece of steel, of exceedingly small and insignificant appearance, by manual labour. Four thousand hair-springs scarcely weigh more than a single ounce, but cost often more than £1000! 'The chisel of the sculptor,' as Mr Thomson justly remarks, 'may add immense value to a block of marble, and the cameo may become of great price from the labour bestowed, but art offers no example wherein the cost of the material is so greatly enhanced by human skill as in the balance-spring.'

the quicker will be its vibrations. Thus effects of an extremely varied description can be produced on the motions of a watch by the slightest difference of length and taper in a hair-spring. And it is thus that the correctness of the time-keeping is essentially dependent on the principle adopted in the formation of this apparently most insignificant little appendage. So much is this the case, that if the hair-spring be isochronal in a free or detached escapement, the time shown will be the same, notwithstanding changes in the motion of the wheels, or even in the power of the mainspring. In England, where time-keepers have been brought to their greatest perfection, it is considered that isochronism is most easily attainable by using the cylindrical helical spring (*s*), which is applied to all marine chronometers.



One of the most recent improvements in watches, or rather in chronometers, has been invented and patented by Mr Dent of London, and consists in coating the balance and balance-spring with *gold* by the electro-metallurgic process (see ELECTRICITY), by which means they are secured from rust. Another invention of the same gentleman is that of balance or hair-springs made of *glass*, which, singular to say, appear decidedly preferable to those of steel, their principal disadvantage being the difficulty of making them with certainty or accuracy.

Compensation.

But let a watch be ever so perfect—in the correction of the inequalities of its mainspring by a fusee mathematically adjusted to it, in the formation and the position or pitching in of all its wheels and pinions, in the principle and execution of its escapement, and even in the accuracy with which its hair-spring vibrates in equal times—still it will vary in the time it indicates *on every change of temperature*, however slight, unless it be *compensated*.

From what we have already stated in treating of the compensation-pendulum in clocks, the intelligent reader will readily appreciate the difficulties to be here overcome, and will probably conclude, that as in clocks the compensation has been effected by means of the pendulum, so in watches it must have been effected by means of the balance-spring or balance. Such is the fact: but as there was no room here, and indeed no analogous opportunity, for the introduction of mercury, the idea of compensation by virtue of the different degrees of expansion in different metals, as in the gridiron pendulum, was the only one that remained to be entertained; and here also the ingenuity of human invention has indeed triumphed; and the method of making compound balances for watches has been justly considered one of the most curious of our metalline manufactures. When completed, the compensation balance consists of a double or compound rim or ring, the outer part of which is of brass, and the inner of steel, to which the brass is added while in a molten state. The opposite sides of this ring are united by a steel bar, the whole of the steel part, indeed, being filed out of one piece of metal. One half of the ring is then cut or filed away at one side of the bar, and the other half at the other side, as represented in the figure last above given; and the balance is loaded either with small screws, as in that figure, or with sliding weights on each half of the ring, in order to regulate the rate of the chronometer or watch. The compensation, then, is thus effected: an increase of temperature *diminishes* the elastic force of the hair-spring, which would cause the machine to *lose* time; but the same degree of heat expands the outer or brazen part of the ring of the balance more than it does the inner or steel part—brass expanding more than steel by heat, and contracting more by cold—and so, not being able to separate, a curvature of the whole arm of the ring *inwards* ensues, which lessens the inertia or checking weight of the balance; so that the hair-spring now *requires* less force to influence it to the same degree as before; and thus its *loss* of power is *compensated*. On the other hand, cold *increases* the elastic force of the hair-spring, which would cause the machine to *gain* time; but the brass contracting more than the steel, curves the arm outwards, and increases the inertia, or resistance of the balance, allowing the spring no more influence over it now than it had before. The screws are turned in or out, or the place of the sliding weights adjusted, by experiments on the rate of the machine; so that if an increase of temperature causes it to gain time, or a decrease to lose, the screws must be turned outwards, or the weights moved farther from the ends of the arms; if the contrary be the case, then of course the contrary changes must be made.

The compensation-curb is another instrument for correcting variations in the rate of going from variations in temperature. It limits or extends the length of movement in the hair-spring itself, by a self-moving action, also caused by a difference in the effect of change of temperature on two different metals, and is called a *curb*, from the name of a small piece of mechanism which operates similarly on the balance-spring in regulating a watch by hand.

CHRONOMETERS.

The term *chronometer* is, properly speaking, applicable to all time-keepers, but it is now more usually applied to marine time-keepers only, which are machines of a size between watches and clocks. Some watches, however, made like chronometers in every respect but in size, are called pocket chronometers. But neither of these are anything else than merely such time-keepers as combine all those chief excellences in horological invention just described, including compensation balance, cylindrical spring, detached escapement, &c. so as to constitute the most accurate time-measurer possible; the purpose of marine chronometers being to discover the longitude at sea; for it is only necessary to ascertain the exact difference in time between two places on different meridians, in order to determine their difference of longitude, or distance eastward or westward of each other. Reverting to what has been already said on this subject under ASTRONOMY, the general reader will at once perceive that so soon as a time-keeper could be made that would keep time with perfect accuracy, such an instrument, set to the time of any seaport, for instance, in Britain—whose precise meridian or longitude was known—and carried abroad in a vessel sailing thence, would afford the means of ascertaining the longitude at sea, by simply observing the instant that the sun reached his meridian there, when of course it would be mid-day, or twelve o'clock noon; and at the same time observing the difference between this time and that shown by the time-keeper, which would necessarily be different if the longitude was different—the amount of the difference giving him his longitude, on the calculation that 15 degrees east or west make *one hour* of time, or 15 geographical miles *one minute*. If, for example, the time-keeper had been set to time at the meridian of Greenwich observatory [where, in fact, chronometers are now usually adjusted, and where a signal hoisted every day on the instant that twelve o'clock strikes, or rather on the instant that the sun arrives at the meridian there, proclaims the true time of day, on that meridian, to all the mariners in sight of it, that they may be able, without trouble or mistake, to adjust their chronometers accordingly], and if it was but eleven o'clock on the time-keeper thus set, while it was of course twelve o'clock or mid-day at the time and place where the meridian was taken at sea, then that place must have been in longitude 15 degrees *west* of the meridian of Greenwich; if, on the other hand, it was one o'clock instead of eleven at that moment, the longitude must have been 15 degrees *east*, not west, of the meridian of Greenwich. By knowing also the time when any particular star passed the meridian at Greenwich, the navigator, in a similar manner, could calculate his longitude by an observation of the same star at sea. Lunar observations, eclipses, or the like, might be made use of on similar principles.

It was a clear perception of the fact, that the longitude might thus be at any time determined, could time-keepers be made to measure time with accuracy, that led Sir Isaac Newton and others to recommend to government the offer of a public reward for the accomplishment of so desirable an object; and it was the hope of reaping the splendid reward of £20,000, which government accordingly did offer, that formed the very mainspring to all those high exertions of horological ingenuity which led to the final success of John Harrison, after an unwearied labour of forty years—a success which, in turn, resulted in the present highly advanced state of horology, the perfection of which, as a most scientific art, is perhaps only paralleled by the perfection of astronomy as a cognate science deeply indebted to it, and indeed to which it is as indispensable, in almost every respect, to the present condition of society.

USEFUL HINTS.

For the attainment of habits of punctuality, for the regulation of the usual routine of business and of everyday life, for the morning's timely arousement and the evening's sufficient repose, and for other and innumerable purposes of convenience, necessity, and pleasure, much, in reality, often depends on the judicious selection of a time-keeper. And even the character of a young man has been known to be much influenced by the quality of his watch, the possessor of an accurate time-keeper becoming ambitious to emulate its excellence, and thus gradually acquiring habits remarkable for punctuality. It is therefore to be regretted—even though in many cases a very indifferent time-keeper may be thought all that is required for general purposes—that no efficient instruction can be given to the inexperienced, especially towards the selection of a watch, as none but a workman possessing the highest knowledge of his art is capable of forming a correct opinion of its relative merits. The hints given by a skilful and practical artist himself, however, who has had years of the most attentive and constant experience, cannot but be deemed invaluable; and as such we would especially recommend to the inexperienced in horology, a popular little volume, published by Messrs Boone of New Bond Street—namely, 'Thomson's Time and Time-Keepers,' for the useful as well as pleasing and interesting instruction with which it is stored.

Amongst many valuable hints for the proper selection of time-keepers contained in Mr Thomson's little volume, we shall take the liberty of briefly instancing the following; and first of clocks:—These, in general, measure time more accurately than watches, especially eight-day weight or long-clocks, which are also cheapest. Long and heavy pendulums are to be preferred. The pendulum should occupy the whole available length of the case, except in regulators, or in pendulums beating seconds. A light pendulum shows a clock to be badly constructed, or deficient in power. Steel rods are better than brass, well-seasoned and varnished wood than steel, and compensation-rods than either. The clock should be steadily fixed to the wall, or firmly placed on *three feet* sufficiently far apart, so that the mechanism may be uninfluenced by the oscillations of the pendulum. Clocks are regulated by lengthening the pendulum, to make them lose, and by shortening it, to make them gain; this is very generally done by turning a nut or screw *below* the weight or *bob* of the pendulum, *to the right to gain, or to the left to lose*; or, if the screw is *above* the weight, the rule is *reversed*. Many French clocks, and a few old English ones, are liable to derangement in striking, unless the hands are moved rapidly *forward*. The hands of English clocks, in general, may be turned either way without injury, and the same with a watch, unless it has an alarum.

An intelligent, careful man, may be safely trusted with the cleaning, adjusting, or repairing of clocks, while a diversity of talent and experience is necessary to qualify him for the manipulation of watches. 'The possessor of a good picture would doubtless inquire into the ability of the artist before he intrusted him to retouch it; and this caution is equally necessary for a watch, as many of the best construction have sustained irreparable injury from the hands of unskilful workmen. Even bad watches (which are by far the greatest number) require the aid of better hands than those which constructed them.' A clever artist may enable even a bad watch to perform tolerably well. Watches should ordinarily be cleaned every second or third year; small, flat, or complicated ones oftener. All require care in handling. They should be regularly wound as nearly at the same hour as possible; and while being wound, should be held steadily in the hand, so as to have no circular motion themselves. When hung up, let the watch have support, and be perfectly at rest; or when laid horizontally, let it be placed on a soft substance for more general support, otherwise the motion of the balance will generate a pendulous motion of the watch, causing much variation in time. Should a watch vary by heat or cold, as when worn or not worn in the pocket, the hands may be set to time; but the regulator should not be altered, if set to the ordinary temperature of the season. Compensation-watches, if properly constructed, do not so vary. A trial even of a year or two is no proof of the substantial worth of a watch. Dealers themselves may be deceived. A duplex watch may be very bad, while a vertical one may be very good, so that workmanship is as important as principle. Many low-priced and bad watches have eight or even ten holes jewelled, while many good and costly ones have but four: a hole can be jewelled for three shillings. 'The high-sounding description, the handsome exterior, the offered trial, and enticing cheapness, are effective baits to the short-sighted.' External ornament forms but a small item of expense, and the prices therefore will, in general, point out the comparative qualities of the work in the shop of an artist of known integrity and ability.

The large thick old watch is less absurd than some recently made little thicker than half-a-crown, or even much smaller, as in the latest and rarest novelty amongst the beautiful and ingenious Genevese watches, some of which little exceed the size of a shilling. The lever watch is capable of great accuracy, and is preferable to the vertical, though the principle of the latter is more generally understood, and more easily repaired; lever watches, however, are neither expensive to repair nor liable to derangement. The horizontal or cylinder watch is liable to great tear and wear, but performs with considerable accuracy. The duplex watch, with a compensation balance, when well constructed, and treated with ordinary care, will keep time with the greatest accuracy; but being delicate, it does not stand violent exercise: a bad duplex watch is most expensive to repair. The detached watch, the escapement of which is the only one used in marine chronometers, is the most perfect, but requires care. Repeaters are expensive to repair as well as to purchase, but may be as accurate as others. Watches showing seconds are often useful, and, if well made, are neither expensive nor easily deranged. A watch may be handsome, yet bad; but a good watch is seldom unsightly. The spring for shutting the shells is not so good as the snap; it often allows dust to penetrate to the works. The covers of hunting-watches will not protect the glass when the hunters are very flat. The extreme accuracy of marine chronometers is partly produced by their being kept constantly in a horizontal position. They are only required to show *equal* time; whether they gain or lose is of little consequence, provided they are regular, and *keep* their known rate.

CHEMISTRY.

THE material world immediately under our observation, including such parts of the earth's crust as have been explored, the plants and animals upon its surface, and the atmosphere which envelops it, is found to consist of fifty-four simple substances, just as all the words which compose a language are resolvable into a few letters. These substances, having hitherto resisted all endeavours to divide or resolve them into any others, are termed the *elements of matter*, or *simple bodies*. By this it is not peremptorily affirmed that there are only fifty-four elementary substances in nature, for, as will hereafter be seen, several others have recently been added to the list; neither is it maintained that these substances are absolutely simple, and incapable of being reduced to fewer elements, or even, as some chemists have hinted, to a single primary element, of which all other bodies are but conditional phases. All that is here meant is, that at present there are upwards of fifty substances which cannot be reduced, by the known processes of chemistry, to any other condition. The investigation of the laws under which these various elementary bodies have formed the numerous compound substances which we see in nature, and the means by which compound substances can be resolved into their original elements, or simple elements thrown into new combinations, are the objects of the science of Chemistry.

The term *chemistry* is of doubtful derivation; but it seems to have been applied at an early period to various methods of melting or preparing metals, and was identified with the visionary efforts of alchemy, which professed to be the art of transmuting copper and other base metals into gold and silver. It is only within the last seventy or eighty years that chemistry has risen to the rank of a science; but during that period, it has advanced towards perfection with a rapidity unparalleled in the history of philosophy. The applications of chemistry are universal. There is no science so immediately conducive to human comfort. To whatever art or manufacture we turn our attention, we find that it has either been created by chemistry, or owes to it some of its greatest improvements. In the present sheet, it is our object to present a simple and intelligible view of the *principles* of this exceedingly important science, reserving its *applications* in the industrial arts for subsequent treatment.

CHEMICAL ATTRACTION.

When particles of different kinds of matter are brought into contact, they frequently unite, and form new substances, differing widely in many instances from those by whose union they have been formed. This is called *chemical attraction*, or *chemical affinity*; because it is said that the particles of certain bodies, having an affinity for each other, will unite, while others, having no affinity, do not readily enter into union. It might almost be supposed that there are such things as preferences and dislikes among the particles of matter. Thus if a piece of marble be thrown into vitriol or sulphuric acid, their particles will unite with great rapidity and commotion, and there will result a compound differing in all respects from the acid or the marble. This is at once an instance of affinity between two substances, and an exhibition of stronger and weaker affinity. The commotion or effervescence in the experiment arises from the disengagement of a gaseous (carbonic) acid in combination with the basis of the marble, in consequence of the sulphuric acid having a stronger affinity for it. When a piece of caustic magnesia is thrown into vitriol, we have a case of simple affinity, with a complete change also of properties. Both the vitriol and magnesia are eminently hurtful to life. All their elements combine, without any disengagement, and the result is the production of Epsom salts, a compound with properties entirely new. Neither ingredient has been destroyed; they can again be extracted pure from the compound; but they have changed their characters through the force of affinity. But if a piece of quartz or gold be thrown into the acid, no change is produced in either, because the particles of the respective substances have no affinity for each other.

This process of affinity is termed in chemical language *combination*, and is quite distinct from *aggregation*, which is the union of particles of a similar kind, forming a mass which has the general properties of the particles of which it is composed, whatever may be its structure or form. It is also to be distinguished from *mixture*, in which the particles, although they may be intimately blended, are not, as it were, amalgamated with each other, so as to lose their own individual properties. The difference between combination and mixture will be clearly seen from the following example:— If into a crystal bottle we pour a quantity of oil and a quantity of water, and shake them well, the two substances can never be made to unite permanently together. Although they appear to do so for a short while after the experiment is made, yet if the vessel be allowed to stand for a sufficient length of time, the particles of water, being heavier than those of oil, will descend to the bottom, whilst those of the oil will settle upon the top. Here it is evident that no chemical attraction has been exerted between the particles of the two bodies, because no chemical change has taken place. In a word, there has been a mechanical mixture, without any chemical combination. But if with the water in this experiment we mix a quantity of potash, so as to form a pretty strong solution, the results will be very different: the particles of the bodies will intimately combine with each other, and a compound will be formed having properties entirely different from either the oil or the potash. The compound substance thus obtained is the useful article soap; and if its water be evaporated by the application of heat, it assumes a solid consistency, as in the form in which it is commonly used for domestic purposes.

It sometimes happens that two bodies will readily combine with each other, but if a third body be added, the combination will be destroyed; the first of the two bodies having a stronger affinity for the third than it had for the second. Thus if magnesia be dissolved in nitric acid, a complete union takes place; but if lime be added to the compound, the nitric acid unites with the lime in preference, and the magnesia, which was formerly invisible, falls, or is *precipitated*, to the bottom of the vessel. Again, if a piece of aqueous sulphate of copper (common blue vitriol) be suspended by a thread in a glassful of water, the crystals shortly disappear, and the whole fluid becomes tinged with blue. Here the solid is said to be *dissolved*—that is, the cohesion of its particles is destroyed, and the compound is called a *solution* of the solid. Such a solution differs entirely from chemical union, and is merely a very perfect mechanical mixture—the same as if we had dissolved sugar in water, or salt in water. The restoration of cohesion to a body after it has been deprived of it, is exhibited in a great variety of instances. For example, if a quantity of sugar be dissolved in water, and the solution be allowed to stand till the water has evaporated, the attraction of cohesion will take effect between the particles of the sugar, which will again resume the solid form. Here, however, a remarkable circumstance has occurred: whatever the state of the sugar may have been originally, it invariably, in resuming its solidity, assumes a particular form, one of great regularity and beauty. It was formerly opaque, it is now transparent; originally a shapeless mass, it is now a prism of six sides, surpassing in lustre and symmetry the products of the lapidary's wheel. This solid spontaneous production is called a *Crystal;* the process by which it is produced, *Crystallisation;* and the science, the object of which is to study the forms of crystals, *Crystallography.*

Bodies, whether solid, liquid, or gaseous, are susceptible of assuming the *crystalline form*, and the substances which do so are numberless. The shapes which the crystals take, and the facility with which they assume them, are various. Instances of crystallisation, such as sea-salt, Epsom salts, saltpetre, are familiar to every one. Water, it is well known, when cooled to a certain degree, assumes the form of ice, which is crystalline. There are three methods of producing artificial crystals: first, by dissolving the substance in a hot liquid, and either allowing the solution to cool, or evaporating it by continued heat; second, by making the substance assume the aërial form; and third, by melting it by fire without the presence of a liquid, and allowing it to cool slowly. The two first are the most common methods of forming crystals, and by the third, sulphur, spermaceti, bismuth, &c. may be made to assume the crystalline state. If as much alum be put into boiling water as the water will readily dissolve, crystals will be deposited as soon as the liquid cools. The presence of the atmosphere has considerable influence upon the formation of crystals. If as great a quantity of Glauber salt (sulphate of soda) be dissolved in a flask half filled with boiling water as the water will hold in solution, and the flask be corked, no crystals will be formed as the liquid cools. Remove the cork, however, and crystallisation commences as the air enters, a solid crystalline mass being almost instantaneously formed. If the weather is warm, crystallisation will not perhaps take place even after the solution is cool. In this case the introduction of a small crystal into the flask will instantly induce the process of crystallisation.

The same body does not invariably exhibit the same form of crystals; there may be several forms of crystals belonging to one body, but in one or other of these it is sure to crystallise, and not according to any other form. It is also to be observed that very different kinds of matter may crystallise after the same model.

The general name for the substance formed by chemical attraction is a *compound*; the substances of which it is composed are called its component or *constituent parts* or principles. The separation of these is termed *decomposition*; and when decomposition is performed for the purpose of ascertaining the ultimate composition of a body, it is named *chemical analysis*. The reunion of the constituent parts is denominated *chemical synthesis*. Integrant particles of a body differ from the constituent particles thus:—The latter are the most minute parts into which a compound body can be resolved by decomposition, and are hence of a different nature, both with regard to each other, and the substance itself which their mutual union gives rise to. The integrant particles are the most minute parts into which any body can be resolved *without* decomposition.

LAWS OF COMBINATION AND DECOMPOSITION.

There are various laws connected with, and phenomena attendant upon, chemical attraction. While of course it can operate only between bodies of a different nature, the qualities which characterise these bodies when separate are changed or annihilated by their combination. Thus not only their active properties, but their density, temperature, form, colour, taste, smell, and sonorousness, are generally affected. Chemical attraction can take place between two, three, or even a greater number of bodies. The force of chemical affinity between the constituents of a body, is estimated by that which is requisite for their separation. It has been already remarked that the degree of attraction varies very considerably in different bodies; and it is evident that from this variation all chemical compositions and decompositions take place. The preference of uniting with another substance which any given body is found to exercise, is metaphorically termed *elective attraction*, or *affinity*. It is of two kinds, each of which derives its appellation from the number and the powers of the principles which may be brought into contact with each other. When a simple substance is presented to a compound one, and unites with one of the constituents of the latter, so as to separate it from that with which it is combined, and by this means producing a decomposition, it is said to be effected by *single elective affinity*. Some substances, however, will not be thus easily decomposed; and it is found necessary to introduce two or more principles, in order to effect the end in view. When two principles, therefore, are presented to a compound body, and when the principles unite each with one of those of the compound substance, two new substances are formed; and all instances of decomposition in this manner are said to be effected by *double elective affinity.* It is to be observed that all changes effected in this manner are permanent, and that the new compound thus formed cannot be decomposed, until a substance having a more powerful attraction for one of its constituents than they have for each other is brought into contact with them.

To Sir Isaac Newton we are indebted for the first attempt at a rational explanation of chemical combination. He was of opinion that the minute atoms of certain bodies attract each other with an unknown but enormous force, which begins to exert itself only when the particles are at very small distances from each other, and that, accordingly, this force exerts itself, and the bodies unite, when they are brought within the requisite distance. These views slowly made their way into the science; but towards the middle of the eighteenth century, they seem to have been almost universally adopted. The term chemical affinity was substituted for that of attraction, and the strength of the affinity existing in bodies came to be measured according to the order in which they were decomposed. It is unnecessary to mention the various tables of affinity which were published previously to that of Bergman, who, in 1775, gave to the world a copious table of affinities, and appears to have fixed the opinions of chemists in general to his own views of the subject. According to this philosopher, the affinity of each of the bodies, say *a*, *b*, *c*, *d*, for *x*, differs in intensity in such a manner, that the degree of affinity in each may be expressed by numbers. He supposed affinity to be elective, in consequence of which, if *a* have a greater affinity for *x* than *b*, if *a* be presented to the compound *b x*, a decomposition will ensue, *b* will be set at liberty, and a new compound *a x* will be formed.

ATOMIC THEORY.

This theory was not discovered all at once, and immediately acknowledged by chemists; it was gradually brought to light by the repeated experiments of successive philosophers, of whose labours, however, it will be impossible to exhibit a view in this place. To our countryman Dalton, we are indebted for the first development and demonstration of the fact, that bodies unite in definite proportions; and of which we shall now attempt to present the reader with as clear and simple a view as possible. Whilst engaged in determining the composition of the two gases called severally carburetted hydrogen and olefiant gas, he discovered that for complete combustion they require *different* but *determinate* quantities of oxygen gas. One volume—that is, any stated measure—of carburetted hydrogen requires two volumes of oxygen gas, whilst a volume of olefiant gas requires three.

The conclusions at which Dalton arrived are, that bodies consist of *atoms*, incapable of further diminution or division; that in chemical combinations it is these ultimate particles which unite; and that in the case above mentioned of the combustion of the two inflammable gases, carburetted hydrogen is a compound of one atom of hydrogen and one atom of carbon; whilst olefiant gas is a compound of one atom of hydrogen and *two* atoms of carbon. The atoms he considered as spheres, and represented them by such symbols as a circle with a dot in the centre, a circle with a vertical diameter, and the like. In this manner the composition of a number of the best known bodies was represented by him, and the ratios of the weights of the atoms of the simple bodies inferred. For instance, he concluded from his experiments that carburetted hydrogen is composed of—hydrogen one, and carbon six; while olefiant gas is composed of—hydrogen one, and carbon twelve. Now, as the former gas consists of one atom of hydrogen and one atom of carbon, then the weights of these atoms are to each other in the relation of one to six. If the weight of the atom of hydrogen, therefore, be represented by one, that of carbon will be six. In this manner the ratios of the weight of the atoms of all the simple bodies may be ascertained by a careful analysis of the compounds formed by their union.

The combinations of mercury or quicksilver with some other bodies, afford an illustration of the theory. Its first compound with oxygen, one of the gases of which the atmosphere is composed, consists of two hundred and two parts of mercury, and eight of oxygen. If, however, the metal be subjected to a considerable degree of heat, it will be converted into a red shining mass, which is also a compound of the metal with oxygen; but in the latter case, sixteen parts of oxygen have united with the two hundred and two parts of the metal. The explanation of this is, that eight is the chemical equivalent of oxygen, and two hundred and two of mercury. In every successive compound which they make, their proportions form a multiple of these equivalents. Every other simple body has, in like manner, its equivalent number, and to its compounds the same rule applies. Innumerable instances of this might be adduced, but these are sufficient to prove the remarkable truth, that when different substances combine by chemical attraction, the proportions of the ingredients are always uniform; that for every atom present of one substance, there is exactly one, or two, or three, &c. of the other. If, for instance, any quantity of sulphur, intermediate between the two combinations of that substance with mercury, be added, it will not combine with it, but remain as a foreign ingredient in the sulphuret of mercury, as the compound is termed. All bodies, however, do not unite in several proportions, thus giving rise to several distinct compounds from two elements; there are many elementary bodies which will only unite with each other in one proportion, so that any two of such substances can only form one compound. This law, however, is not universal, as it is well known that water and alcohol, and water and sulphuric acid, will unite in any proportions. Water will also unite in any proportion with soluble salt, until it becomes completely saturated. Bodies which unite in any proportions form an infinite variety of compounds, and are distinguished by their being united by a weak affinity, and also by the compounds formed differing little from their simple constituents or from each other.

These remarks must be held as applying to *inorganic chemistry* chiefly; *organic chemistry*, or that which treats of the properties of vegetable and animal substances, presents many exceptions to the principles of combination now laid down.

EQUIVALENT RATIOS—SYMBOLS—CLASSES.

The result of investigations of chemical unions has been the formation of scales exhibiting the equivalent ratios of the simple elements, expressed in numbers. For this purpose it is evident that some body must be fixed upon, and expressed by unity. Hydrogen gas, being the lightest known body in nature, and combining in the smallest proportion by weight with the other simple substances, has been taken as a standard of comparison for the combining proportions or *equivalent numbers* of all other bodies; and which, in all likelihood, are simple multiples of its number. Oxygen has also, by some chemists, been taken as the standard of comparison, and represented by ten. Water is a compound of eight parts by weight of oxygen, with one part by weight of hydrogen; which two gaseous bodies we shall afterwards describe. Whenever hydrogen and oxygen gases are burnt in any proportion whatsoever, they invariably form water; and they cannot be made to combine directly in any other proportion. From this, Dalton concluded that water is a compound of one atom of hydrogen and one atom of oxygen. But the weight of the latter gas being eight times that of the former, then it followed that the atom of oxygen was just eight times heavier than the atom of hydrogen. Hence if the latter be represented by one, then will the former be represented by eight, according to those who take hydrogen as the standard. Those who take oxygen as the standard, and represent it by 10, make the equivalent for hydrogen 1·25: the result is of course the same, the proportion of 1·25 to 10 being exactly the same as that of 1 to 8. These observations relative to water lead us to speak of the doctrine of volumes, so generally embraced by chemists upon the continent. The union of gases is always effected in simple proportions of their volumes; and a volume of one gas combines with an equal volume, or twice or three times the volume, of another gas; and in no intermediate proportion.

'The impracticability in many cases,' says Turner, 'of contriving convenient names expressive of the constitution of chemical compounds, especially of minerals, suggested the employment of *symbols* as an abbreviated mode of denoting the composition of bodies. It was thought that the names of elementary substances, instead of being written at full length, might often be more conveniently indicated by the first letter of their names; and that the combination of elements with each other might be expressed by placing together, in some way to be agreed on, the letters which represent them. The advantage of such a symbolic language was felt so strongly by Berzelius, that he some years ago contrived a set of symbols, which he has since used extensively in his writings; and other eminent chemists, as well as mineralogists, believing symbols to be useful, adopted those which Berzelius used. The consequence is, that symbolic expressions, called *chemical formulæ*, are now almost universally employed in the language of chemistry.' The following table exhibits at once the names, symbols, and equivalents of the commonly admitted elements:—

Elements.	*Symb.*	*Equiv.*	*Elements.*	*Symb.*	*Equiv.*
Aluminium, -	Al.	13·7	Molybdenum,	Mo.	47·96
Antimony, (Lat. *Stibium*), -	Sb.	64·6	Nickel, - -	Ni.	29·5
Arsenic, -	As.	37·7	Nitrogen, -	N.	14·5
Barium, - -	Ba.	68·7	Osmium, - -	Os.	99·7
Bismuth, -	Bi.	213·	Oxygen, - -	O.	8·
Boron, - -	Bo.	10·9	Palladium, - -	Pa.	53·3
Bromine, -	Br.	78·4	Phosphorus, -	P.	15·7
Cadmium, - -	Cd.	55·8	Platinum, -	Pt.	98·8
Calcium, -	Ca.	20·5	Potassium (Lat. *Kalium*), -	K.	39·13
Carbon, - -	C.	6·12	Rhodium, -	R.	52·2
Cerium, -	Ce.	46·	Selenium, - -	Se.	39·6
Chlorine, - -	Cl.	35·42	Silicon, -	Si.	7·5
Chromium, -	Cr.	28·	Silver (*Argentum*),	Ag.	108·
Cobalt, - -	Co.	29·5	Sodium or Natrium, - -	Na.	23·3
Columbium or Tantalum, -	Ta.		Strontium, -	Sr.	43·8
Copper (*Cuprum*),	Cu.	31·6	Sulphur, - -	S.	16·1
Fluorine, -	F.	18·68	Tellurium, -	Te.	64·2
Glucinium, -	G.	17·7	Thorium, - -	Th.	59·6
Gold (*Aurum*),	Au.	199·2	Tin (*Stannum*),	Sn.	58·9
Hydrogen, -	H.	1·	Titanium, -	Ti.	24·3
Iodine, - -	I.	126·3	Tungsten or Wolfram, -	W.	94·8
Iridium, - -	Ir.	98·8	Vanadium, -	V.	68·6
Iron (*Ferrum*),	Fe.	28·	Uranium, -	U.	217·
Lead (*Plumbum*),	Pb.	103·6	Yttrium, - -	Y.	32·2
Lithium, - -	Li.	6·	Zinc, - -	Zn.	32·3
Magnesium, -	Mg.	12·7	Zirconium, -	Zr.	33·7
Manganese, -	Mn.	27·7			
Mercury (*Hydrargyrum*), -	Hg.	202·			

, We exclude *Didymium*, *Erbium*, *Terbium*, *Lantanium*, *Niobium*, *Pelopium*, and *Ruthenium*—substances of very recent discovery, but by many now admitted as established elements. Their symbols are respectively D. E. T. La. Nb. Pe. and Ru.

Applying these symbols, HO or H + O represents water—that is, one equivalent of hydrogen and one of oxygen; S + 3O, sulphuric acid—that is, one equivalent of sulphur and three of oxygen; and in the same manner N + 5O, nitric acid; H + Cl, hydrochloric acid; and so on. The brevity and lucidity of the system is admirable; and to a practised chemical eye, a few lines of properly-constructed formulæ may convey more information than pages of description, and with less risk of misconception and error.

For the convenience of study, the fifty-four elementary substances have been arranged into classes. One system of classification, and that which we adopt, is dependent upon the elements being metallic or non-metallic. 1st, The NON-METALLIC elements are thirteen in number—namely, oxygen, hydrogen, nitrogen, chlorine, bromine, iodine, fluorine, carbon, boron, silicon, sulphur, selenium, and phosphorus. The first three are termed *gazolytes*, or bodies which are permanently gaseous; the next four *halogens*, or bodies which produce salts when in union with the metals; and the remaining six *metalloids*, or bodies which resemble the metals in the chemical relations. Oxygen, chlorine, bromine, iodine, and fluorine, having a tendency to combine with almost all other substances, and their union being generally accompanied by light and heat, have hence been termed *supporters of combustion*. Some of the other non-metallic elements, instead of supporting the combustion of others, are themselves combustible; and from their property of generally forming acids, when combined with the supporters of combustion, have been termed *acidifiable bases*. Those bodies which, when united with the supporters, become alkalies, have been called *alkalifiable bases*. 2d, The METALLIC elements are forty-one in number—namely, potassium, sodium, lithium, calcium, barium, strontium, magnesium, aluminium, thorium, glucinium, zirconium, yttrium, manganese, zinc, iron, tin, cadmium, cobalt, nickel, arsenic, chromium, vanadium, molybdenum, tungsten, columbium, antimony, uranium, cerium, bismuth, titanium, tellurium, copper, lead, mercury, silver, gold, platinum, paladium, rhodium, osmium, iridium. Of these the first twelve, combined with oxygen, form the alkalies and earth, and are therefore distinguished as the *metallic bases of the alkalies and earths*; the remaining twenty-nine are subdivided according to the effects which they produce upon water at a red heat, and to the effects produced by heat upon their oxides. Thus seven decompose water at a red heat; fourteen of them do not decompose water at any temperature, nor can their oxides be reduced by the sole action of heat; and the remaining eight are metals whose oxides can be reduced by a red heat.

ACIDS, SALTS, METALLIC OXIDES, EARTHS, ALKALIES.

Acids are a most important class of chemical compounds, and have the following characteristic properties:—The greater number of them have a sour taste, and are very corrosive. With few exceptions, they change vegetable blues to red, they are mostly soluble in water, and they unite with the alkalies, earths, and metallic oxides, forming what are called *salts*—an order of bodies of the highest importance in the arts, manufactures, &c. Some acids are destitute of a sour taste, but their affinity for the three classes of bodies above named is a universal characteristic. Acids are all compound bodies, and some of them have more than one *basis* or radical. There are a number of acidifying principles, but oxygen (which shall be immediately described) is the most extensive one. The acid is distinguished by the name of its base, and its degree of oxidation—that is, the quantity of oxygen it contains, by the termination of that name in *ous* or *ic*, or the prefix *hypo* (under). The highest degree of oxygenation is marked by the termination *ic*, as nitric acid, and the salt which is formed from it is made to terminate in *ate*, as nitrate of potash; the next by that of *ous*, as nitrous acid, and the salt which is formed from it is made to terminate in *ite*; and the lowest by *hypo*, as the hyponitrous acid. Sometimes oxygen combines in a greater quantity with the acidifiable radicals, in which case the product is said to be superoxygenated. All acids are not susceptible of these various degrees of oxygenation, some being limited to only one. There are a considerable number of acids, and the number is continually increasing by the discovery of new ones; but of the most important there are few, and these we shall notice as we come to treat of their bases.

A *salt* is the term usually employed to denote a compound, in definite proportions, of acid matter with an alkali, earth, or metallic oxide. When the proportions of the constituents are so adjusted that the resulting substance does not affect the colour of infusion of litmus or red cabbage, it is then called a *neutral* salt, because the peculiar powers of both bodies are suspended and concealed; they are rendered neutral or inactive. When bodies combine in such a way as to satisfy their mutual affinities, they are said to *saturate* each other. When the predominance of acid is evinced by the red of these infusions, the salt is said to be acidulous, and the prefix *super* or *bi* is used to indicate this excess of acid. If, on the contrary, the acid matter is deficient, or short of the quantity necessary for neutralising the alkalinity of the base, the salt is then said to be with excess of base, and the prefix *sub* is attached to its name. These must be understood, however, only as general rules. There are exceptions to be found in the case of some salts, as the compounds formed by an acid and an alkali, an earth, or a metallic oxide, are denominated. For example, a certain salt formed by nitric acid and lead, though the acid be perfectly neutralised, reddens vegetable blues; and a salt formed by boracic acid with soda retains the powers of an alkali, in the respect in question, though with a double proportion of acid in it. A *double salt* is a compound of two salts—as, for example, tartrate of potassa combined with tartrate of soda; and a *triple salt* is a compound of three salts.

Metals, such as iron, copper, lead, &c. are familiarly known to every one, but there are a great many others which are very rarely to be met with. The following are some of the characters which distinguish metals from other bodies:—They are for the most part hard and heavy, and are all opaque; insoluble in water; they possess a peculiar lustre; admit of being so highly polished as to reflect light; are capable of being melted by heat, and of recovering their solidity by cooling; most of them may be extended by hammering, and all are rapid conductors of electricity. They are of various colours, and require different degrees of heat to fuse or melt them. They generally occur in the earth in what are called *veins*, and are seldom found in the pure metallic state, but generally in combination with some other substance, in which state they are called *ores*. The metals, which are all simple bodies, will be individually noticed afterwards. (See also METALS AND METALLURGY.) Most of them, when subjected to heat until they become melted, combine with the oxygen of the atmosphere, and form what are called *oxides*. Oxides are destitute of those properties which distinguish the metal from which they are formed. Instead of being bright, shining, elastic, and ductile substances, they are generally a dry, earthy-looking powder. Other substances, besides metals, however, are capable of being converted into oxides; and it must be kept distinctly in view, that in every case there is not so much oxygen imparted as will produce *acidification*. Oxygen frequently combines in various proportions with a substance, rendering it an oxide, but without advancing it to the state of an acid. In order to distinguish each compound thus formed, the language of chemistry is very systematic. The first is called a *protoxide*; the second, a *deutoxide* or *binoxide*; the third a *tritoxide* or *teroxide*; and the highest degree of oxidation a *peroxide*. The Latin term *sesqui* (one and a half) denotes that the elements exist in a compound, in the ratio of one and a half—as the sesqui-carbonate of ammonia, When a simple non-metallic substance combines with another, with a metal, or with a metallic oxide, the name of the compound terminates in *uret*—as carburet of iron, sulphuret of mercury, &c.

The term *Earths* was formerly, and is still, but in a modified sense, applied to several substances which compose all the various rocky substances, clays, and soils, which constitute the crust of the globe. They are tasteless, inodorous, dry, uninflammable, sparingly soluble, difficult of fusion, and of moderate specific gravity. These bodies will be more particularly described when we come to treat of their metallic bases.

Alkalies may be defined as bodies which combine with acids so as to impair or neutralise their activity, and produce what are called salts. They are distinguished by properties the reverse of acids, and the two classes are generally looked upon as antagonist substances. Besides the power of neutralising acids, there are four alkalies—namely, potash, soda, ammonia, and lithia—which possess the following properties in a high degree: They change vegetable blue to green, red to purple, and yellow to a reddish brown; they have an acrid and urinous taste; they are powerful corrosives of animal matter, with which they combine so as to produce neutrality; they also unite with oils and fats, forming the well-known substance soap; they combine with water and alcohol in any proportion. Four of the earths—namely, lime, baryta, strontia, and magnesia—possess alkaline properties to a considerable extent, and are hence called *alkaline earths*. These bodies differ from the pure alkalies, inasmuch as they become insoluble in water when neutralised by carbonic acid. Moreover, alkalies possess the power of changing vegetable colours *after* being saturated with carbonic acid, and by this criterion they are distinguished from alkaline earths.

It was long observed that the properties of earths very nearly resemble those of the compounds of oxygen and metals called metallic oxides; but it remained for the brilliant genius of Sir Humphry Davy to show that both the earths and alkalies are metallic oxides. It thus appears, then, that the globe is one vast mass of various kinds of metals, disguised by various substances, but chiefly by oxygen. Earths and alkalies are simply metallic oxides; whilst a further impregnation of these substances with oxygen produces an acid; and, lastly, the union of acids with alkalies, &c. gives rise to that very numerous and important class of substances called salts.

ACTION OF THE IMPONDERABLES.

Before proceeding to the consideration of the individual elements, it will be necessary to advert to the influence which the *imponderables*—heat, light, and electricity—exercise over chemical phenomena. Referring to MATTER, OPTICS, and ELECTRICITY, where these agents are treated at length, we shall here merely recapitulate:—In our investigations of the phenomena of the material universe, we perceive two kinds of motion, which result from the two principles *attraction* and *repulsion*. Of the former we have already spoken; repulsion, like attraction, takes place both at sensible and insensible distances. The former is exemplified by the flying off of the same light bodies which have been first attracted, after they have been some time in contact with a piece of excited resin or glass, and also by the recession from each other of the two similar ends of two magnetised needles. Repulsion at insensible distances, which is chiefly excited by heat, or, as it is chemically termed, *caloric*, is exhibited in a variety of phenomena.

The principal effects of heat are expansion, liquefaction, vaporisation, evaporation, and ignition. With few exceptions, bodies are capable of *expansion* by means of heat; the gases being the most expansive, fluids less so, and solids least of all. The general law, therefore, is, that the expansion and contraction of matter are, with a few exceptions, dependent upon the increase and diminution of heat. The quantity or condition of heat that is discoverable by the thermometer, or by the organs of sensation, is called *temperature*. We are unacquainted with the extremes of temperature relative either to heat or cold. It has been compared to a chain, the extremities of which are concealed from view, whilst only a few of the middle links are exposed to observation. Although the universal result of an increase of temperature is an increase of bulk to the body thus subjected to heat, yet all bodies are not alike expanded by the application of the same quantity of heat. It of course follows as a general law, that different bodies at equal temperatures do not contain the same quantities of caloric. This quality of matter is called the *capacity* of bodies for heat, and the quantity of heat which is necessary to raise any particular body to a certain temperature, is called its *specific* caloric. Heat, however, in some cases, causes contraction instead of expansion. Thus water is of greater bulk at a temperature of 32° (the freezing-point) than it is at 39½°; and in like manner with the earth, alumina, to be afterwards described. Some solids also—as iron, antimony, bismuth, and many salts—contract when melted, and expand as they become solid.

The rapid production of a thin vapour, as when water is converted into steam, is termed *vaporisation*. The boiling-point of water, in a vessel exposed to the ordinary atmospheric pressure, is 212°, and although more heat be applied to the vessel in which it is contained, the temperature of the water is not increased. If this degree of heat be continued, the watery particles separate from each other, and become steam or vapour. Steam is colourless, transparent, and invisible, resembling the atmosphere, and is 1696 times greater in bulk than water. Water can be made to boil at a lower temperature than 212° by removing the pressure of the air. If a flask be half filled with water, the water made to boil, and as the steam escapes, a cork be put into the mouth of the flask, upon the heat being removed, the water will continue to boil, the heat in it being sufficient for that purpose when there is no pressure from the air. If the flask be put into cold water, the boiling will increase, from the steam being more effectually condensed; whereas, if the flask be put into boiling water, so as to prevent the condensation of the steam, the ebullition will immediately cease. Liquid substances give off vapour from their surface at temperatures below the boiling-point, which is termed *evaporation*. It is called spontaneous evaporation when this takes place at the ordinary temperature of the atmosphere. A large quantity of vapour is given off from the surface of the earth and sea, which eventually forms clouds, or is condensed into rain and dew. Evaporation always produces cold when heat is not applied; the heat necessary for it being derived from surrounding objects.

All substances become luminous when heated to 800° in the dark, and 1000° in daylight, unless they are converted into vapour at a less elevated temperature. The light is red at first, and in this state a body is said to be in a state of *ignition*. If more heat is applied, the body becomes white, when it is said to be *incandescent*.

When a body changes from the solid to the fluid state, there is a quantity of heat absorbed, which has no effect in raising the temperature. This has been called *latent* heat, a discovery effected by Dr Black, and which we shall shortly explain. For a demonstration of this doctrine, we may have recourse to water. If ice, at a temperature below 32°, be exposed to a warmer atmosphere, it receives caloric, and gradually rises to that point of the thermometrical scale. But as soon as it reaches it, the rise of temperature ceases, the ice begins to melt, and during the whole period of its liquefaction, its temperature, as also that of the water flowing from it, remains stationary at 32°. It is evident that, as caloric has continued to be communicated, a quantity of it has disappeared, and become absorbed during the fusion. The same phenomenon takes place when a liquid is converted into vapour; and the inference drawn from it is, that when a body passes from one state into another, a quantity of heat, or caloric, is lost, becomes latent, or passes into the body without raising its temperature. Dr Black was of opinion that this latent heat became chemically combined with the solid, and was the cause of fluidity. Dr Irvine, his pupil, took a different view of the subject. He supposed that the absorption of heat into the latent state is not the cause of liquefaction and vaporisation, but the effect. The absorption he attributed to what is called change of capacity for heat, or that quality of matter which causes one kind to be more or less heated than another, by the addition of the same quantity of heat. He concluded, as a general law, that the capacity of all solids for heat is increased by fusion, and that of all fluids by evaporisation.

Combustion is a process not yet perfectly understood. It is usually described as the union of a *combustible body* with a *supporter of combustion*, attended with the evolution of *light* and *heat*. The combustible body is that which *burns*, but in general will neither support combustion nor burn, except in presence of a supporter of combustion. The supporter, again, does not itself burn, though necessary to the burning of a combustible. Oxygen gas, the ingredient which enables the air to support combustion, possesses, when pure, a high degree of the supporting quality. If a lighted taper, a combustible body, be plunged into this gas, the taper burns vividly, but the *gas* itself is not ignited. If, on the other hand, the taper be plunged into a combustible gas, such as pure coal gas, the gas is instantly ignited, but the taper is extinguished. These are general rules, relating to supporters of combustion and combustible bodies. By examining the effects of combustion, in the case of a candle burning in the air of the atmosphere, it has been proved pretty clearly that a chemical action of the following kind takes place:—The combustible matter of the candle consists chiefly of two simple bodies—hydrogen gas and carbon—while oxygen is the supporter of combustion in the air. On burning a candle under a bell-shaped glass, filled with common air, a fluid gathers on the glass, which proves, on examination, to be pure water. The hydrogen of the burning body has here entered into combination with part of the oxygen of the air, forming water, a compound of the two. The carbon of the burning body also enters into union with a portion of the atmospheric oxygen, forming carbonic acid gas, which is left floating in place of the original quantity of oxygen. The presence of these can be proved, and the same process takes place in the case of coal, wood, &c. Thus it is seen that combustion only changes the forms of the burned bodies, and does not annihilate them. The phenomena of combustion are thus so far explicable, but unfortunately the source of the *light* and *heat* yet remains a mystery. It is unknown whether the chemical action is the cause of the light and heat being evolved, or the evolution of these the cause of the chemical action. Where all is doubt, it would be vain to dwell on this point. The laws stated respecting combustible bodies, and supporters of combustion, only apply generally, it is also to be observed, and under ordinary circumstances. Under the oxy-hydrogen blowpipe, the most incombustible bodies can be made combustible; and combustion can be shown to take place under an exhausted receiver, without the presence of any supporter, at least of a gaseous kind.

The nature of *light*, and the laws which determine its radiation, reflection, refraction, and so forth, have been fully explained under the science of Optics: here we can only take notice of its more prominent chemical relations. The connection between light and heat is so obvious, that it is scarcely possible to examine the one independently of the other. If a mass of iron be put into a fire for some time, no change is produced, except the expansion of the metal, and the elevation of its temperature. Gradually, however, as the heat is communicated, a remarkable occurrence will be observed: the iron becomes ignited, or red-hot; in other words, it emits light, and renders objects visible. The prime source of light is the sun, yielding what is termed *solar light*; all kinds of artificial light—as that from fires, candles, &c.—is called *terrestrial* light. Light passes freely through the atmosphere, and striking upon objects, is reflected, or thrown back by them; and thus they become visible. By means of a wedge of glass called a prism, light can be separated into seven colours, which are violet, indigo, blue, green, yellow, orange, and red. Light, taking the common acceptation of the term, is resolvable also into *luminous*, *calorific*, and *chemical* rays. Thus the heat of the sun's rays may be absorbed, or intercepted, without affecting their luminous properties, and so certain rays can be separated from their light; and their heat and light can also be intercepted so as to leave a principle which excites neither heat nor light, but which produces very remarkable chemical changes.

The chemical influence of light is conspicuous in a variety of natural and artificial processes. In vegetation it is indispensable, as without it plants do not acquire their due elementary constitution. They are weakly, inodorous, and fail to exhibit their natural colours and products. Vegetables which grow in the dark have a blanched appearance. The power of light to dispel vegetable colours is manifest in bleaching, where a dingy web becomes pure and white by exposure to the sun's rays. Its energy is still more decisively seen in the influence which it exerts in promoting chemical combination and decomposition; the latter effect having been made use of as a *photometer*, or measure of its power. Light enters into a kind of transitory union with certain substances, rendering them visible in the dark. Bodies which possess this property are called phosphorescent; such are the shells of fish, the bones of land animals, marble, limestone, and the like. The glow-worm is a remarkable instance of phosphorescence in living animals. The *Daguerreotype*, as well as Mr Talbot's method of *photography*, is founded on the action of the chemical rays on certain substances. The iodide of silver, formed by exposing a plate of silver to the vapour of iodine, is the substance used in the Daguerreotype; the chloride, iodide, and bromide of silver, formed on the surface of paper in a thin and uniform layer, are the bases of Talbot's method—both of which will be fully treated at length in a subsequent number.

The chemical agency of *galvanism* and *electricity* has been already described in No. 17. The latter is frequently employed to produce the combination of gases, and sometimes to effect their separation. It appears to act by the heat which it occasions, and therefore upon the same principle as flame.

I.—NON-METALLIC ELEMENTS.

Oxygen.

Oxygen gas is a permanently elastic fluid—that is, one which no compressing force, or degree of cold, hitherto applied, has ever been able to reduce to a liquid or solid state. It forms, as we have already observed, one of the constituents of the atmosphere, is colourless, and destitute of taste and smell. Its specific gravity is 1·1026, that of common air being reckoned unity. Combustible bodies burn in it with more brilliancy, and more light and heat is evolved, than when combustion takes place in the atmosphere. If a candle, the wick of which is red-hot, be introduced into a vessel containing oxygen, the candle will instantly be lighted. Oxygen has the power of combining with every other simple body; the multifarious compounds which it thus forms, such as oxides, acids, and bases, or alkalies, we have already adverted to. It was discovered by Priestley in 1774: its name, from *oxys* and *gennaein*, denotes that it is a *generator of acidity*.

In the act of respiration, oxygen, in the nice economy of the human body, is made to unite with it, and becomes a portion of the human frame. Vegetables also inhale and exhale it at certain seasons, so as admirably to supply what is absorbed by animals. It is the intensely rapid chemical union of oxygen with the combustible body, which gives rise to the light and heat in our common fires, candles, &c. Though necessary to respiration, it is singular that oxygen in a state of purity is deleterious. When an animal—as a rabbit, for example—is introduced into a medium of pure oxygen, it breathes at first without any apparent inconvenience; but after an hour or so, the circulation and respiration become rapid, and the system is highly excited. Symptoms of debility subsequently ensue, followed by insensibility; and in eight or ten hours life becomes extinct.

Oxygen may be readily procured from a variety of substances, as, for instance, from saltpetre, or the black oxide of manganese. These may be introduced into a gun barrel, with the touch-hole plugged up. From the orifice of the barrel let a tube be conducted into an inverted glass jar, filled with water. When the other extremity of the apparatus is subjected to heat, the oxygen gas is expelled from the manganese, and entering the glass jar, displaces the water, and fills the vessel. This is a cheap and easy method of obtaining this remarkable aëriform body. It can also be prepared by putting 1000 grains of binoxide of manganese into a retort with an equal weight of aqueous sulphuric acid. This is done by means of a retort fixed over a spirit-lamp. The bent tube of the retort enters a pneumatic trough, in which jars are placed for receiving the gas as it passes from the neck of the retort. When oxygen of great purity is required, it is better to obtain it from chlorate of potassa, heated nearly to redness in a green glass retort. Thus treated, the salt first liquefies; and as the heat increases, the gas is given off with effervescence, leaving a white compound behind, which is chloride of potassium. Symbolically represented, the change which takes place is this:—Original compound $KO + Cl\ O_5$; result, $KCl + O_6$; so that the six equivalents of oxygen are wholly liberated.

Hydrogen.

Hydrogen gas is a permanently elastic fluid, transparent and colourless, and when *pure*, destitute of taste or smell. It can scarcely be said to exist in an isolated state, but it forms one of the constituents of water, from which it can be disengaged by various simple processes. It is the lightest body with which we are acquainted, being nearly 14½ times lighter than atmospheric air. A bladder filled with this gas will ascend in the atmosphere, in the same manner as a piece of cork or wood plunged by force to the bottom of a vessel of water. Hydrogen will not support combustion, but is itself remarkably combustible, whence its early name, *inflammable air*. When one volume of oxygen is mixed with two of hydrogen, it burns with a loud explosion, by an electric spark, or the contact of a red-hot wire. The product of this experiment is water; hence the term hydrogen, or *generator of water*. It is said that a few cautious draughts of this gas may be taken; but it cannot be inspired for any length of time without occasioning death. Hydrogen was first correctly described by Cavendish in 1766.

By far the most important compound of hydrogen with any other substance is that with oxygen, forming the indispensable fluid which covers nearly two-thirds of our globe — *water*. Water is thus an oxide of hydrogen—a compound never found absolutely pure in nature. In the ocean it is salt and brackish, from the presence chiefly of chloride of sodium; in springs it is either carbonated — that is, contains carbonic acid; sulphureous, from the presence of sulphuretted hydrogen; chalybeate, from the union of the sulphate or carbonate of iron; and so on, according to the nature of the mineral ingredients through which it percolates. When it contains a chemical compound of lime, it is said to be *hard*, and in this condition it decomposes the soap which is employed with it, and destroys its detergent properties. The impurity of water may thus arise either from chemical union or mechanical mixture with other bodies. The latter can generally be removed by filtration; but when the union is chemical, distillation (a process to be afterwards described) is necessary to produce a pure liquid.

Hydrogen also unites with the other supporters of combustion; but the compounds, except muriatic acid (to be afterwards mentioned), are not of any great importance. The flame of hydrogen, though feebly luminous, is intensely hot; and the most intense heat that can be produced is caused by the combustion of hydrogen in oxygen gas. Upon this principle is constructed the *oxy-hydrogen blowpipe*, one of the most important applications of hydrogen gas.

Hydrogen may be prepared by putting 500 grains of zinc into a common beer bottle, and pouring upon the zinc three ounces of water and five drachms of aqueous sulphuric acid. The hydrogen is disengaged as the acid, the oxygen in the water, and the metal combine. By means of a bent tube from the bottle, the gas can be conveyed into jars placed in a trough.

Azote, or Nitrogen.

This gas is permanently elastic, transparent, colourless, and inodorous; specific gravity, 0·9722. When breathed, it destroys animal life (hence the term *a-zote*); and a burning body, if immersed in a jar containing it, is instantly extinguished. It is not combustible; it enters extensively into combination; it is an abundant element in animal matter; and its existence in such large quantity is a chief distinction between the constitution of animal and vegetable life. It was first noticed by Rutherford of Edinburgh in 1772; and discovered to be a constituent of the atmosphere by Lavoisier in 1775. The air consists mainly of nitrogen and oxygen, in the proportion (if these ingredients be alone regarded) of 210 oxygen to 790 nitrogen, by measure; and of 231 to 769 by weight. Common atmospheric air alone contains, as constant ingredients in every situation, a little carbonic acid gas and vapour of water. In volume, the carbonic acid forms about 1-2000th part; or 0·5 parts in 1000 by measure; which is equal to 0·75 parts in 1000 by weight. In some situations the carbonic acid is so much as 0·62 volumes in 1000—at other places, only 0·37 volumes in 1000. Its proportion is greater in summer than in winter, during night than in the day-time, in elevated situations than on the plains. The watery vapour is more variable in proportion. The mean is supposed to be about 10 parts in 1000 by weight, 15 by volume. The quantity is determined by the temperature, heat being the sole cause which sustains the vapour in the aërial state. Whether the nitrogen and oxygen of the atmosphere be merely a mechanical mixture or a chemical compound, is not precisely determined; the majority of chemists, however, lean to the former opinion, and found their reasonings accordingly. Be this as it may, it is the oxygen which performs the chief part in the process of respiration, the nitrogen acting in a negative capacity as a simple diluent. Each individual is supposed, on an average, to breathe about twenty times every minute—to take in about sixteen cubic inches of air (12·8 nitrogen + 3·2 oxygen) at each inspiration—to return nearly the whole of the nitrogen (12·8 cubic inches), and 4-5ths of the oxygen (2·56 cubic inches), and to replace the remaining 5th of oxygen by an equal volume of carbonic acid gas (·64 cubic inch).

That nitrogen has the property of combining with all the supporters of combustion, there can be little doubt; but the subject has not yet been thoroughly investigated. With oxygen it unites in no fewer than five proportions—namely, one of nitrogen to one, two, three, four, and five of oxygen respectively *by weight*, or one of nitrogen to a half, one, one and a-half, two, and two and a-half *by volume*. Of these compounds, by far the most important is nitric acid, or the *aqua-fortis* of the alchemists. The term nitrogen is derived from its being an element or *generator of* nitric acid.

Nitric Acid.—This virulent substance is a compound of one volume nitrogen, and two and a-half volumes of oxygen, or by weight N + 5O. Common nitric acid is of an orange colour, on account of its containing a little muriatic acid, as also a little sulphuric acid and water. Light has likewise an effect upon it. The specific gravity of the strongest procurable nitric acid, or *double aquafortis*, as it is sometimes called, is 1·55, and then it contains one-seventh of its weight of water; that of commerce is about 1·423, and contains two-fifths of its weight of water. Nitric acid has very remarkable effects upon water with regard to the production of heat. If diluted with half its weight of water, heat is evolved; but if the water be in the state of snow, intense cold is the result. Hence this compound is employed to produce great degrees of cold. If nitric acid, highly concentrated, be thrown upon phosphorus, charcoal, or oil of turpentine, it inflames them. It is very extensively used in the arts, particularly for the purification of gold, for etching on copper plates, &c.; and recently it has assumed additional importance from its being one of the principal ingredients used in the preparation of Dr Schönbein's 'gun-cotton.'

Nitric acid also forms a numerous and important class of salts, having the generic name of *Nitrates*—such as nitrate of silver, nitrate of potash, &c. Some of these we shall notice afterwards. *Nitrous acid* is a compound of the same kind, but with a lesser quantity of oxygen. Amongst the other compounds of azote and oxygen, that entitled the *protoxide of azote*, or, as it was formerly called, *nitrous oxide*, is the most remarkable. Davy discovered that we may breathe it for a short while without any effect being produced, except an exhilaration of the mind; hence the term *laughing gas*, which is sometimes applied to it. Combustibles burn in it more brilliantly than in common air. Faraday has lately succeeded in solidifying this gas under a pressure of 50 atmospheres at 45°; and is of opinion that it might be employed in this state with greater advantage than solid carbonic acid, for producing intense cold by its evaporation *in vacuo* when mixed with ether. There is also a *deutoxide of azote*, and a *hyponitrous acid;* but these do not require minute detail. Azote combines likewise with chlorine and bromine. Nitric acid can be procured by filling a glass retort about one-third full of equal weights of aqueous sulphuric acid and common nitre. The retort is then subjected to heat, and a vapour is distilled over, which, condensed, is nitric acid.

Ammonia, or *Hartshorn*.—This important substance is formed by the combination of azote with hydrogen, and is obtained in the state of gas, by means of the salt called *sal ammoniac*, which is a compound of muriatic acid and ammonia. This substance is to be introduced into a retort, along with quicklime, and then subjected to heat. Ammonia is driven off in the form of gas, and is to be collected in glass jars standing over mercury. Ammoniacal gas is colourless, has a strong pungent smell, an acrid caustic taste, and cannot be drawn into the lungs. Its specific gravity is 0·59027. Water absorbs 780 times its volume of this gas, and in this state it is employed for chemical purposes. When the gas is mixed with chlorine, a sudden combustion and detonation take place. The chlorine unites with the hydrogen of the ammonia, and forms muriatic acid, whilst the azote is disengaged in the state of gas. The muriatic acid formed combines with a portion of ammonia, and forms sal ammoniac. Ammonia is an alkali, and possesses the properties distinguishing this class of substances in a very decided manner. It of course neutralises acids, and the salts which it forms are numerous, and of considerable importance.

Chlorine.

This is a gaseous body, of a yellowish-green colour (whence its name), of a strong suffocating smell, and of a pretty strong astringent taste. It was discovered by Scheele in 1774, and regarded as a compound substance, till Davy, in 1809, established its title to rank with the simple bodies. Reckoning air as unity, its specific gravity is 2·5. If breathed undiluted, it destroys animal life; however, it not only supports combustion, but possesses the remarkable quality of setting fire to many of the metals, even at the common temperature of the air, when beaten out into thin leaves, and introduced into it. In these cases the combustible substances unite with the chlorine, and form *chlorides*.

Chlorine gas is obtained by the action of muriatic acid on peroxide of manganese. The most convenient mode of preparing it is by mixing the acid with half its weight of finely-powdered peroxide in a glass flask; the gas is liberated with effervescence, and should be collected in dry bottles. For the purposes of manufacture on a large and cheap scale, the process is modified thus:—Three parts of sea-salt are intimately mixed with one of peroxide of manganese, and to this mixture two parts sulphuric acid, diluted with an equal weight of water, are added.

Chlorine possesses the property of destroying all vegetable colours, and of rendering vegetable bodies exposed to its action white. This property has occasioned the introduction of chlorine (combined with lime) into bleaching; for if unbleached linens be exposed to its action, the matter which gives them their gray colour is destroyed, and the substance assumes a brilliant whiteness. Chlorine, however, must be used cautiously; for if applied in its pure, and not sufficiently diluted state, it destroys the fibre of the cloth. It is also used in fumigation, being destructive of effluvia arising from putrefaction, disease, &c. Chlorine combines with oxygen in four different proportions: two of them contain so much oxygen as to form acids; these are chloric acid and perchloric acid; but as the other two do not manifest any acid properties, they are to be considered as oxides, and are called protoxide of chlorine and peroxide of chlorine. Besides uniting with oxygen, chlorine combines with hydrogen, and forms the well-known acid called

Muriatic or *Hydrochloric Acid*.—If chlorine and hydrogen be mixed together in equal volumes, and exposed to common daylight in a glass flask, they will in a little time combine, and even explode in combining, if exposed to sunlight, or the light of a candle: two volumes of muriatic gas result. Its specific gravity is 1·2844; in its pure state this gas is transparent, colourless, and elastic; under very strong pressure it condenses into a liquid. Water absorbs this gas with avidity. One cubic inch at 69° absorbs 417,822 cubic inches of the gas; heat is produced, and, when cold, the bulk of the water is increased to 1·3433 cubic inches. This is liquid muriatic acid. With these proportions of constituents, its specific gravity is 1·1958; one hundred grains of it consist of 40·39 of real acid, and 59·61 of water. It is a colourless liquid; and when exposed to the air, it smokes, because the gas exhaled condenses the moisture of the atmosphere. It extinguishes both flame and life, and is not inflammable. It is of a pungent, suffocating, and somewhat aromatic smell. It powerfully reddens vegetable blues. The best method of obtaining it is by pouring sulphuric acid upon an equal weight of sea-salt, and collecting the gas which is given off over mercury. An immense number of salts are formed from the combination of muriatic acid with oxides; such as common sea-salt, which is a muriate of soda, or chloride of sodium. These are very extensively used, both in the arts and medicine. Chlorine combines with azote, and forms what is called

Chloride of Nitrogen.—This is an oily liquid, and the most powerfully-explosive compound known. In this respect it is one of the most dangerous substances of nature; it consists of four volumes of chlorine combined with one of azote. Chlorine combines with carbon, but the compounds are unimportant.

Bromine.

The term *bromine* is from a Greek word signifying 'a strong disagreeable odour.' This substance was discovered so lately as the year 1826 by Balard of

Montpellier. It resembles chlorine in many of its habitudes; at common temperatures, it is a liquid of a brownish-red colour, very disagreeable smell, sharp strong taste, powerfully corrosive of organic bodies; and when taken internally, a violent poison. Its specific gravity is 2·96; it destroys vegetable colours almost as powerfully as chlorine. Like chlorine, it sets fire to certain metals when brought into contact with it; it is not combustible, and it extinguishes combustion; it becomes solid at a little below zero; but if combined with water, so as to form a hydrate, it affords fine red crystals at 32°.

An acid is formed by the combination of bromine with oxygen, and is called bromic acid; another with hydrogen is called hydrobromic acid. Chlorine also combines with it, and forms a chloride. There are numerous other combinations of bromine, but the compounds are economically unimportant.

Bromine is usually extracted from *bittern*—that is, the uncrystallisable residue left after chloride of sodium (common salt) has been extracted from sea-water. It appears to be an essential ingredient of the saline matter of the ocean, and is found in all its waters, as well as in most of the plants and animals which inhabit them. It occurs also in many saline springs.

Iodine.

This substance was first discovered in 1812 by a saltpetre manufacturer of Paris. It is derivable from sea plants, and in some of its properties much resembles chlorine, which is also a marine production. If common sea-weed be powdered dry, and treated with sulphuric acid whilst subjected to heat, a violet-coloured vapour is expelled, which, if collected in a vessel, condenses into scaly dark-gray crystals, with somewhat of a metallic lustre. These are iodine, so called from the violet colour of its vapour; iodine being a Greek word, and signifying 'violet-coloured.' Its specific gravity is 3·0844. Its smell is disagreeable, its taste acrid and hot, and it possesses poisonous properties. It is a powerful stimulant, and has of late been much employed as a medicine. It destroys vegetable colours, but not so completely as chlorine. It melts when heated to 225°, and volatilises at 352°. It forms a beautiful blue colour when mingled with water holding starch in solution; it is itself slightly soluble in water, but more so in alcohol and ether. Iodine combines with oxygen in three proportions, forming iodic acid, iodous acid, and oxide of iodine; with chlorine, forming chloriodic acid; with bromine in two proportions, forming bromides; and also with azote and hydrogen. A compound of iodine and azote is exceedingly explosive. But a particular account of these substances does not require to be given in this place.

Fluorine.

The existence of this substance, strange to say, is conjectural; yet its separate identity is supported by the strongest analogies. It exists, or rather is supposed to exist, in fluor, or Derbyshire spar, and is thus provisionally called fluorine. If some of this mineral in powder be distilled with strong sulphuric acid, from a leaden retort into a leaden receiver, kept cold with ice, an intensely active fluid is produced. 'It has,' says Davy, 'the appearance of sulphuric acid, but it is much more volatile. When applied to the skin, it instantly disorganises it, and produces very painful wounds. When it is dropped into water, a hissing noise is produced, with much heat, and an acid fluid is formed.' This substance has been called *hydrofluoric acid*, because it is conjectured to have fluorine as a base, combined with hydrogen, to form an acid, upon the principle which we have formerly described. Other views have been adopted with respect to this substance, but the above is the one now generally admitted. The diluted solution, or the vapour of hydrofluoric acid, acts energetically on glass, and is sometimes employed for the purpose of *etching* on this material. Fluorine also forms acids with boron and silicon.

Carbon.

Carbon, or charcoal, is found in many different forms, and can be prepared by burning wood, coal, &c. in close vessels. The diamond is pure carbon, and plumbago, or black-lead, is principally composed of this substance with a little iron. It burns in oxygen with considerable brilliancy, although in common air it emits but a feeble light. If carbon be burned in a close vessel, filled with oxygen, the carbon will be entirely consumed, and the oxygen so much changed, that if a lighted taper be put into it the light will be extinguished. Carbon combines with all the supporters of combustion, and with oxygen forms carbonic acid.

Carbonic Acid, discovered by Black in 1757, and described by him under the name of *fixed air*, may be prepared in the pneumatic trough, by putting into the retort an ounce of hydrochloric acid, previously mixed with two ounces of water, along with a tablespoonful of the carbonate of lime. An effervescence takes place between the acid and the lime, carbonic acid gas being given off, which can be collected in the jars, and condensed in water. Carbonic acid is fatal to animal life, and the gas will extinguish a candle introduced into it. A candle cannot burn in a mixture of four measures of atmospheric air and one of carbonic acid; and no animal can live in air which contains sufficient carbonic acid to extinguish a candle; hence the practice of letting down a burning taper into old wells, pits, brewers' tuns, and the like, before any one ventures to descend. If the light is extinguished, the air is certainly impure; and there is generally thought to be no danger if the taper continues to burn; but instances have been known of the atmosphere being sufficiently loaded with carbonic acid to produce insensibility, and yet not so foul as to extinguish a candle. Water, under the ordinary pressure of the atmosphere, absorbs a certain amount of carbonic acid, and under pressure, may be saturated with it, in which state it sparkles when poured from one vessel to another. All kinds of spring and well-water contain carbonic acid absorbed from the atmosphere, and to its presence they are partly indebted for their pleasant flavour. Boiling deprives water of its carbonic acid, whence its insipid taste. The agreeable pungency of beer, porter, ale, and many other beverages, is in a great measure owing to its presence; by the loss of which, on exposure to the air, they become flat and stale. Thus, though deleterious when breathed into the lungs, carbonic acid is exhilarating and wholesome when taken in moderate quantities into the stomach.

Oxalic Acid is another well-known combination of carbon with oxygen, and may be formed by digesting sugar along with nitric acid. The acid is deposited in small crystals, which have an intensely acid taste, and when taken internally, even in small quantities, destroys life. It combines with bases, and forms a genus of salts called *oxalates*. Carbon is capable of uniting with chlorine in three different proportions, with bromine in one or two, and with iodine in two. But we must pass from these compounds to those of far greater moment which it forms with hydrogen.

There are many combinations of carbon with hydrogen, and much uncertainty prevails both with regard to their number and nature; they are all designated *hydrocarbons*, or more properly *hydrocarburets*;—*Carburetted hydrogen*, a spontaneous production of nature in mines, is one of the most terrific instruments of destruction, and a great obstacle to human industry; for, by mixing with a certain quantity of common air, it acquires the property of exploding when accidentally kindled, and thousands of human lives have fallen sacrifices to its violence, until Sir Humphry Davy's invention of the safety-lamp greatly divested it of its terrors. (See MINING.) Davy's safety-lamp consists of a common lamp surrounded with wire-gauze. On analysing the carburetted hydrogen, or fire-damp, Sir Humphry Davy found that it would not explode when mixed with less than six times, or with more than fourteen times, its volume of atmospheric air; that air rendered impure by the combustion of a candle will not explode fire-damp, though the candle will still burn for a time; and that, if a candle be burnt in a close vessel, with small apertures only above and below the flame, no explosion will ensue. The flame within will be enlarged, but no explosion take place; and it was found that the gas usually generated in mines will not explode in a tube less than one-eighth of an inch in diameter.

Bicarburetted hydrogen is the chief, although not the most abundant ingredient in *coal gas*, now so generally used for illumination; the other ingredients are carburetted hydrogen, hydrogen, and carbonic oxide. Coal gas is made by introducing a quantity of bituminous coal into a large iron cylinder called a retort, close at one end, and furnished with a mouth-piece at the other, for closing or opening it; there is also a tube for carrying off the gas and other products as they form. A quick strong heat is applied round the cylinder, and a vast quantity of gas, composed of the four ingredients just mentioned, is thus extricated, with tar and an ammoniacal liquor, both of which are condensed by passing through pipes immersed in cold water. There is a great difference in the relative proportions of the gases in the mixture, as also in the quantity of tar, according to the quality of the coal, and the mode of applying the heat. The more tar the gas holds dissolved, the more dense will be the flame when the gas is made to burn, and the more disagreeable will be the smell when it is not burning. A slow heat gives much tar and little gas, and that little of a poor quality; a quick heat gives much gas, of good quality, and less tar. Owing to these and other causes, the illuminating power of coal gas varies much. Before it is let through the conducting tubes for public consumption, it is well agitated in contact with a mixture of lime and water, or passed through strata of loosely-strewed hydrate of lime: it is thus deprived of much of its smell, and also of some of its illuminating power. (See LIGHTING.) There are other less important compounds of carbon and hydrogen, and the whole correspond with the law of multiple combination already described. *Naphtha* and *naphthaline* are hydrocarburets; the former a transparent volatile fluid, the latter a transparent volatile solid, which assumes the form of crystalline plates: both are obtained from coal tar by distillation.

Cyanogen.—This substance is a gaseous compound of azote and carbon—technically, a *bicarburet of nitrogen*. It burns with a purple flame, and destroys life on being breathed. Cyanogen unites with a variety of bodies, and forms many important compounds.

Boron.

The *borax* of commerce is a compound of boracic acid and soda, and is brought chiefly from India, under the name of *tinkal*. Boracic acid is a compound of oxygen and boron, in the proportion, it is supposed, of one atom of the latter to three of the former. Pure boron, the existence of which was discovered by Davy in 1807, is an opaque brownish-olive powder, infusible, and not volatile at any temperature to which it has as yet been subjected. It neither dissolves in, nor acts upon, water. At about 600°, it takes fire, and combines with oxygen, forming

Boracic Acid.—This substance evinces the usual properties of an acid, but it is not a powerful one at ordinary temperatures. At high temperatures, however, it displaces the strongest of the other acids, and is exceedingly useful in fluxing out the baser metals from the nobler. When the acid is detached from borax, by vitriol being poured upon that compound, it exhibits itself in scaly crystals. It dissolves in rectified spirits, and if the solution be set on fire, it burns with a green flame. Borax itself, when heated, melts into a perfectly clear glass, which is the basis of some artificial gems of considerable beauty. Borax communicates its own fusible nature to other bodies; hence it is used as a flux. *Flux* is a general term made use of to denote any substance or mixture employed to assist the fusion of minerals. There are a considerable number of such bodies; the alkalies are those most generally used. Boracic acid is the only known compound of boron with oxygen. There has been no compound yet discovered of boron with either bromine or iodine, but it combines with chlorine, forming a gaseous acid, to which the name of *borochloric acid* has been given; and also with fluorine, forming

Fluoboric Acid, which exists in the gaseous state. It is colourless, has an exceedingly acid taste, and a smell similar to muriatic acid. It contains no water, but possesses a powerful affinity for that fluid, and is on that account sometimes used as a test of the presence of moisture in gases. Its specific gravity is 2·362; and it seems to consist of one atom of boron and three of fluorine (BF_3). The combinations of boron with hydrogen, azote, and carbon, are still unknown.

Silicon.

Quartz, or *rock-crystal*, which constitutes so considerable a portion of the crust of the earth, consists essentially of a peculiar acid substance, called *silica*, or *silicic acid*. This substance is a compound of oxygen, with a base which has been entitled *silicon*; as established by Berzelius in 1824. It is a powder of a deep brown colour, and very similar to boron in its appearance, and in its relations to other matter. It stains the fingers, and adheres to everything that comes in contact with it. It can be exposed to a very high temperature without being fused; after ignition, the specific gravity of silicon is about 1·837. It dissolves in a mixture of fluoric and nitric acids with great facility, although it is not acted upon by them singly. When mixed with dry carbonate of potash, or soda, and heated far below redness, it burns vividly, at the expense of the carbonic acid; carbonic oxide is disengaged, and the residue is tinged black by carbon being deposited. By this process silicon is converted into silica, which is a compound of one atom of silicon and one atom of oxygen. Silicic acid forms several important compounds, called *silicates*, with the fixed alkalies, and various metallic oxides. Every kind of ordinary glass is a silicate; the varieties (bottle, plate, flint, &c.) depending on the nature of the alkali or oxide, the proportions of the constituents, and the admixture of foreign matters.

Silicon combines with chlorine, forming a *chloride of silicon*. This is a colourless volatile liquid, having a suffocating smell, and probably acid properties. With fluorine, silicon unites, and forms *Fluosilicic Acid*, which is a gaseous substance, transparent, colourless, and having a smell like muriatic acid. It smokes when mixed with moist air, and it is rapidly absorbed by water. Its specific gravity is 3·6. It combines with carbon, but no other compounds are known.

Sulphur.

Sulphur, or brimstone, is a substance whose appearance is too familiarly known to require particular description. In many parts of the world it is found in a state of great purity. It occurs plentifully in volcanic countries, and is an abundant ingredient in various minerals, as in iron and copper pyrites. It is a non-conductor of electricity, and, when rubbed, becomes highly electric. It has a specific gravity of about 2. Its point of fusion is 232°; between 232° and 280° it possesses the highest degree of fluidity, is then of an amber colour, and if cast into cylindrical moulds, forms the common *roll sulphur* of commerce. It begins to thicken about 320°, and acquires a reddish tint; and at temperatures between 428° and 482° it becomes thick and highly tenacious. From 482° to its boiling-point it again becomes liquid, but never to the same extent as when at 248°. When heated to 430°, or thereby, and suddenly cooled, by being poured into water, it becomes a ductile mass, and may be used for taking impressions of seals, &c. It begins to rise slowly in vapour before it is completely fused, but at

550°, or thereby, it volatilizes rapidly; its condensed fumes forming the fine powder known as the *flowers of sulphur*. Sulphur is extensively used in the arts; for instance, in the manufacture of gunpowder. With oxygen it combines in four proportions, forming four compounds, all of which possess acid properties.

Sulphurous Acid.—When sulphur is heated to 300° in the open air it takes fire, and burns with a pale blue flame, at the same time emitting abundance of fumes of a suffocating nature, which are sulphurous acid. It is colourless, extinguishes flame, is not inflammable, converts vegetable blues to red, forms a class of salts called *Sulphites*, and has a specific gravity of 2·2222. This gas blenches various textures, as those of silk, wool, and straw; the liquid acid bleaches sponge. Sulphurous acid is supposed to consist of equal bulks of oxygen and sulphur. Its proportions are one part of sulphur to two of oxygen.

Sulphuric Acid, or *Oil of Vitriol.*—This acid is made in great quantities for the use of bleachers, and other manufacturers, by burning sulphur in leaden chambers. At the same time a quantity of nitric acid, from the decomposition of saltpetre, is admitted into the chamber. The sulphur is converted into sulphurous acid. Five atoms of this acid unite with one atom of nitric acid, and two atoms of water, and form a white solid salt, which falls to the bottom of the chamber into a quantity of water placed to receive it. As soon as it comes in contact with the water, a strong effervescence takes place: the nitric acid is decomposed, and converts the sulphurous into sulphuric acid, while at the same time a quantity of deutoxide of azote is disengaged. This gas, coming into contact with the oxygen of the air, is converted into nitric acid, which combines with an additional dose of sulphurous acid, and is decomposed as before. Thus the process goes on as long as sulphurous acid and oxygen gas exist in the leaden chamber. Sulphuric acid thus obtained is a colourless liquid, possessing some viscidity; and when as much concentrated as possible, its specific gravity is 1·837. Sulphuric acid is one of the most powerfully-corrosive bodies known to us. The following are some of its principal properties: When mixed with water, to which it has a very powerful attraction, a decrease of volume occurs, and a considerable degree of heat is generated. It freezes when sufficiently cooled, and the crystals are sometimes large, distinct, and hard. When exposed to the air, this acid discharges whitish gray vapours, which are sulphuric acid in a dry state. Acid of specific gravity 1·690, contains about one-tenth of water, and is so volatile, that it boils at 120°. The constitution of sulphuric acid is—sulphur one part and oxygen three parts. It forms a very numerous and important class of salts called *Sulphates*. The other two compounds of sulphur and oxygen—namely, the hyposulphurous and hyposulphuric acids—it is unnecessary to notice. Sulphur unites with chlorine in two proportions. It also combines with bromine, iodine, and fluorine, but its next most important combinations are those with hydrogen.

Sulphuretted Hydrogen, or Hydrosulphuric Acid.—This is a colourless gas, having a strong fœtid smell, something like rotten eggs, and a sweetish taste. It is a non-supporter of combustion, and, when breathed, destroys animal life. Its specific gravity is 1·1805. It is combustible, and burns with a bluish red flame. Water absorbs 3·66 times its bulk of this gas; and if it be passed through water tinged with a vegetable blue, it will change the colour to red. A few drops of nitric acid let fall into a vessel filled with sulphuretted hydrogen, will set fire to it. This gas blackens silver, and darkens the woodwork of rooms painted with white lead, from human exhalations containing a portion of it. Its atomic constituents are said to be one atom of sulphur and one atom of hydrogen. Double the quantity of sulphur to the same proportion of hydrogen forms what is called the *bisulphuret of hydrogen*. No compound of sulphur and nitrogen is known, but with carbon there is more than one. With boron and silicon, sulphur forms sulphurets.

Selenium.

This is a substance nearly allied to sulphur in its nature, although it in some respects partakes also of the character of a metal. It was discovered by Berzelius in 1818, and derives its name from *selené*, 'the moon,' from its strong analogy to another element, tellurium, so called from *tellus*, 'the earth.' It melts at about 212°, and on cooling becomes solid, in which state it has a metallic lustre, and a deep brown colour. It is soft, and easily reduced to powder, which is of a deep red. Its specific gravity is 4·3. It is a bad conductor of heat, a non-conductor of electricity, and is also non-electric. Like sulphur, it sublimes into flowers. It combines with oxygen in three proportions, forming *oxide of selenium*, a gaseous body; *selenous acid*, which has an acid and acrimonious taste; and, lastly, *selenic acid*, which resembles sulphuric acid in its consistence and in many of its properties. It is to be remarked that the compounds of selenium and oxygen bear a strong analogy to some of those of oxygen with sulphur. Selenium combines also with sulphur, chlorine, and carbon.

Phosphorus.

This well-known substance is commonly prepared from bones, which consist chiefly of the phosphate of lime. This salt is decomposed by sulphuric acid, and after going through a difficult process, the phosphorus is distilled into a receiver in the shape of melted drops. It is an amber-coloured and semi-transparent solid. Its specific gravity is 1·748. It is so very combustible that it takes fire in the air, emitting a white smoke, having the smell of garlic, and appears luminous in the dark; whence its name from the Greek, *phōs*, 'light,' and *pherein*, 'to carry.' At the temperature of 148° it burns with a large resplendent flame, giving out a white smoke, which is—

Phosphoric Acid.—This substance can be obtained by other processes, in which case it exhibits itself as a transparent solid body like glass. It has no smell, but an exceedingly sour taste; it is not corrosive. Its atomic constituents are supposed to be two atoms of phosphorus to five atoms of oxygen. Phosphorus also produces another acid called *phosphorous acid*, containing a smaller proportional quantity of oxygen; and a third, called *hypophosphorous*, containing still less of the gas.

Phosphuretted Hydrogen is a colourless gas, has a smell like garlic, and a very bitter taste; its specific gravity is 1·7708. It burns spontaneously. When mixed with oxygen, *rarefaction* causes them to explode, as *condensation* produces explosion in other gases—a very remarkable property of this substance. This gas may be detonated also with protoxide and deutoxide of azote. When mixed with chlorine gas, it burns with a greenish-yellow flame. It is composed of equal volumes of hydrogen and phosphorus vapour. There are other compounds formed of these two substances: phosphorus combines also with chlorine, bromine, and iodine, in two proportions each; and unites with fluorine, carbon, sulphur, and selenium.

II.—METALLIC ELEMENTS.

Alkaline Bases.

Potassium is the base of that well-known and very useful article potash. The properties of potassium were first determined by Davy in 1807, to whom we are indebted for the discovery of the composition of the alkaline bodies. It is a white metal, like silver. At 32° it is hard and brittle, at 50° is soft and malleable, at 192½° melts, and at a low red heat evaporates. Its specific gravity at 60° is 0·865, being lighter than water. When exposed to the air, it rapidly absorbs oxygen, and forms potash. This latter body, as found in commerce, is always combined with water, which cannot be expelled by heat. When potassium is thrown on the surface of water, upon which it swims, it decomposes that fluid with such rapidity that the metal takes fire, and burns with a red flame. Potassium combines with two proportions of oxygen; it also unites with chlorine, bromine, iodine, hydrogen, sulphur, and several other bodies. The protohydrate of potassa, which is solid at common temperatures, is employed in surgery as a caustic, under the name of *potassa fusa*: it destroys all animal textures.

Sodium is a metal so similar in most respects to the foregoing, as to stand in no need of particular description. It is the base of the alkali called soda, which is formed when the metal is brought into contact with water, or when it is heated in oxygen. It decomposes water, and in its relations to other bodies, bears a strong resemblance to potassium. The uses of soda are well known, as are those of common salt, which is chloride of sodium. Sulphuret of sodium was lately discovered to be the colouring principle of the *lapis lazuli*, and since then has been used in the preparation of artificial ultramarine, the finer specimens of which are quite equal to the natural product, and much less expensive. Sodium, which was discovered after potassium in 1807, is called *Natrium* by the German chemists; hence its symbol Na.

Lithium is the metallic base of the alkali called lithia, which is of a white colour, and has a taste fully as caustic as that of potash itself. It is of course an oxide of lithium—LO. Lithium likewise unites with chlorine (LCl) and fluorine (LF), but its other combinations are unknown.

Bases of the Alkaline Earths.

Barium is the metallic basis of barytes, an alkaline earth, which is so named from its great density; *barys*, heavy. It is of a gray silvery appearance, absorbing oxygen rapidly by exposure to the air, thus forming barytes; and it also rapidly decomposes water. Barium combines with sulphur and phosphorus, and also forms compounds with chlorine, bromine, iodine, and fluorine.

Strontium.—This metal is the base of strontia, an earth very similar to the foregoing. Strontium and barium, both discovered by Davy, resemble each other very much in most of their properties, and their combinations with oxygen have also a very strong resemblance. Strontium also unites with chlorine, iodine, fluorine, phosphorus, and sulphur. It was originally extracted from strontianite, native carbonate of strontia, a mineral found at Strontian in Scotland; hence the name *strontites*, or *strontia*.

Calcium is the metallic base of the well-known and indispensable commodity lime. *Lime* (*calx*) has been known from the remotest ages, and appears always in combination with an acid, most commonly with the carbonic, constituting *limestone*, *marble*, *calcareous spar*, *chalk*, and frequently with sulphuric acid, constituting *gypsum*, *selenite*, and *sulphate of lime*. It combines also with various other acids. Calcium is white, like silver, solid, and much heavier than water. When heated in the open air, it burns brilliantly, and quicklime is produced. Calcium unites with oxygen in two proportions, forming lime and peroxide of calcium. Pure lime has an acrid taste, and is sparingly soluble in water. It, however, readily absorbs water poured upon it, and swells, producing at the same time a great heat. The fact is, that the water becomes solidified, and of course gives out a great quantity of heat, which accounts for the rise of the temperature. This process is called slaking lime. Lime combines with chlorine, and forms *chloride of lime*—a substance which has become an important article of commerce, under the name of *bleaching-powder*. It is a white powder, with a hot taste, having the power of destroying vegetable colours. Calcium combines with sulphur, phosphorus, iodine, fluorine, and bromine.

Magnesium.—This metal is the basis of magnesia, a substance universally known from its frequent employment in medicine. Magnesium is obtained in brown scales, which, when rubbed against agate, leave a metallic stain, of a leaden colour. It was indicated by Davy, but determined by Bussy in 1830. It burns with a red light, and by thus combining with oxygen, becomes *magnesia*. This is a soft, elastic, tasteless powder, not sensibly soluble in water, and slowly changing vegetable blues to green. Magnesium forms salts with chlorine, bromine, and iodine.

Bases of the Earths.

This family comprehends five substances, the oxides of which are white tasteless powders, distinguished by the name of *earths*:—

Aluminium.—Alumina, which, when pure, is a fine light powder of brilliant whiteness, is an essential constituent in every kind of clay, and constitutes the base of *alum*, from which substance it may easily be obtained. It is a compound of oxygen and aluminium, consisting of two parts of the former to three of the latter. This metal, when burnished, assumes a metallic lustre resembling that of tin. It is not easily fused; but at a red heat it burns with great splendour, and is converted into alumina. This substance, so useful in the manufacture of every species of pottery, is the only compound known of oxygen with aluminium. Alumina possesses the remarkable property of shrinking into less bulk, according to the intensity of the heat which is applied to it; hence it was employed by Wedgewood as a kind of thermometer, or rather *pyrometer*, for measuring very high degrees of temperature, in furnaces for instance. A gauge is used for measuring the amount of the contraction. Aluminium combines with chlorine, phosphorus, sulphur, and selenium.

Glucinium.—Glucina, which is the oxide of glucinium, exists to about fourteen per cent. in the beryl or emerald, from which it can be extracted. Glucinium is a dark-gray powder, which, when burnished, acquires the metallic lustre. It is very difficult of fusion. When heated in air or oxygen, it burns brilliantly, and affords the oxide glucina—the only compound which it forms with oxygen. Glucina, which consists of 100 metal and 44·44 oxygen, is a soft, tasteless, white powder, which, when wet, is somewhat plastic, like alumina. It neither dissolves in water nor melts in the fire. Its salts have a sweetish taste (whence its name), like those of alumina; and both of these earths are in this respect opposed to magnesia, which, with acids, affords salts of a bitterish taste. Glucinium combines with chlorine, phosphorus, sulphur, selenium, iodine, and bromine.

Yttrium.—Yttria, which constitutes the oxide of this metal, is obtained from a scarce mineral called *gadolinite*, found at Ytterby in Sweden. Yttrium is procured from it in iron-gray scales. If heated in common air or oxygen, it burns brilliantly, forming the earth yttria; and as far as is known, this is the only compound formed by the union of oxygen and yttrium. The latter substance combines with chlorine and the combustibles. Yttrium was discovered by Gadolin in 1794; and very recently Mosander asserts the existence of two closely-allied metals, which he calls *Erbium* and *Terbium*, also from Ytterby.

Zirconium.—The earth called zirconia is a harsh whitish powder, destitute of taste or smell. The base zirconium is composed of brilliant scales, which are probably metallic, although the substance has not as yet evinced the metallic lustre. When heated in common air, it takes fire, and is converted into zirconia, which is perfectly white. This is the only compound which it forms with oxygen. It unites with chlorine, carbon, and sulphur.

Thorium, discovered by Berzelius in 1828, is a metal of a leaden-gray colour, heavy, and under the burnisher shows metallic lustre. If it be heated in open air, it burns with much splendour, and the resulting snow-white oxide is the earth thorina. This is the only compound of thorium with oxygen, and the resulting substance is distinguished from the other earths by various properties. Thorium, when heated in vapour of sulphur, burns, and it also unites with chlorine and phosphorus.

Metals which decompose Water at a red heat.

Iron.—This well-known substance is one of the seven metals with which the ancients were acquainted; these were gold, silver, copper, iron, tin, lead, and mercury. Iron is a metal of great utility, and it is fortunately found abundantly. Almost every mineral contains it. The ore from which the iron of Great Britain is chiefly obtained is a *carbonate of iron.* Iron, after passing through a fiery ordeal, has a grayish colour, a metallic lustre, and when burnished, a good deal of brilliancy. Its hardness exceeds that of most metals; and when in the state of steel, it may be rendered harder than most bodies. Its specific gravity is 7·843 after hammering. It is attracted by the magnet, and may itself be converted into a permanent magnet. It is malleable at every temperature, very ductile, and very combustible, for we see a thin wire burn in the flame of a common candle. It burns brilliantly in oxygen, with which it combines in two proportions, forming oxides, or *rusts.* It combines also with chlorine, bromine, iodine, boron, sulphur, selenium, phosphorus, arsenic, chromium, and antimony; but the most important of its combinations with simple substances are those with carbon, which form the important compounds *cast-iron, steel,* and *plumbago.* Iron forms with the acids a numerous and valuable class of salts. (See METALLURGY.)

Manganese.—When this substance is pure, which is rarely the case, it is rather whiter than cast-iron, of a granular texture, and may be reduced to powder by pounding. Its specific gravity is 8·013. It is attracted by the magnet only at a very low temperature. It gradually absorbs oxygen from the atmosphere, and decomposes water, a property which it loses when alloyed with iron. It is much in use. Glass-makers use it for two purposes; first, for communicating a purple or violet colour, or for destroying all colour, and rendering the glass colourless. Manganese has a strong affinity for oxygen, with which it combines in seven proportions, forming acids and oxides. It unites also with chlorine, fluorine, carbon, and sulphur.

Nickel.—This metal, when pure, has a white colour, like silver; is rather softer than iron; is malleable both hot and cold; is attracted by the magnet; and, like iron, can be converted into one. Its specific gravity is 8·380 after fusion. The preparations of this metal contain poisonous qualities. Nickel combines readily with oxygen, forming two oxides. It also unites with chlorine, carbon, sulphur, phosphorus, and arsenic. Nickel is chiefly derived from a copper-coloured mineral found in Westphalia, called *kupfernickel; nickel* being an epithet of detraction, because the ore looked like copper, and yet none could be extracted from it. Nickel is a principal ingredient in the alloy called German silver.

Cobalt.—This metal has a gray colour, with a shade of red, and is not brilliant. Its texture is granular; it is rather soft and brittle; its specific gravity is 8·7. It is used for giving a blue colour to glass and porcelain; the tint is beautiful, and hence the metal bears a high price. It unites with oxygen, and forms two oxides; these are the preparations of cobalt used in the arts. It also combines with chlorine, sulphur, selenium, and phosphorus. Its name is derived from *kobold,* an evil spirit, because the German miners, at a time when they were ignorant of its value, considered it unfavourable to the presence of more valuable metals.

Zinc.—This metal is of a bluish-white colour, and is composed of plates adhering together. It is a hard metal, being acted on by the file with difficulty; and after fusion, its specific gravity is 6·896. It becomes malleable at 212°, and melts at 773°, or before it is quite red. When heated red-hot with access of air, it takes fire, burns with an exceedingly beautiful greenish or bluish-white flame, and is at the same time converted into the only oxide of zinc with which we are acquainted. It is of a snow-white colour, is tasteless, and insoluble in water. With copper, zinc forms that well-known and useful alloy called *brass.* Zinc combines with, and is set on fire by, chlorine; it enters into union with phosphorus, sulphur, selenium, iodine, and various metals.

Cadmium.—This metal, which is commonly associated with the ores of zinc, has a white colour, with a shade of bluish-gray, and resembles tin in its appearance. It is very malleable, and has a specific gravity after fusion of 8·6040. It unites with oxygen, chlorine, and some other supporters, but the compounds are unimportant.

Tin possesses a fine white colour, with a slight shade of blue, and has a good deal of brilliancy. Its specific gravity after fusion is 7·285. It is very malleable. Tin leaf, or *tinfoil,* as it is called, is about the one-thousandth part of an inch thick, and it might be made much thinner if requisite. It is ductile, but of inferior tenacity. It is very flexible, and produces a remarkable crackling noise when bended. It melts at 442°; but a very violent heat is required before it will evaporate. It slowly tarnishes with the air, and when intensely heated, oxygen being supplied, it burns with great brilliancy. Tin combines with oxygen in three proportions, forming the protoxide, which is *black,* the sesquioxide, which is *grayish,* and the peroxide, which is *yellow.* It also unites with chlorine, bromine, iodine, sulphur, selenium, phosphorus, and fluorine. It alloys with various metals. It is used in coating vessels, either in a pure state or alloyed. Pewter is composed of lead and tin; the latter rendering the former, a poisonous metal, quite innocuous.

Metals which decompose Water at any Temperature, and the Oxides of which are not reduced to the Metallic State by the sole Action of Heat.

Arsenic.—The *White Arsenic* of commerce is a combination of this metal and oxygen. When mixed with *black flux* (cream of tartar, with about half its weight of nitre, heated to redness in a covered crucible), and subjected to heat, it is reduced to the metallic state. It has a bluish-white colour, is soft, brittle, and easily reduced to fine powder. Its specific gravity is 5·672. When moderately heated, it evaporates, combining with oxygen, and forming the arsenic of commerce, so well known for its destructiveness to animal life. With oxygen, arsenic forms two acids—the *arsenious* and *arsenic. Arsenious acid* is a white, brittle, compact substance, having a weak, acrid taste, which at last leaves an impression of sweetness. It is one of the most virulent poisons known. *Arsenic acid* is quite similar in its constitution to phosphoric acid. Arsenic combines with chlorine, bromine, iodine, fluorine, hydrogen, sulphur, phosphorus, and selenium.

Antimony, which was discovered by Basil Valentine in 1490, possesses, when pure, a silver-white colour. Its texture is fibrous, and it is easily reduced to powder by being pounded in a mortar. Its specific gravity is 6·8. It melts when heated nearly to redness, and at a higher heat it is sublimated in white fumes. It combines with oxygen in three proportions, and forms three compounds, two of which possess acid properties. The other is an oxide, which constitutes the base of all the active medicinal preparations of this metal. With chlorine it combines in two proportions, forming two chlorides, which are analogous to two of the compounds formed with oxygen. It also combines with bromine, iodine, fluorine, sulphur, selenium, phosphorus, and arsenic. Antimony is extensively used in the arts, particularly in typefounding, stereotyping, and the manufacture of the white-metal utensils now so generally used as substitutes for silver.

Tellurium is a metal, having a silver-white colour, and considerable brilliancy. It has a laminated texture, is brittle, may easily be reduced to powder, and has a specific gravity of 6·1379. It fuses at a temperature rather higher than that which is necessary to melt lead. It combines with oxygen, and forms *oxide of tellurium.* This compound possesses at once acid and alkaline properties. When tellurium is heated before the blowpipe, it burns with a blue flame, emitting a white smoke, which is the oxide. Tellurium burns spontaneously in chlorine gas, and forms a *chloride of tellurium*. It also unites with iodine, hydrogen, and carbon. The other combinations of this metal are still unknown.

Chromium is a metal of a whitish colour and brittle consistency. Its specific gravity is 5·9. It requires a very high degree of heat to melt it, and is only obtained pure in small grains. No acid readily dissolves it, except the fluoric. Chromium combines with two proportions of oxygen, forming two compounds, which have received the names of *green oxide* and *chromic acid*. Chromium unites with chlorine, sulphur, phosphorus, and probably fluorine. It is used in coloured glass making, and glass and porcelain painting. It is also used in enamelling, and as a rich, strong, and durable pigment. To glass and enamel it communicates a green colour, but to the painter it affords one of his prettiest yellows. Chrome red is the bichromate of potassa.

Vanadium, which was discovered by Sefström in 1830, is a whitish metal resembling silver, brittle, a good conductor of electricity, and is easily dissolved in nitric acid and aqua regia. When heated rather under redness, it takes fire, burns with a dull flame, and is converted into a black-coloured oxide. It combines with oxygen in three proportions, forming, first, *black oxide*, or protoxide, the *binoxide*, and *vanadic acid*. It combines also with chlorine, sulphur, and phosphorus, but its other compounds are unknown.

Uranium is a metal of an iron-gray colour, of considerable lustre, and when heated to redness, takes fire. It produces a deep green protoxide, which gives a black colour to porcelain, and a fawn-coloured peroxide, which communicates to porcelain an orange colour. Its specific gravity is 9. *Molybdenum* has a silvery-white colour, is brittle, and has a specific gravity of 8·636. *Tungsten* is of a grayish-white colour, is very hard and heavy, having a specific gravity of 17·4. *Columbium*, when burnished, assumes a yellowish-white colour and a metallic lustre. *Titanium* has a copper-red colour, and considerable brilliancy. It crystallises in cubes, is hard enough to scratch rock-crystal, and has a specific gravity of 5·3. All these metals combine with oxygen, and some of the other supporters; but the oxides and acids so formed are not deserving of particular mention. *Cerium* exists in a reddish-coloured mineral found in Sweden, called *cerite*. Cerium is a dark-gray powder, having a metallic lustre; but its properties have not yet been properly determined. It, however, combines with oxygen, chlorine, carbon, sulphur, and phosphorus. *Lantanium* and *Didymium*, very recently discovered by Mosander, may also be ranked under this family, though likewise closely allied to Yttrium and Zirconium.

Lead.—This is one of the most abundant of all the metals, and one of the softest and most fusible. Lead has a bluish-white colour, and a good deal of lustre; but it soon tarnishes. Its specific gravity after fusion, which takes place at 606°, is 11·351. Lead is very malleable; it is also ductile, but its wire possesses little tenacity. By exposure to a very strong heat, it is volatilized, and at the heat of burning hydrogen, urged by oxygen, it burns with a bluish flame. While exposed to the atmosphere during fusion, it imbibes oxygen, and is converted into an oxide. There are three oxides of lead—the protoxide, which is known in commerce and the arts as a yellow paint, under the name *massicot*, or, if it be semi-vitrified, *litharge*; the deutoxide is also a paint of a brilliant red colour, inclining to orange; it obtains the name of *minium*, or *red lead*; and the peroxide, which is of a deep puce *brown* colour. When heated with sulphur, spontaneous combustion takes place. Lead also combines with chlorine, bromine, iodine, sulphur, selenium, arsenic, &c. It is rendered hard by antimony; and the alloy, mixed with a little tin, constitutes the material from which printers' types are elaborated. The salts of lead are numerous, and very important. *White lead*, or *ceruse*, the only white used in all oil paintings, is made by subjecting thin plates of lead, rolled up spirally, to the fumes of vinegar. The lead soon becomes corroded, and assumes a white appearance and a brittle consistency. If this substance be dissolved in acetic acid, or vinegar, it becomes *sugar of lead*. Lead is never found native; by far the most common state in which it occurs in nature is sulphuret of lead, or *galena*.

Copper, in point of general utility, ranks next to iron. It possesses a rose-red colour, and a great degree of brilliancy. Its specific gravity, after being rolled out into plates, is 8·953. It has great malleability, and very considerable ductility. A bar of cast copper, one quarter of an inch thick, requires 1192 lbs. to break it, whilst hammered copper requires nearly 1000 lbs. more to break it. It melts at 196°; and if the heat be increased, it evaporates in fumes, which are visible. When rubbed, it emits a smell. When heated in a hydrogen flame urged by oxygen, it burns brilliantly, emitting a dazzling green light; a piece of copper in a coal fire tinges the blaze green. When exposed to air, it oxidates into a green carbonate of copper, slowly, and when in contact with moisture. With oxygen it combines in three proportions, forming three oxides, two of which occur native; the other is not a permanent compound. Copper combines also with chlorine, iodine, sulphur, phosphorus, arsenic, and tin. Its alloys with the latter metal are very important, forming *bronze*, *bell-metal*, and other alloys.

Bismuth, discovered in 1530, has a reddish-white colour, and is composed of broad plates adhering to each other. It is one of the most fusible of the metals, melting at 476°; it communicates its fusibility to other metals; hence its use as a *flux* and *solder*. Its specific gravity is 9·833. Although not very brittle, it is not malleable, unless when heated, nor can it be drawn into wire. A mixture of tin, lead, and bismuth, is so fusible that it melts when thrown into boiling water. A toy of this kind is well known; it is a spoon, which, when immersed in a very hot liquid, immediately melts. Bismuth combines with oxygen, chlorine, bromine, iodine, sulphur, and selenium. What is called Newton's fusible metal, is a compound of eight parts by weight of bismuth, five of lead, and three of tin; it melts at 212°. The nitrate of bismuth has been used as a mordant; it also furnishes the medicinal powder called *pearl white*.

Metals whose Oxides are decomposed by a red heat.

Mercury or Quicksilver.—This metal has a silver-white colour, possesses great brilliancy, and remains fluid at the common temperature of the atmosphere. Its specific gravity at 60° is 13·56846; at 39° below zero, when it assumes the solid form, it is 15·612°. When solid, it may be beaten out with a hammer, or cut with a knife. When heated to 656°, it boils; and when heated in the open air, it oxidises. The oxides and chlorides of mercury afford an admirable proof of the truth of the atomic theory. It combines also with bromine, iodine, sulphur, selenium, and phosphorus. The compounds which mercury forms with the other metals are usually termed amalgams. This metal occurs in South America and in Spain, in great abundance; but the mine of Idria, in Carniola, an Austrian province, is perhaps the greatest in the world, and has been wrought for more than three centuries.

Silver.—This metal is of a fine white colour, with a slight shade of yellow. When polished, it displays a great deal of brilliancy and beauty. It is very malleable, and may be beaten out into leaves so thin as 1-100,000th of an inch. It is softer than copper, and harder than gold; but its tenacity is inferior to the former metal. When melted and cooled slowly, its specific gravity is 10·3946; when hammered and rolled, it is a little higher. Its melting-point is 1830°; and if it be kept melted for a long time, it absorbs oxygen; but possesses the very singular property of parting with the oxygen on solidifying. The presence of a little copper deprives it of this property. Silver forms with oxygen only one well-known oxide. It also unites with chlorine, bromine, iodine, sulphur, selenium, phosphorus, and arsenic. There are numerous alloys of silver, but few of much consequence. Silver is found in all parts of the world, sometimes associated with a variety of other metals and substances as an ore, and sometimes in the native state.

Gold, the most valuable of all the metals, always occurs in nature in the metallic state, although seldom pure. It has a beautiful yellow colour, and considerable lustre, which it retains, not being liable to be tarnished by exposure to the air. It is rather softer than silver, and after fusion, it has a specific gravity of 19·3. It is the most malleable of metals, and may be beaten out into leaves no thicker than 1-282,000th of an inch; and the gold leaf with which silver wire is covered is only 1-12th of that thickness. Its tenacity is considerable, but inferior to that of silver. It melts at 2016°. It is insoluble in sulphuric, nitric, and muriatic acid; but is readily dissolves in aqua regia, which is a compound of the two latter. It is difficult to oxidise gold, and still more to burn it; but both can be accomplished. Oxygen combines with gold in two proportions, possibly in three, forming oxides. Gold also unites with chlorine, bromine, iodine, sulphur, phosphorus, and arsenic. There are a number of alloys of gold; the standard gold coin of the realm is an alloy of eleven parts of gold to one of copper or silver, or sometimes both.

Platinum.—This metal is white, like silver; whence its name from the Spanish word *plata*, silver. Its specific gravity is 21·47, so that it is heavier than gold; its hardness is intermediate between copper and iron. It is very ductile and malleable, though much less so than gold. Its tenacity is considerable. It will not melt in the heat of our most powerful furnaces, but it may be fused by the oxihydrogen blowpipe. Its property of resisting high temperatures without fusion is a most important one; and on this account, as well as its property of resisting the action of most chemical agents, it has been employed in the formation of vessels which it is necessary to subject to an extraordinary degree of heat. Like gold, it resists the action of all the single acids, but dissolves in aqua regia. It combines with oxygen in probably four proportions, forming oxides. It unites also with chlorine, bromine, iodine, silicon, sulphur, selenium, and phosphorus. There are numerous alloys of platinum, but they are not of much importance. There is a form of this metal which possesses extraordinary properties; it is called *spongy platinum*. It is prepared by dissolving platinum in a mixture of nitric and muriatic acids by heat; muriate of ammonia is added, when a precipitate falls, which must be filtered and dried. If a small quantity of this powder be heated by a candle, it will become incandescent, as if it took fire. It is, when cold, fit for use. If a jet of hydrogen, from a tube of a very slender bore, be directed on it from a little distance, the metal immediately becomes red-hot, and it sets fire to the hydrogen. This may be repeated a great number of times; but the sponge at last loses its power; the smaller the quantity, the sooner its power is lost.

Palladium, Rhodium, Iridium, and Osmium.—These four metals occur in the platinum of commerce, and were discovered by Tennant in 1803. They are procurable in very small quantities; they have not been applied to any use of moment; they possess no very remarkable qualities, and therefore do not require to be minutely described. They all unite with oxygen and chlorine, and some of them with the other supporters. *Ruthenium*, recently discovered by Claus in the insoluble residue of the ore of platinum, may be added to this group.

Such is a brief sketch of the fifty-four simple substances (sixty-one, if we admit the metallic bases lately discovered by Mosander, Claus, and Rose), whose numerous combinations give rise to the infinite variety of objects which are found ready-formed in the laboratory of nature, or have been discovered in that of the philosopher. The minerals and metals of commerce will be further treated under the heads MINING and METALLURGY.

ORGANIC CHEMISTRY.

Vitality enables plants and animals to absorb and assimilate food, consisting of the elements necessary for their increase, and also to reproduce beings of their own kind, by means of certain organs; hence they are said to be *organized*, and the substances of which they are composed are known by the general name of *organic matter*. Earths, minerals, metals, and the like, not possessing vitality, have no organs, and consist only of *inorganic matter*. Organic chemistry—in contradistinction to Inorganic chemistry—is therefore that department of the science which treats of the composition, properties, and uses, as well as of the origin, of all substances produced in the animal and vegetable kingdoms, and of the artificial compounds arising from their decomposition. By virtue of his knowledge, the chemist can decompose, transform, reconstruct, and imitate in a wonderful manner the products of the inorganic world; but while he can in like manner decompose and transform the products of the organic, he is utterly impotent to reconstruct a single organ, or imitate its functions. The chemistry of Vitality is far beyond his art; he is only as yet beginning to acquire a faint conception of its principles and functions. He finds, however, so far as the ultimate analysis of organic substances can show, that plants and animals are composed of the same elements as inorganic matter; and that the two branches of the science are not essentially different, so far as the nature of these elements is concerned. There is this peculiarity, however, that a certain class of organic compounds possess the property of uniting with the elements, and of forming with them new combinations, which are analogous in their properties to the combinations of two simple bodies. Such compounds are called 'compound radicals;' hence the term *chemistry of compound radicals*.

VEGETABLE COMPOUNDS.

Notwithstanding the infinite diversity of form which vegetable substances assume, it has been proved that they are all mainly composed of the same elements, and these are only *four* in number—namely, oxygen, hydrogen, carbon, and nitrogen. These, again, by uniting amongst themselves, form the compounds which constitute the vegetable structure; and being the more immediate objects of sense in the investigation of any organisation, these are called their *proximate principles*. Existing ready-formed in roots, woods, barks, leaves, flowers, fruits, and seeds, we find a considerable number of proximate principles, in the form of acids, alkalies, sweet principles, bitter principles, oils, exudations; some poisonous, others wholesome; some spontaneously separating, others remaining obstinately combined. We shall give a brief outline of these, referring for further details to VEGETABLE PHYSIOLOGY, AGRICULTURE, ALIMENTARY SUBSTANCES, AND MEDICINE.

Common *Citric Acid* exists in the juice of lemons, and, when crystallised, one hundred grains consist of—water 23⅔, and pure acid 76⅓, which is a compound of 42·1 oxygen, 31·58 carbon, and 2·63 hydrogen. *Sorbic acid* is the sour principle of apples, sorbus berries, and other fruits. It consists of the same ingredients as the former. *Tartaric acid* is the sour principle of grapes; when a large quantity of them are left to ferment, the result, it is well known, is wine. On the side of the vessel containing this liquor, crystals of the acid, combined with potash, are formed, and these, when purified, are *cream of tartar*. Twelve parts in the 100 are water; and the remaining 88 consist of oxygen 52·97, carbon 32·39, and hydrogen 2·64 parts. *Oxalic acid.*—The plant called sorrel is valued for its acidulous taste, which is conferred upon it by this acid. It has no hydrogen in its composition, consisting merely of oxygen and carbon. It is an active poison, and from resembling Epsom salts in appearance, many persons have fallen victims to its virulence. The antidote is powdered chalk. *Gallic acid* is obtained from nut-galls. Its most remarkable property is that of changing the colour of solutions containing iron to an intense blue-black colour, as in the case of common writing-ink. One hundred grains consist of 56·25 carbon, 37·5 oxygen, and 6·25 hydrogen. *Prussic* or *Hydrocyanic* acid, found in various fruits and flowers, is a most powerful poison. It is formed of hydrogen and cyanogen, a noxious inflammable gas. Such acids as those just described exist ready formed in fruits, &c.; they are simple *educts*. But there are others formed by chemical changes produced on certain elements contained in vegetables, which afford the base of the acid; these are acid *products*: some are produced by the agency of heat, others by the action of nitric acid. *Acetic acid* or vinegar is one of these, being a product of any liquid capable of undergoing the vinous fermentation. Fermentation produces alcohol, and alcohol, by oxidation, is converted into acetic acid. Several acids, when distilled at a high temperature, undergo decomposition, and new acids are formed. Their names remain the same, or have the word *pyro* prefixed, as *pyrocitric acid*, *pyroligneous acid*, &c.

It has also been ascertained that *alkalies*, as well as acids, exist ready formed in plants as one of their constituent principles. Those which evince alkaline properties of a weak character are entitled *alkaloids*. The alkalies are *quinine* and *cinchona*, which resemble each other, have a bitter taste, and neutralise acids. *Morphia*, which is obtained from opium, is a white crystalline powder; *strychnia*, one of the most powerful bitters and poisons, which has of late been much used in medicine; *brucia*, also a violent poison; *digitalia*, which is procured from the leaves of foxglove; *hyoscyamia*, *atropia*, *veratria*, *emetina*, &c. which are derived from henbane, deadly nightshade, &c.

Of the other proximate principles, the first deserving of notice is the woody fibre which constitutes the solid basis of all vegetable structures. It is called *lignin*, from *lignum*, wood; and consists of 52 carbon, and 48 of oxygen and hydrogen, in the ratio which forms water. With lignin are associated various other bodies, such as *resins*, which are various and abundant. In the different species of the pine-tree, we discover that peculiar liquid resin called *turpentine*. From resins are obtained what are called *essential oils*; because, after the resin has been heated in a distilling apparatus, an odoriferous oil distils over, and leaves the resin hard, dark, and odourless. The *essence* of the substance is supposed to have passed away in the aeriform state; hence the name. From its speedily evaporating on being exposed to the air, it is also called *volatile oil*. The seeds of plants yield another oil, which, not evaporating, is called *fixed oil*. To these two oils there are two substances bearing some analogy—*wax* and *camphor*. The former, when melted, possesses some of the properties of a fixed oil; and the latter seems to possess the properties of a concrete volatile oil, although it possesses qualities distinct from those of all other bodies. *Gum*, for instance gum-arabic, has the following properties: namely, transparency, tastelessness, perfect solubility in water, viscidity of the solution, capability of cementing fragments, and of affording a varnish, and total insolubility in spirit of wine. There is a class of bodies called *gum resins* whose properties are intermediate between those of gum and resin; and somewhat allied to resins, although essentially different in most of their properties, are the substances *caoutchouc* and *gutta percha*. They are the exuded juices of peculiar trees, and are composed of carbon and hydrogen.

From wheaten flour a substance is obtained called *gluten*, from its glutinous nature. There are two principles in this substance—the one is called *gliadin*, and the other *zimomin*. A substance called *vegetable albumen* seems to be the basis of all emulsive grains in place of starch, and greatly resembles it. *Starch* is a fine white sediment, precipitated from the white and brittle parts of vegetables, particularly the tuberose roots, and the seeds of the gramineous plants. One of the most remarkable properties of starch, or, as it is called, *fecula*, is that of being convertible into sugar by the action of diluted sulphuric acid. Every one, we suppose, should know what *sugar* is; being in particular a sweetener of the kindly beverages tea and coffee. It is derived from many sources—from the sugar-cane, maple-tree, beetroot, and grapes. Nothing is easier than its formation from grapes: grape juice is to be saturated with chalk, clarified with white of eggs, or blood, and evaporated; after a few days, it assumes the form of a crystalline mass. *Tannin*.—From oak bark, or nut-galls, a peculiar substance is obtained, called tannin—so named from being the material employed in tanning leather. It is inodorous, colourless, and possesses a rough astringent bitter taste.

ANIMAL COMPOUNDS.

The chief substances which enter into the composition of animal matter are oxygen, hydrogen, azote, carbon, phosphorus, and lime. We also find certain acids and metals, but in quantity so minute, as not to affect the truth of the general statement.

Bone consists of phosphate and carbonate of lime, and two other ingredients—*cartilage* and *gelatine*. The latter is the coagulating, or rather elastic, principle in all *animal jellies*. When bones are burned in a close vessel, they form *ivory black*. *Fibrin* is obtained from the vessels; when recently obtained, it is elastic; but when perfectly dry, it is somewhat horny and transparent. There is an important substance called *osmazome*, which communicates to soups and broths their peculiar taste and smell, and the greater the quantity present, the better is the soup. The *tendons*, *ligaments*, and *membranes*, are nearly allied to gelatine in their nature. *Fatty* substances, as lard and oils, are formed chiefly of carbon, with a little hydrogen and oxygen, one or both. *Albumen* is a substance very abundant in animal matter. It occurs nearly pure in the white of eggs. Of this substance in the coagulated state, along with gelatine, are *horns*, *nails*, and *hoofs* composed. The *brain*, the thinking organ of man, consists of water 80, white fat 4·53, red fat 0·7, osmazome 1·12, albumen 7, phosphorus 1·5, sulphur and various salts 5·15 parts in the hundred.

Of the fluids of the animal body, *blood*, one of the most important, is viscid, of a red colour, exhaling a vapour of a peculiar odour. When left at rest a few hours, its appearance is very much altered, having separated into two parts—one quite liquid, of a greenish whey-like colour, and called *serum*; the other an elastic firm jelly, of a crimson red colour and thick consistence, resembling a deposit, which is called the *crassamentum*, or *clot*. If this clot be repeatedly washed with cold water, it parts with its red colour to the water, becomes white, and a fibrous matter remains, which, when subjected to analysis, proves to be *fibrin*. Serum coagulates when heated to about 160°, nearly in the same manner as the white of an egg, but the colour is not pure white. If the serum thus coagulated be cut in slices, a fluid will exude which is called the *serosity* of blood; it consists chiefly of water, holding a little altered albumen and a little common salt in solution. Serum is composed of water, albumen, soda, and some salts of soda. Clot is composed of fibrin, albumen, red colouring matter, a little iron, and carbonic acid. During the conversion of arterial into venous blood (as explained under ANIMAL PHYSIOLOGY), nitrogen, hydrogen, and other elements, are spent in the formation of new products, while the proximate principles of the blood remain, with an increased proportion of carbon. In this state it is exposed to the atmospheric air in the lungs, the oxygen of which abstracts its excess of carbon, and forms the carbonic acid expired; and this process constitutes the conversion of venous into arterial blood.

CHEMISTRY APPLIED TO THE ARTS.

CHEMISTRY, or that department of physical science which recognises the nature and composition of bodies, and the new forms and properties they may be made to assume, is now indispensable to the proper conducting of almost every useful art. Agriculture, which may be considered the most important of all the arts, is radically dependent on chemistry; for without a knowledge of that science, the husbandman remains ignorant of the constitution of his soils and crops, the action of the atmosphere and sun's light, and the properties of those materials which are required to enrich his exhausted fields. Baking, brewing, distilling, and indeed all the operations by which food is prepared from the condition in which it is furnished by nature, are in general a series of chemical processes. So, likewise, is the manufacture of pottery-ware, porcelain, glass, paper; the operations of bleaching, dyeing, and calico-printing; the preparation of soap, gunpowder, ink, salt, drugs, paints, perfumery, and various other articles in daily demand. The applications of chemistry to the arts are in reality so numerous, that, to do the subject justice, we should require to take in nearly the whole circle of manufacturing industry. To do so, however, is beyond our limited means, even were it desirable; and our object in the present sheet is to give a short account of the manner in which chemistry is practically applied in those industrial operations to which we have not elsewhere alluded. The design in view is not to teach any one art, but to incite to a *general study of chemistry* among those classes who are engaged in such branches of manufacture as involve an elementary change in substance. Manufactures of this kind may be termed *chemical*, in contradistinction to those whose elaboration mainly depends upon principles that are *mechanical*. Thus the conversion of sand, potash, and lime into glass; of common salt into soda; hides into leather; or charcoal, sulphur, and saltpetre, into gunpowder, are chiefly chemical processes: while the conversion of flax into cloth, iron-ore into sheet-iron, or clay into pottery, are principally mechanical, though in both there is a necessary blending of chemical with mechanical appliances. 'Technology' being a systematic exposition of the principles upon which all processes employed in the arts are based, CHEMICAL TECHNOLOGY may be regarded as the scientific title of the present subject, which should properly commence with a description of the principal apparatus required in practice.

THE LABORATORY.

A *laboratory* is a chemist's workshop. It is the place in which he performs his experiments, and requires to be airy and spacious, to have a command of water, to be provided with suitable tables and shelves, mortars, filters, furnaces, jars, retorts, and other apparatus. Above all, it should be furnished with the means of rapid ventilation, so as to carry off any noxious fumes that may arise; should be kept in methodical order—every substance being properly labelled, as little waste as possible allowed, and the greatest caution exercised, with a view to prevent mistakes and injuries. For beginners and amateurs, who may not possess an independent laboratory, any unfurnished apartment may be used; and sets of portable apparatus, accompanied with specimens of the elementary substances, may be procured from the dealers in most of our large towns. With such portable apparatus many highly interesting experiments may be performed, and a very considerable amount of practical knowledge obtained. Nor need great expense be incurred, if the student is possessed of an ordinary degree of mechanical skill, as, with a little ingenuity, he may make the same apparatus answer a variety of purposes.

Balances of an exact and very delicate nature are essentially requisite, as correct weighing is indispensable to every chemical experiment. There should be at least two balances; one for weighing heavy matters, and another for very minute quantities. The last instrument should be sufficiently delicate to weigh from 600 to 1000 grains, and downwards, indicating, distinctly and certainly, differences of an exceedingly minute amount, even to the thousandth part of a grain. As it is by carefully weighing substances, both before and after being experimented upon, that the exact constituent parts of bodies are determined, and the most important chemical truths ascertained, the balance and weights should be carefully examined at intervals, and their accuracy tested. Such balances ought to be preserved in glass cases, be fitted with apparatus for regulating their centres of suspension and gravity, and for rendering them immovable at pleasure, and have indices attached, whereby the minutest fraction of a grain may be ascertained. In weighing, variations of temperature, absorption of moisture from the atmosphere, and other similar conditions, must be carefully attended to, otherwise the results will be vitiated, and without value.

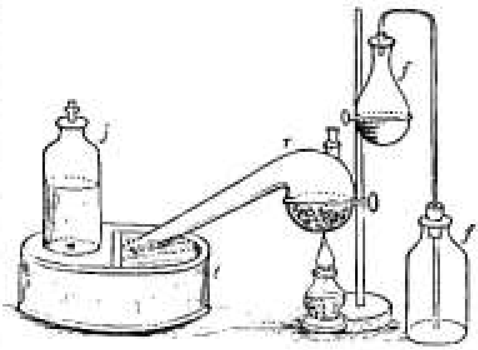
Measures are necessary for ascertaining the bulk of liquids or gases, and two integers are sufficient—the pint and the cubic inch. Measures should be made of glass, and have a graduated scale marked on both sides. They are commonly of a cylindrical shape, like a phial bottle, and possess a small spout at the orifice. The graduations on these instruments are sometimes very minute, and indicate exceedingly small quantities of the fluids and gases. The measures should be verified by weighing into them successively portions of mercury and water. A cubic inch of the former, at a temperature of 62°, weighs 3425·35 grains, and the same quantity of the latter, at the same temperature, weighs 252·458 grains. Water answers well enough for estimation down to the cubic inch, but for the tenths and the hundredths of an inch, mercury is both more exact and more expeditious.

Furnaces of one kind or other are indispensable, as heat is one of the most powerful and extensively useful agents employed by the chemist for ascertaining the properties of bodies. Dr Black's portable furnace, which is much used, consists of a stout iron case, like a round stove in shape. Above is an aperture for an iron pot, to contain sand; and other openings may also be observed, for introducing tubes and different kinds of apparatus. The pipe carrying away the smoke must be prolonged or connected with a chimney. Furnaces upon a large scale are constructed in various ways of fire-brick, as will be more fully described under METALLURGY. This degree of heat can be produced either by propelling air upon the combustible matter by means of bellows, in which case the furnace is called a *blast-furnace*, or by forming long flues, and raising a high chimney. The higher the chimney is raised, the more powerful is the draught. Upon the top of a furnace of this open kind, and also upon the flues, close by the fire, vessels containing sand, and hence called *sand-baths*, are placed. In these, bodies can be raised to a high degree of temperature. Where any degree of heat below 212° is required, *water-baths* are the media employed. Charcoal is the substance most commonly used in furnaces. It produces an intense heat, without smoke, but very soon consumes. Coke, or charred coal, produces a strong and lasting heat. One of the most convenient forms in which heat can be applied to any chemical operation, is that of placing a spirit-lamp under a glass retort, fixed to a simple kind of stand, as shown in next column. The lamp is trimmed with cotton wick, and fed by alcohol, which gives a pure flame, and generates a high degree of heat. Where a higher temperature is required, the *Argand*, or chemical burner, is applied. In general, common gas is now employed as the heating power.

The *blowpipe* is one of the most useful articles in the laboratory of the chemist or mineralogist. The principle on which it operates is that of a blast-furnace, on so minute a scale as to be capable of being held in the hand. The pipe, which is made of tin or brass, of a shape resembling that represented in the adjoining fig., is usually eight or ten inches in length; *m* being the mouth or upper end, through which the breath is impelled, and *o* the small orifice, at the point of the side tube, from which the blast comes. By placing the upper end of the instrument in the mouth, and urging a stream of air upon the flame of a lamp or candle, an intense degree of heat is produced, which may be brought to bear upon any substance. The orifice should be fitted with a platinum nozle or jet, as that metal resists any degree of heat which can be produced by the blowpipe, and can be readily cleared by burning when the opening happens to be stopped up by dirt or grease. In using the blowpipe, the air must not be forced directly from the lungs, as such would soon exhaust the operator, besides the injurious effect that it might have upon his health; but the mouth must be filled with air, and this suffered to pass very gradually through the instrument, aided by the compression of the muscles of the cheeks and lips, the operator breathing at the same time through his nostrils. This, which is confessedly rather troublesome at first, is rendered perfectly easy after a few trials; so that, with a little practice, a blast of several minutes' duration may be kept up without the least trouble or fatigue. Substances, when exposed to the flame, are supported on a piece of well-burnt charcoal, or at the end of a thin platinum wire bent into a loop. Otherwise, they are held by a pair of tongs or forceps with platinum points; and occasionally in a narrow glass tube, three or four inches long, and open at both ends; or in one of the same length, but of larger diameter, and closed at one end, so as to form a little flask or test tube. The rationale of the intense heat produced by the blowpipe, is that the gaseous matter of the flame undergoes complete and rapid combustion, and is moreover concentrated to a point or focus by the stream of oxygen made to play upon it. If the two gases oxygen and hydrogen be mixed together in the proportions which form water, and compressed to the amount of many atmospheres in a metallic box provided with a small tube, what is called an *oxy-hydrogen blowpipe* is formed. By this apparatus, which is quite safe when properly constructed, an almost incredible degree of heat can be produced. The self-acting *alcohol blowpipe*, in which the vapour of that spirit is made to act as the blasting force, is another variety of the instrument; more ingenious, however, than practically useful.

Crucibles are open vessels which resist very high temperatures. They are made of various shapes, triangular or circular, and of different kinds of materials, but by far the greater number are formed of earthenware—that is, of clay free from lime, mixed with sand or groundware of the same description. To promote chemical action, what are called *fluxes* (which will be afterwards described) are employed. Now it is important that the crucible be made of a substance which is not rendered more fusible by a flux. Wedgewood's crucibles are made of a close white ware; and although thin, they are not easily dissolved: they retain fluxes at moderate temperatures longer than other crucibles. Those made of a mixture of coarse plumbago and clay are also excellent in these respects. But the most valuable in the laboratory are the Hessian and Cornish crucibles. Charcoal and metallic ones are likewise used; those formed of platinum being the most generally useful, although at first somewhat expensive.

Retorts are vessels employed for many distillations, and most frequently for those which require a degree of heat higher than that of boiling water. This vessel (*r*) is a species of bottle with a long neck, so bent, that it makes with the globular belly of the retort an angle of about sixty degrees. The most capacious part of the retort is called its belly, its upper part the arch or roof (which may or may not be fitted with a ground stopper, according to the purpose for which it is employed), and the bent part the neck. Retorts are composed of different kinds of materials, those of glass being by far the most common. They answer for all operations conducted at temperatures less than that at which glass softens; and from their transparency, they admit of constant observation of the materials within: they are, besides, acted upon or injured by few substances, and



may be easily cleaned. To the bent neck of the retort various tubes can be fitted, and the evaporated substance conducted into a refrigerator. Common flasks (*f,f*) and bent tubes answer many purposes equally well, and are often more convenient. For distillations or sublimations requiring high degrees of temperature, metallic and earthenware retorts are had recourse to.

A *pneumatic trough* (*t*) is a vessel constructed so as to retain water, and large enough to admit of jars being filled in it. Shelves and supports are fixed in it beneath the surface of the water; on these, vessels may be firmly placed. If, now, a large open-mouthed glass jar (*j*) be filled with water, inverted beneath the surface of the water in the trough, and put upon one of these stands, a tube from a retort or other distilling vessel, introduced into the inverted mouth of the jar, will convey the gaseous matter, which, displacing the water occupying the jar, can thus easily be collected in it. In this manner gases are obtained. If the jar be provided with a stopcock, they can easily be withdrawn into vessels fitted to retain them. Instead of water, mercury, which is fluid at ordinary temperatures, is used in experiments where water would absorb the gases, or where exceeding nicety is required.

Tests.—Alkalies and acids in a free state possess the power, even in very small quantities, of effecting certain general and regular changes in the tints of some vegetable colours. Accordingly, colours of this description are used for ascertaining the presence of these bodies when in excess or uncombined, and are called *tests*, from their testing or distinguishing the chemical composition of bodies; or *re-agents*, from their reacting upon the elements of bodies. Litmus and turmeric are most generally used; the former a blue colouring matter prepared from the *Lichen rochella*, the latter a yellow colouring matter obtained from the *Curcuma longa*. They are prepared by dipping unsized and bibulous paper in concentrated infusions of these substances. The litmus imparts a fine blue tinge to the paper, the turmeric a yellow one. In using these test-papers with a fluid suspected to contain free acid or alkali, or knowing that one of these substances is predominant, in order to ascertain which is so, all that is necessary is, to moisten the papers with the liquid, and observe the change which is effected; if the fluid be acid, the blue colour of the litmus will immediately become red; if alkaline, the yellow colour of the turmeric will be changed to brown. *Test-tubes*, for holding minute quantities either of solids or liquids, are small tubes closed at one end, varying from four to eight inches in length, and of different widths. They are made of thin, well-annealed glass.

A *flux* is a substance made use of to assist the fusion and union of minerals or metals. It acts by protecting the substance from the air, by dissolving impurities which would otherwise be infusible, and by conveying active agents, such as charcoal and reducing matter, into contact with the substance operated upon. Upon a large scale, limestone and fusible spar are used as fluxes. What is called *crude flux*, is a mixture of nitre and cream of tartar, put into the vessel along with the substance to be fused. *White flux* consists of the same ingredients, in equal quantities, but they are first deflagrated in an earthen crucible heated red-hot at the bottom. *Black flux* has the same constituents as the preceding, but the weight of the tartar is double that of the nitre. Borax also forms an efficient and readily available flux.

Lutes are soft adhesive mixtures, principally earthy, used either for closing apertures existing at the junction of different pieces of apparatus, or for coating the exterior of vessels which have to be subjected to very high temperatures. The lutes employed for junctions pass into the nature of cements, which are substances used for uniting or joining together things of the same or different kinds, so as to form a whole. The best lute used for coating a vessel is made of Stourbridge clay. It is formed into a paste, which should be beaten until it becomes perfectly ductile and uniform, flattened into a cake, and then applied to the vessel which it is wished to coat. What is called *fat lute* is prepared by beating dried and finely-pulverised clay (pipeclay or Cornish clay) with drying linseed oil, until the mixture be soft and ductile. A paste of linseed meal forms an exceedingly strong lute; but becomes so hard, that it is difficult to remove it. Caustic lime, when mixed with various mineral and vegetable substances in solution, affords numerous cements and lutes, which become hard when dry, and are impervious to vapours. One of the best is that obtained by using white of egg diluted with its bulk of water. The fluids are to be beaten together until the mixture pours with perfect liquidity. There is then added a quantity of dry slaked lime in powder, until the mixture assumes the consistency of thin paste. A solution of glue, or the serum of blood, is sometimes substituted for the white of egg. White lead ground with oil also makes a very useful lute or cement. Soft cement consists of yellow wax (which alone is sometimes used as a cement) melted with its weight of turpentine, and a little Venetian red to give it a colour. When cold, it is hard like soap; but when pressed by the hand, the heat renders it pliant.

A great variety of other apparatus and materials besides those enumerated, are either necessary or useful in a laboratory. Electrifying machines, galvanic batteries, air-pumps, syringes, tubes bent into various forms, and of different sizes, for fitting into the necks of retorts, &c. mortars, dishes for holding both solids and fluids, as well as other materials which it is unnecessary to name, are frequently required; but, as already mentioned, a very convenient small laboratory, in which a vast number of interesting experiments can be performed, may be furnished at very little expense.

GENERAL PROCESSES.

Trituration.—As a general principle, the more minutely matter is divided, the more rapid will be the chemical action exerted between the particles. This division of matter is effected in various ways. First, by trituration, or the reduction of substances to a state of powder, which is a mechanical action not affecting the physical state of the body, and only relating to solids. In accomplishing this, the pestle and mortar are generally used. Externally, mortars are usually shaped like a flower-pot, the inside, at the bottom, being curved like the thick end of an egg. They are made of various materials, such as metal, porphyry, Wedgewood-ware, agate, and so on, according to the purposes to which they are applied. The pestle is generally of the same material as the mortar, and is a solid rod, having a rounded bulb at one end for pounding the substance in the mortar. Trituration answers very well the purpose of promoting chemical action in a number of experiments, but by fusion and solution it is rendered more complete. *Levigation* differs from ordinary trituration, inasmuch as a fluid is added to assist the operation.

Fusion.—Bodies are said to be in a state of fusion when, heat being applied to them, they assume the liquid form, a state in which all the particles of a substance move easily amongst themselves. Metals, as is well known, may be reduced to a liquid condition by melting or fusing them in a crucible over a sharp heat, or in a furnace. For the degree of heat at which most metals fuse, we refer to the previous sheet. Substances which admit of being fused are termed *fusible*, while those which resist the action of fire are termed *refractory*. Fusion differs from liquefaction, in being applied chiefly to metals and other substances which melt at a high temperature. *Igneous fusion* is the melting of anhydrous salts (salts without water of crystallisation) by heat, without their undergoing decomposition; *aqueous fusion* is the dissolving by heat of salts which contain water of crystallisation.

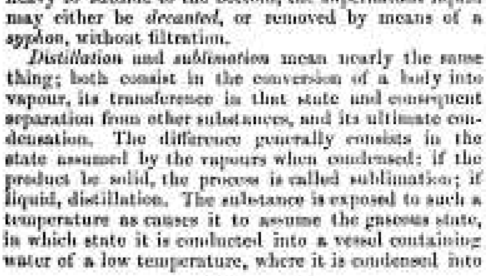
Vitrifaction is a peculiar kind of fusion, by which certain materials, when exposed to an intense heat, melt, and form that transparent substance called glass or crystal. The materials employed to form common glass are silica or sea sand, an alkali, such as carbonate of potass, and a metallic oxide. (See *Glass-making*, in article FICTILE MANUFACTURES.) It is less generally understood that a kind of glass, soluble in water, may be made from silica and carbonate of potassa. 'Mix intimately 200 grains of fine sand, and 600 of fine carbonate of potassa; fuse the mixture in a crucible capable of containing four times as much. Carbonic acid escapes, the silica and potassa combine, and produce glass. Pour out the glass, which is commonly termed *silicated potassa*, on an iron plate, and dissolve it in water, the large quantity of alkali rendering it soluble in this fluid. The compound formed in this manner constitutes pure *silica soap*, having all the detergent properties of common soap; it is, however, more active, and leaves a harsh feeling upon the hand. In commerce, silica soap is generally mixed with a considerable portion of common soap, and occasionally adulterated with sand.'

Solution.—When a solid body, such as a piece of sugar, is put into water, it is gradually dissolved; and when the lump of saccharine matter has disappeared, and become mixed with the water, and remains so, it is said to be held in solution by it. Liquids are called *solvents*, from their acting on, or holding in solution, either solid or aëriform fluids; and a fluid which holds in solution as much of any substance as it can dissolve, is said to be *saturated*. Supersaturated and subsaturated are relative terms, respectively signifying more and less than complete saturation. Heat greatly promotes the rapidity of solution; and for this purpose glass vessels having a rounded bottom, such as a Florence flask, and placed upon a spirit-lamp, are very commonly employed. In processes connected with the subdivision of matter, when hot water is merely poured upon the substance, the process is called *infusion*; and when the substance is boiled, the result is called a *decoction*. There is a process of solution called *lixiviation*, which consists in the separation of a soluble body from an insoluble one by means of washing; or it may be the soluble from the insoluble portion of the same body. *Maceration* is the steeping of any substance, with a view either simply to soften it, or to promote the separation of its parts.

Desiccation, or the drying of substances, may be carried on without exhaustion by means of what are called *desiccators* or dryers. This is better effected in close vessels than in the open air, unless a current be taken advantage of. In these processes, sulphuric acid, chloride of calcium, carbonate of potash, quicklime, and similar absorbents, may be used. A moist precipitate placed above a basin of common quicklime, the whole being covered with a jar or receiver, will speedily undergo complete desiccation.

Filtration consists in putting mixed substances into vessels which are porous enough to admit of the passage of one substance through them, but close enough to retain another. Unsized paper, cloth, flannel, tow, sponge, sand, pulverised glass, flints, porous stones, earthenware, and many other substances, are used on different occasions; but the first is almost exclusively used in a laboratory, a few of the others now and then being resorted to only on particular occasions. Of course it is only mechanically-suspended particles that can be separated by filtration; and the finer these particles, the closer must be the texture of the filtering medium. When the solid particles are sufficiently heavy to subside to the bottom, the supernatant liquid may either be *decanted*, or removed by means of a *syphon*, without filtration.

Distillation and *sublimation* mean nearly the same thing; both consist in the conversion of a body into vapour, its transference in that state and consequent separation from other substances, and its ultimate condensation. The difference generally consists in the state assumed by the vapours when condensed: if the product be solid, the process is called sublimation; if liquid, distillation. The substance is exposed to such a temperature as causes it to assume the gaseous state, in which state it is conducted into a vessel containing water of a low temperature, where it is condensed into



a fluid or solid state. A common still consists of a metal boiler for containing the substance to be distilled; a head terminating in a beak is adapted to it; the latter is made to fit into the commencement of a spiral tube, called a *worm*, fixed in a tub—the whole of this part of the apparatus being called the *refrigerator* (*r*). The substance is raised into vapour in the still, and being condensed in the worm, runs out at its lower extremity. Distillations are usually effected in the laboratory by means of glass retorts and flasks; for substances, however, which require a greater degree of temperature to effect their distillation, metallic or earthenware retorts are employed. Bodies which are very volatile are distilled or sublimed in an *alembic* (*a*), which consists of a globular bottom and conical-shaped head, whence a nose or beak passes off in a downward direction into a receiver. The recondensed products of sublimation are generally known by the name of *sublimates*. *Rectification* is the process of purifying by repeated distillation.

Evaporation is a process so simple, as scarcely to require description; it is merely the assumption of the gaseous form by bodies either at ordinary temperatures, or when heat is applied to them. In this general characteristic it resembles distillation and sublimation, but it differs from these processes in this respect—that the substance evaporated is generally allowed to pass off uncollected by a refrigerator, not being that part of the mixture which is required. The vessels used in evaporation are made of porcelain, glass, platinum, or silver, and have usually the shape of a shallow basin. A great improvement in evaporation has recently been introduced into the refining of sugar—namely, its being boiled in vacuum pans. It is well known that there are few articles of vegetable production which are not injured by being boiled at a temperature of 212°; but to boil them at a lower temperature, it is necessary to remove the pressure of the atmosphere. This is now accomplished by using close copper vessels of a flattened spherical form. On the top is a raised part, from which a pipe proceeds, attached to an air-pump. At the side of this pipe another enters the vacuum pan, from which fresh syrup can be made to enter at pleasure by means of a stopcock. At the bottom of the pan is another stopcock, through which the boiled syrup can be taken out when sufficiently concentrated. The pan is heated by means of steam pipes, which surround it; and the liquid boils at, or even below, 150°. The air-pump for removing the atmospheric pressure, in large sugar-refining establishments, is worked by a steam-engine. By this process the quality of any substance, particularly perfumes and medicinal extracts, from which liquid is to be evaporated, is greatly improved, and a saving of material effected.

Fermentation is the term which expresses the changes which animal and vegetable matter undergoes spontaneously when the principle of life is extinct; and is one of the means which nature adopts to destroy useless substances, and reduce them to their elementary properties. Chemists reckon five distinct species of fermentation—namely, the saccharine fermentation, in which gum and starch are changed into sugar; the vinous fermentation, in which sugar is converted into alcohol; the acetous fermentation, in which alcohol and other substances are converted into vinegar; the mucilaginous fermentation, in which slime is produced instead of alcohol from sugar; and the putrid fermentation, which is the decomposition of animal and vegetable bodies. The change of the substance of barley into sugar, or a material possessing the qualities of sugar, takes place on a large scale in *malting*. Malt is dried barley, which has previously been caused to sprout and partially grow by steeping in water; in the course of germination or malting, a chemical union is effected between a portion of the water and the starch of the barley, and the saccharine matter is the result. A saccharine material can, on similar principles, be produced by boiling one part of starch in twelve parts of water, and allowing the compound to stand for a month or so. At the end of this time, about one-half the quantity of starch is converted into sugar, a fifth into gum, and the remainder is found to be a starch paste somewhat altered.

Fermentation, whether of an infusion of malted grain or any other vegetable substance, is a necessary preliminary to change the material into an alcoholic beverage. The actual process of fermentation, for example, in reference to wine, is as follows:—Ripe grape juice is put into a vessel, and allowed to stand for some time, exposed to the ordinary temperature of summer. At the end of a certain period the liquor becomes muddy; an internal motion takes place, and sometimes the temperature is found to be elevated; air-bubbles rise to the surface, occasioning a bubbling noise when they break; and the bulk of the liquid being increased, it has a tendency to boil over. From this circumstance, the process is called fermentation, from the Latin word *fervere*, to boil. The bubbles created rise to the surface, involved in a viscid matter, the whole resembling froth, which, parting with the air, subsides to the bottom, and the liquor becomes tranquil and transparent. This viscid matter is well known under the name of *yeast* or *barm*, and it has the property of exciting fermentation in bodies not otherwise at the moment predisposed to it. The grape juice has now been entirely changed into an intoxicating liquor, the base of which is alcohol, and this process is termed *vinous fermentation*. A great quantity of carbonic acid is given out during this kind of fermentation, and the various chemical changes which take place have been thus briefly described:—Some of the carbon and some of the oxygen combine to form carbonic acid; while the remainder of the carbon, the remainder of the oxygen, and the whole of the hydrogen, combine to form alcohol; and we may totally neglect the decomposition of the yeast, it amounting to almost nothing. Thus is this inert, solid, fixed, sweet matter, resolved by a new arrangement of its principles into substances which possess none of these properties, and one of which exerts a control of so singular a nature over the animal economy.

Liquor vinously fermented is subject to a new series of phenomena. On being put aside for some time, a fresh commotion is observable, accompanied with the disengagement of a small quantity of gas; and floating filaments or shreds begin to thicken in the liquid, collecting into a gelatinous cake. This is indicative of another change. The vinous flavour and the alcholic or intoxicating quality have disappeared, whilst the liquid has become at once sour and transparent. In short, the wine has become vinegar, called in Latin *acetum*; and the process is called the *acetous fermentation*. Let this vinegar be kept for a length of time, and another, and, from the previous quality of the liquor, unexpected change takes place. It becomes mantled with a green mould; the acidity and pungent smell disappear, and a fetid odour becomes perceptible; in other words, *putrefaction* is produced, a process under which the material is resolved into invisible but odorous gases.

The most remarkable feature in the product of fermentation is the intoxicating quality. This quality arises from the chemical change into *alcohol*, a concentrated spirit or essence, which, in one of its purest forms, obtained from distillation, is called spirit of wine. Alcohol exists to a lesser or greater extent in all fermented liquors, such as ale, porter, or beer; but it is more concentrated, or free of watery fluids, in the form of brandy, whisky, gin, rum, and similar intoxicating liquids. The alcoholic part of such liquids stimulates, but gives no actual nutrition; the only nutritive part is the undecomposed starch and gum not changed into saccharine material. Alcohol dissolves the greater number of acids, the volatile oils, the resins, tar and extractive matter, and many of the soaps; while dissolving pure soda and potassa, it does not act on their carbonates. The composition of alcohol has been investigated by eminent chemists, and the result is, that of 100 parts there are 13·70 of hydrogen, 51·98 of carbon, and of oxygen 34·32. When alcohol is distilled along with certain acids, a peculiar compound is formed, called *ether*, an exceedingly volatile fluid, used in medicine and philosophical experiments.

While the various phenomena of fermentation, as above briefly noticed, are well understood by practical chemists, of the actual cause of the ferment little has yet been discovered. It is only known in a general sense that fermentation is the rapid growth of microscopic vegetation (see VEGETABLE PHYSIOLOGY), which continues to be developed so long as the elements necessary to its increase are present, and a certain temperature is maintained. For practical operations depending on the principles of fermentation, see ALIMENTARY SUBSTANCES.

Antiseptics.—Animal and vegetable bodies may be saved from putrefaction, or the last process of dissolution, by putting them in a substance which will coagulate the albumen, that being the first part which suffers decomposition. This may be effected by steeping the bodies in alcohol, oil of turpentine, or other volatile oils. Pyroligneous acid, from containing a small proportion of creosote, has a strong power of preserving animal matter from decay. The earthy salts are also antiseptics; but common salt, saltpetre, and sal ammoniac, are the articles most generally used for the purpose of preservation. For the purpose of extinguishing the odour, or offensive gases, arising from the decay of animal substances, none of the chemical products is so useful, or so readily available, as chloride of lime. By sprinkling a small quantity in an apartment containing an unwholesome putrefactive odour, the air is instantly deprived of its noxious properties, and is sweetened. Putrefaction goes on most rapidly at a temperature of from 70° to 80°, but is altogether stopped at the freezing-point. Thus fish and flesh may be kept fresh for any length of time when imbedded in ice. The abstraction of the oxygen gas will also preserve meat. The simplest manner in which this can be done is to enclose the meat in tin cases, leaving only a small hole in the closely-soldered lid. The air may then be expelled by dipping the cases for a minute into steam. On lifting them out, a drop of solder quickly placed on the hole prevents the rush of air back into the vessel. On this principle of excluding the air, cases of preserved meats are now manufactured to a great extent for exportation. (See PREPARATION AND PRESERVATION OF FOOD.) The proper drying of an animal substance is likewise an invariable preventive of putrescence. Animal matter should be dried at a temperature of from 120° to 140°; but even when dried, the addition of a little salt will be necessary. The salt is supposed to absorb the water from the albumen; and alcohol, sugar, &c. act in the same way. Animal substances may also be preserved for any length of time by being saturated with a vegetable extract known in chemistry by the name of *tannin*; and this has given rise to the common process of tanning the skins of animals, and so making them into leather. Tannin exists in all vegetables possessing an astringent taste and quality, but is found in greatest perfection in oak bark and nut-galls. The principle upon which it acts is the imbibing of an astringent and hardening quality by the mass of the substance, by which it is constitutionally altered. Corrosive sublimate, and other chemicals, are now extensively used for the prevention of decay in timber, canvas, and other vegetable preparations; but the applications of these we reserve for subsequent treatment.

Such is a brief outline of the leading processes by which the raw material of nature is made available to the purposes of civilised life. They will receive further exemplification when we come to treat of the arts to which they may be applied.

ANALYSIS.

The art of analysing the compounds of matter, or, in other words, of resolving them into the various elements of which they are framed, constitutes one of the most difficult yet important branches of chemical science. More particularly is it important in relation to numberless practical purposes of life. There are few trades which do not owe much of the success with which they are conducted, in an advanced state of society, to the light which chemistry has thrown on the nature of the substances employed in them, and the consequent improvements therein introduced. To the highest moral interests even of the social body, chemical analysis is of vital moment. It is the basis of medical jurisprudence. Without the knowledge of poisons possessed by the professors of that science, and their ability to separate by analysis the most minute portions of these from any compounds with which they may have been mixed, innocence might often perish under the erring severity of the laws, and guilt escape the penalty justly incurred.

When the investigation of any body is confined to the *nature* and *properties* of its constituent elements, the analysis is said to be *qualitative*; but if the *quantity* of every individual element is to be ascertained, the analysis is termed *quantitive*. A qualitative investigation may be made with a twofold view—either to prove that a certain body is or is not contained in a substance, as iron in water, or to ascertain all the constituents of that substance. The object of a quantitive analysis is to exhibit the elements revealed by the qualitative investigation, either in their absolute or proportional amount or weight.

The mode in which chemical analysis, so important in every respect, is conducted, may best be explained by individual examples; but a few general observations will not be out of place. Of the apparatus necessary for the chemical analyst in his laboratory, notice has already been taken; and it is only necessary to add that, in performing analyses, the principal tests and preparations are also required. The latter articles amount in number to about sixty or seventy. They consist chiefly of the sulphuric, nitric, and hydrochloric acids; sulphur, phosphorus, iodine; the principal alkalies and earths, with their most important compounds; mercury, iron, lead, tin, cobalt, antimony, gold, silver, and a few other metals, pure or in a compound state; with a few of the vegetable acids, such as the tartaric and oxalic. Tests and test-papers, most important matters in chemical experiments, are also to be procured. By the application of the common tests, most of the elementary substances can be readily detected; and a list of such tests, with their effects, should always be at hand. Thus acids redden litmus paper; alkalies convert turmeric to a deep reddish-brown; an infusion of galls blackens any solution containing iron; a piece of polished steel dipped in a solution containing copper is instantly coated with metallic copper; and so on with many other substances. Tests of this kind are chiefly valuable as indicators; for most practical purposes, the minutiæ of quality and quantity must be rigidly obtained.

In taking up any body of unknown composition for analysis, very minute quantities only, finely divided and weighed, are used. The body is then, if possible, dissolved, commonly in water, that the particles may be further separated as widely as possible, which is the most favourable condition for the action of other bodies upon it, and display of chemical affinities. It is possible that the body may be insoluble, or but partially soluble in water at a common temperature. In those cases, the processes of infusion, digestion, or decoction will be tried by the analyst, heat adding powerfully to the solvent powers of water. Lixiviation and maceration are also resources of the chemist. Sometimes alcohol or other solvents must be employed, and at times several solvents require to be used in succession, each having the power to take up something insoluble in the others. Once dissolved, the body, or portions of it separately, can be treated with tests; and happily there is not one substance in nature which has not such affinities for one or more substances, in preference to all others, as readily to betray its own nature. The common results of adding one body as a test to another in solution, are either alteration of colour, or precipitation, or gasefaction. In the first case, the two bodies may form a compound, soluble, but of new colour; in the second place, an insoluble substance may be thrown down to the bottom of the solution; and in the third, a gas may be set free. All of these results may be combined in some cases. The experimenter may, moreover, vaporise and crystallise: fusion and condensation are processes also at his command. When simple solution can be effected in no way, and at no temperature, the analyst may have recourse to other agents. Chemical action may be induced by pressure, by electricity, or even by light.

These are the general ways and means by which the chemical analyst prosecutes his investigations. By way of particular example, let us take a case in the department of *medical jurisprudence*. Let us suppose a medical man called upon to examine a case of poisoning, where the only cause of death that can be suspected is the use of copper vessels when corroded by articles of food. The object, then, is to analyse the vegetable or animal fluids remaining on the stomach, or preserved otherwise, in order to detect the copper, if it exists. Being boiled, the fluid in question is treated or mixed with diluted acetic acid or vinegar, which dissolves out the copper from among the other matters present. Well aware that sulphur has so strong an affinity for copper as to unite with it whenever they meet favourably in solution, forming a compound of both, called a sulphuret of copper, Professor Christison then directs the introduction of sulphur, in the shape of sulphuretted hydrogen gas, after the following preparations have first been made:—'The suspected mixture having been prepared by the addition of acetic acid, is to be subjected to filtration, and any matter left on the filter is to be washed, collected, and dried, the washings being of course added to the fluid which first passed through. The process here divides itself into two; for the oxide of copper may be left on the filter in the form of an insoluble salt, or it may have passed through in solution. But it may be observed in passing, that very few of the salts of copper are insoluble in diluted acetic acid, so that if copper is present at all in a suspected mixture, there are many chances in favour of its being found by the first branch of the analysis.

'*1st*, The solution is to be examined first, both because it is the more likely quarter in which to find the copper, and because the analysis is more easy than that of the solid matter. The solution, then, is to be treated in the usual way with a stream of sulphuretted hydrogen, and immediately boiled to expel the excess of gas. If a brownish-black, or even pale-brown precipitate is then thrown down, there is a presumption in favour of the existence of copper: if there is no precipitate or brown colouration, there is no copper in the fluid. To ascertain precisely the nature of the precipitate, which is some metallic sulphuret, the superincumbent fluid, after ebullition and subsidence of the precipitate, is to be cautiously withdrawn, and its place supplied with water; and when the washing has been several times repeated in the same manner, the precipitate is to be transferred into a watch-glass, or, still better, into a white porcelain cup, and dried. It is next to be collected, and incinerated in a glass tube, to destroy any adhering vegetable or animal matter. The last step in this branch of the process is to convert the sulphuret into the sulphate by the action of a few drops of nitric acid, aided by a gentle heat; and then to add an excess of ammonia, either without or with previous filtration, according to the degree of muddiness in the nitrous solution. If copper is present, the usual deep violet-blue tint will be struck.

'*2d*, If copper is not detected in the filtered part of the suspected matter, it will be necessary to examine also what remained on the filter. This proceeding, which constitutes the second branch of the analysis, will be seldom required in ordinary medico-legal researches, being rendered necessary only by the possibility of the oxide of copper having, either originally or after mixture with the suspected matter, assumed the form of an inorganic salt, insoluble in water or acetic acid. The matter on the filter is first to be well dried, and then heated to redness in a crucible till it be completely charred. The copper which is thus reduced to the metallic state is next to be treated with nitric acid, diluted with its weight of water, and aided in its action by gentle heat. A solution is then procured, which is to be removed by filtration, and tested with ammonia, and the other liquid tests.' Ammonia has a strong affinity for copper, and when added to a saline solution of the latter, throws down a deep blue powder, called the ammoniuret of copper.

The analysis of mineral waters, where the nature and amount of the whole ingredients, and not of one only, form the subject of inquiry, is a task of very great difficulty. Generally, however, non-professional experimenters upon liquids of this description are anxious merely to ascertain the existence or non-existence of certain ingredients, without entering into minute proportional quantities or the like details. The report of a case communicated by the Rev. W. Robertson, junior, of Inverkeithing, to the 'Edinburgh Philosophical Journal,' may give a fair idea of the mode of procedure under such circumstances. It is that of a mineral spring issuing from the coal-formation near Fordel in Fife.

A gas bubbled up through the spring which Mr Robertson first examined. The elementary as well as compound gases have properties and affinities as well-marked as those of fluids or solids, and can be as readily detected. For example, the gas called carbonic acid, present so largely in nature, has such an affinity for lime, that, on contact, it is at once absorbed by lime-water, and renders that liquid turbid. By trials with a graduated glass tube, where the gas or air containing carbonic acid is brought into contact with lime-water, the loss of the acid gas by absorption may be measured, and the proportion of it present in the examined air at once determined. So with other gases, when tested in relation to their respective affinities. Having satisfied himself about the gases present in the spring of Fordel, Mr Robertson then tried the following preliminary experiments to determine the substances contained :—

'Even when recent, it did not perceptibly redden tincture of litmus, though the tint was compared with the colour of the tincture diluted to a similar extent. It did not affect the colour of Brazil wood or turmeric test-paper. With tincture of galls it gave a slight tinge of purple, and ultimately a scanty purplish-brown flocculent precipitate, showing the presence of iron, and by the purplish tinge, also the presence of earthy or alkaline salts.

'The water next day gave no tinge with the tincture, showing the iron to be principally in the state of a carbonate. When the water was evaporated by a gentle heat, flocculi of oxide of iron were deposited; and upon being boiled, gave a considerable yellowish-white precipitate, indicating carbonates. This precipitate was soluble, with considerable effervescence, in nitric acid.

'The water decanted from this precipitate gave no tinge with tincture of galls, but on boiling it with a few drops of nitric acid, to peroxidise the iron which it might contain, the excess of acid being afterwards neutralised by ammonia, it gave unequivocal traces of iron, by a darkish tinge with the tincture. From this it was inferred that the iron in it was in the state of protoxide. A portion of this water, after being thus treated, also gave a red tinge, with sulpho-cyanite of potash. With ferro-cyanite of potash, and a drop of muriatic acid, the water, when recent, gave a whitish precipitate, becoming blue by exposure to the air, indicating iron in the state of protoxide.

'With lime-water, the recent water gave a copious flocculent precipitate, the lime uniting with the excess of the carbonic acid, and the whole of the carbonates falling down together. This precipitate was re-dissolved on adding more of the mineral water, which showed a considerable excess of carbonic acid; and it was also soluble with effervescence in dilute acetic acid. With the bicarbonate of potash there was no precipitate, the whole being kept dissolved by the excess of carbonic acid.

'With ammonia, and also with potash, a flocculent white precipitate took place, partly owing to the abstraction of free carbonic acid. With the carbonates of potash, soda, and ammonia, there were similar precipitates, but more scanty: they were all soluble in a dilute acetic acid.

'With a solution of soap in alcohol, a great milkiness. With acetate of lead, a considerable milkiness, and a precipitate insoluble in acetic acid. With oxalate of ammonia, a considerable precipitate, indicating the presence of lime.

'With carbonate of ammonia and phosphate of soda, an immediate milkiness, and a precipitate, after standing, indicating magnesia; the precipitate soluble in acetic acid. With carbonate of ammonia, or phosphate of soda, separately, no milkiness, after standing for the same length of time.

'With muriate of baryta, a slight precipitate, insoluble in muriatic acid, indicating sulphuric acid. With nitrate of silver, a copious precipitate, white while secluded from the light, becoming rapidly purple on exposure to light, indicating muriatic acid.

'Two ounces of the water, evaporated to dryness, gave, with nitro-muriate of platinum, slight traces of potash. The water, very much concentrated by evaporation, gave, with starch and sulphuric acid, no trace of iodine.

'From the above indications, it was concluded that the water contained sulphuric, muriatic, and carbonic acids, together with protoxide of iron, lime, magnesia, and a little potash. The presence of alumina was inferred to be incompatible with that of the earthy carbonates, neither could any be subsequently detected.' The determination of the quantities of each substance present was the next object with Mr Robertson; but it is not necessary here to carry our notice of the subject beyond generalities.

The agricultural chemist proceeds in a similar way, and with similar instruments. He has the advantage, generally, of knowing beforehand the probable character of the matters on which he operates, and the point is, to determine in what proportions they exist in the particular soil under examination. Where a less exact analysis will suit the purposes of the agriculturist, the following simple plan of ascertaining the qualities of soils may be adopted. We quote, with some slight alterations, from Mr Young's 'Letters of Agricola:'—

'In the field to be examined, take earth a little below the surface, from four separate places, about a quarter of a pound from each: mix them together, and again separate them into four quantities of a quarter of a pound each. Then take one quantity and expose it to the sun, or before the fire, till completely dry; and turn it over frequently, that it may be well mixed together. Being thus powdered, pass it through a fine sieve, which will allow all the particles of sand and gravel to escape, but which will hold back stones, small fibrous roots, and decayed wood. Weigh the two parts—the fine and the rough—separately, and take a note of each. The stones and other bulky materials are then to be examined apart from the roots and wood. If they are hard and rough to the touch, and scratch glass easily, they are siliceous and flinty; if they are without much difficulty broken to pieces by the fingers, and can be scraped by a knife to powder, they are aluminous or clayey; or if, when put in a wine-glass, and common vinegar poured upon them, small air-bubbles ascend to the top of the liquid, they are calcareous. The finely-divided matter which ran through the sieve must next undergo the test of experiment. After being weighed, agitate the whole in water, till the earth be taken up from the bottom and mechanically suspended, adding water till this effect be produced. Allow the mass then to settle for two or three minutes, and in that time the sandy particles will sink to the bottom. Pour off the water, which will then contain the clay in suspension, and the insoluble earth arising from animal and vegetable decomposition. The sand should be first attended to, and if, from inspection, it be thought either siliceous or calcareous in its nature, the requisite tests may be instantly applied. By this time the mixture in the poured-off water will leave deposited at the bottom of the vessel the clay and other earths, with the insoluble animal and vegetable matter. After pouring off the water, dry the sediment, and apply a strong heat, by placing it on the bottom of a pot ignited to redness, and the animal and vegetable matter will fly off in aëriform products. The remainder lying in the bottom will be found to consist of clay, lime, or magnesia.

'To obtain accuracy, another quarter of a pound may be taken, and the whole process gone over a second, a third, or even a fourth time, so that the operator may rectify any blunders he had previously committed, and be satisfied as to the results of the experiment. He should provide himself with a pair of fine scales, and a set of weights, divided at least into half and quarter ounces and drachms. Although vinegar will detect lime by effervescence, it does not dissolve it so effectually as the nitric or muriatic acids, small quantities of which may be obtained from the druggists at a small expense.'

Having ascertained by these, or any other inquiries, what is the composition of the soil, a pretty accurate notion, other things considered, may be obtained respecting its capacity for productive husbandry. If it be necessary to enter on a course of improvement, the defect in composition may be remedied by the application of materials of an opposite quality—an excess of calcareous matter being counteracted by sand and clay, an excess of clay by the admixture of sand, or an excess of sand by the application of clay, peat, &c. An excellent soil for bearing wheat has been found to contain in 100 parts—carbonate of lime, 28; silica, 32; alumina, 29; and of animal and vegetable matter, with moisture, 11. Oxide of iron, to the extent of 2 or 3 per cent. is not unusual in productive soils. (See article AGRICULTURE.)

SPECIAL APPLICATIONS.

In a regular exposition of the industrial applications of chemistry, those arts ought naturally to take precedence which have reference to the production, preparation, and preservation of food. Among these may be ranked Agriculture, as it relates to soils, crops, and manures; Baking of fermented and unfermented breads; Cooking, and the preparation of condiments, as salt, sugar, and the like; Brewing and Distilling of beverages; and we may add Medicine, with its numerous remedial appliances internal and external. As these, however, will form subjects of separate consideration, we here merely indicate their position and connection, and proceed to notice a few of those manufactures the elaboration of which depends more on chemical than on mechanical principles.

Soap.

This exceedingly useful article, of which the ancients were entirely ignorant, is a compound of certain principles in oils, fats, or resin, with a salifiable base. If this base be potash or soda, the compound is used as a detergent in washing clothes. When an alkaline earth or oxide of a common metal, such as lead, which forms litharge, &c. is the base, the compound is insoluble in water. The insoluble compounds, however, are very little used, except in some few cases of surgery. Animal fat, grease, or tallow, as it is variously termed, is a compound of a solid substance called, in chemistry, *stearine*, and of an oil called *oleine*, the basis of which is carbon, with a little hydrogen and oxygen. On subjecting tallow to a hot lye of potash or soda, a chemical change takes place in the constituents, and we have the material named *margaric acid*, and a fluid, *oleic acid*, and together they enter into a saline combination with the alkali. The result, a soapy substance, is thus said to be a union of an alkaline margarate with oleate. Saponification also takes place with vegetable fats and oils, which are now largely employed in commerce.

The commonest *hard soap* is that made chiefly from kelp and tallow. Kelp itself is a result of chemical action. It is made by reducing certain kinds of seaweed to ashes by burning; the result in soluble material is a crude alkali, consisting of sulphate of soda, soda in carbonate and sulphuret, and muriate of soda and potash. It was at one time manufactured in large quantities on the shores of the Western Isles of Scotland, but has latterly been disused, in consequence of the substitution of barilla, and soda-ash from the decomposition of sea-salt. Supposing kelp to be employed in making soap—to every ton of kelp, about one-sixth of new-slaked lime is added. The whole, after mixture, is put into a large tub called a cave, having a perforation at the bottom, shut with a wooden plug. Upon the materials water is very slowly poured. The liquid, after digestion, is suffered to run slowly off into a reservoir sunk in the ground. The first portion, or lye No. 1, is of course the strongest, and is reserved for the last operation in soap-boiling. Six days are required to make one boiling of soap, in which two tons or upwards of tallow may be employed. The lyes 2 and 3, mixed, are used at the beginning, diluted with water, on account of the excess of sea-salt in the kelp. A quantity of lye, not well defined, is poured on the melted tallow, and the mixture is boiled, a workman agitating the materials to facilitate the combination. The fire being withdrawn, and the aqueous liquid having subsided, it is pumped off, and a new portion is thrown in. A second boil is given; and so on, in succession. Two or three boils are performed every twelve hours, for six days, constituting twelve or eighteen operations in the whole. Towards the last, the stronger lye is brought into play. Whenever the workman perceives the saponification perfect, the process is stopped, and the soap is lifted out, poured into the moulds, and afterwards cut into bars.

The compounds of tallow or oils with potash, remain of a soft consistency, and form what are termed *soft soaps*, useful in scouring. We can only afford space for an account of the process of manufacturing one of the common kinds of soft soap, as lately practised by an eminent soap-boiler near Glasgow. Whale or cod oil, to the amount of 273 gallons, is put into a boiler, along with four hundredweight of tallow, and 252 gallons of potash lye. On heat being applied, the mixture froths up very much, but means are adopted to prevent its boiling over. There are then added at intervals fourteen measures of stronger lye, each measure holding twenty-one gallons. After suitable boiling without agitation, the soap is formed, amounting in all to one hundred firkins of sixty-four pounds each, from the above quantity of materials.

What are called *toilet soaps* are made from purified hogs' lard, with the addition of olive, almond, palm, cocoa-nut, and other oils. These, when prepared, are perfumed with various scents. The soap is cut into thin shavings with a plane, and melted in a pan placed within a hot-water or steam bath. When melted, the colouring matter and perfume are added, which generally consist of vermillion, ochre, bergamot, musk, essence of orange-blossom, cinnamon, &c.

Of late, numerous patents have been obtained for the use of dissolved bones, naphtha, hair, fish, dextine, and other substances, in the manufacture of soaps; but as yet few, if any of them, have been commercially successful. The better the raw materials, the finer and more economical the manufactured product; and all that can be expected from the employment of such substances as above-mentioned, is a cheap and inferior article. Another class of these inventions are the soaps which contain admixtures of certain detergent mineral substances, as silica, alumina, soap-stone, porcelain-earth, and fullers'-earth. The firmness of the soap is not diminished by the addition of such substances, which exert, however, a purely mechanical action, and are contained in no kind of chemical combination. The value of the article so manufactured is very much reduced, as a great portion of the real soap is replaced by a substance of similar, but inferior efficacy, and whose price bears no comparison with that of the fats. *Sand soap*, for example, is one of these recent manufactures, and contains from 60 to 70 per cent. of pure sand; *pumice soap* is another, containing from 20 to 30 per cent. of siliceous matter; and *silica soap*, perhaps the best of them, about 20 per cent. of insoluble residue. *Chlorine soaps*, which are now so largely advertised, are preparations intended to realise the idea of the union of the detergent properties of soap with the bleaching effects of the compounds of chlorine. It is almost unnecessary to remark that such a union is impracticable; and these chlorine soaps, in the words of a high authority, 'are nothing more than foolish novelties.'

The real value of soap is mainly dependent upon the amount of dry soap (the dry combination of alkali with the fatty acid) which it contains; and an abundant supply of such a commodity is economically, socially, and morally invaluable. 'Of two countries,' says Baron Liebig, 'with an equal amount of population, the wealthiest and most civilised will consume the greatest weight of soap. This consumption does not subserve sensual gratification, nor depend upon fashion, but upon the feeling of the beauty, comfort, and welfare attendant upon cleanliness; and a regard to this feeling is coincident with wealth and civilisation.'

Candles.

The process of making candles by simply melting tallow, and pouring it, in a liquid state, into moulds containing wicks, requires no particular notice. It is of the improved mode of making tallow-candles to resemble those of wax, and involving an intimate knowledge of chemistry, that we wish to speak.

Some years ago, M. Chevreul, a French chemist, undertook an investigation into the nature of fatty substances, which he found to be composed of what we now know them to be—two materials, *stearine* and *oleine*. He ascertained that the oil does not combine directly with the alkali, but that its two components are converted by it into two corresponding acids, the stearic and oleic, which then combine with the alkali, like the mineral acids. He found, indeed, the analogy perfect between them in every respect. They unite with all the bases, forming compounds, which differ in the degree of their solubility: with potash, for instance, a very soluble compound is formed (soft soap); with soda, hard soap, which is dissolved with more difficulty; while its combination with lime gives rise to a perfectly insoluble compound. These facts have been most important to the soap-maker, in enabling him to reduce his art to scientific principles; they explain why a solution of soap may be used as a test for the purity of water; why rain water is preferred to that from the spring for washing; and why we add soda to hard water before using it with soap, for soda separates the lime which the hard water contains, and thus enables us to dissolve the soap, without producing the curdy precipitate which destroys its cleansing properties.

M. Chevreul separated these acids from their compounds, and found them possessed of the following properties:—Oleic acid is a liquid, clear when pure, and closely resembling oil; stearic acid is solid, and resembles wax in so striking a manner, as to be with difficulty distinguished from it. On finding he could manufacture it at a price much inferior to that at which wax is sold, he, in conjunction with M. Gay-Lussac, another distinguished chemist, took out a 'brevet d'invention' for the preparation and sale of 'chandelles steariques,' from which they never derived any benefit, solely on account of the name, which, merely implying candles prepared from tallow, attracted no attention; whereas manufacturers who took up the trade after the expiration of the patent, and who announced, with less regard to truth, their productions as 'bougies,' or wax candles, speedily made large fortunes. If the reader wishes to prepare and examine the artificial wax himself, it may be easily accomplished. Let him dissolve a little hard white soap in hot rain or distilled water, and to the clear solution, while hot, add some vinegar or other acid. The stearic being a weak acid, is easily separated from its combination with soda, as it exists in soap. Acetate of soda is formed, and the stearic acid rises to the top of the liquid as an oily substance, which, on cooling, solidifies into a cake of artificial wax, mixed with a certain portion of oleic and impurities, which render it softer than if this fluid had been expelled by pressure. A similar process is pursued on a large scale, but regard must be had for economy. The tallow is saponified, not by soda or potash, as in the preparation of soap, but by quicklime. It is only necessary to boil the lime, tallow, and water in a large vessel for some hours, when these ingredients are converted into a kind of hard soap. From this substance stearate and oleate of lime, also the stearic and oleic acids, are separated by the addition of oil of vitriol. They are melted like tallow, run into cakes, and subjected to the powerful action of a hydraulic press, which separates all impurities, and leaves the stearic acid as pure and white as the finest bleached wax, which may be used immediately for the formation of candles. In France, the wicks, besides being plaited, are dipped in a solution of borax, and then dried. The borax fuses during the combustion, and forming a globule on the summit of the wick, assists by its weight to bring it out of the flame in contact with the atmosphere, and thus insures perfect combustion, and obviates the necessity of snuffing. Palmer, an English patentee, accomplishes the same end by making the wick consist of two halves, which are twisted in opposite directions, and at the same time wrapped round by a slender wire. The result is, that the halves separate on combustion, and fork outwards to the exterior portion of the flame, where they are completely consumed.

It was found that the artificial wax generally crystallised in the moulds—a circumstance which prevents the formation of a solid candle. In England, this difficulty was overcome in some cases by the addition of arsenic; but the use of this substance either for this purpose, or for causing the wicks to be more readily reduced to ash, ought never to be permitted, as it is highly prejudicial to health. The French, more scientific than we, had recourse to their knowledge of the laws of crystallisation for the remedy. It is known that regular crystallisation only takes place when the transition of the mass from a fluid to a solid state is so gradual, as to allow time for its molecules to arrange themselves in those determinate forms called crystals: this condition was fulfilled in the cooling of the moulds and their contents; but by plunging them in cold water as soon as the melted stearic acid had been poured in, crystallisation was prevented, and a perfectly solid candle procured. Stearic candles, which can with difficulty be distinguished from wax candles, are now manufactured on a large scale in England, and from their comparative cheapness, are coming universally into use in the houses of the middle and higher classes of society. So much for the value of a knowledge of practical chemistry in one of the commonest of our industrial operations.

Leather.

Leather-making is the art by which the skins of animals are rendered impervious to the action of those external agents which would otherwise decompose them. This effect is brought about by steeping the skins in the certain astringent principle called *tannin*, and may be performed either with the hair on, or, as is generally the case, when it is taken off. Tannin is obtained from the bark of a number of trees, particularly the East India catechu, the common oak, the Spanish chestnut, the Leicester willow, &c. It is found in the largest quantities in catechu—one pound of this, according to Mr Purkis, being equal to seven or eight pounds of oak bark. Tannin is also obtained, by a peculiar preparation, from the gall-nuts of the Levant oak. When the bark of trees is to be used for tanning, it should be stript from the trunk and branches in the spring, when the sap flows most freely. The trees should not be less than thirty years old, for it has been found that the bark possesses more tannin when old than when in a young state. The bark, when dried, is ground in a mill, to reduce it to a rough powder, after which it is ready to be used.

The first process which the skins undergo is steeping in lime-water, which is continued for a longer or shorter time, according as the skins are dry or fresh. Sometimes the skins are salted when they are imported from abroad; and in this case they require to be steeped, beaten, and rubbed, until they are brought to a fresh state. The horns are then cut off, and the skins put in heaps for a day or two, after which they are hung up in a shed. During this process, a slight putrefaction takes place, by which the hair on one side, and the fleshy matter on the other, are easily removed. This is done by a blunt knife, or scraper, the skins being stretched upon a wooden beam called a *horse*. The skins are then immersed for about forty-eight hours in water mixed with a little sulphuric acid, which has the effect of distending the fibres, causing the skins to swell. This process is called *raising*, and by it the tannin principle more easily reaches the inner fibres. When sufficiently raised, the skins are put into a pit with a layer of bark in the bottom. On this skins are laid, and then bark and skins alternately. The pit is filled up with a strong decoction of bark, and the whole is allowed to lie undisturbed for about six weeks. At the end of this time, it will be found that the tannin has become entirely exhausted, when the skins must be taken out, and put again into the pit, along with fresh bark. In this they are allowed to lie for three months; and this process is repeated two or three times, according to the quality of the leather required. From six to eight months in all are sufficient to complete the tanning of the commonest kind of sole leather, called *crop* by the trade; but for the better kinds of sole leather, from a year to a year and a half will be required. *Bend leather* is the strongest of all sole leather, and in manufacturing it, the tanning process is continued for a longer period than is necessary for crop. The best and thickest skins also are selected for this kind.

When properly tanned, crop leather is hung up in an airy house to dry, which is performed slowly, and the article is then fit for the market. Bend leather, after being dried, is beaten into a firm consistence, so that when cut, the edges present a glossy appearance. The instrument with which bend leather is beaten is a broad brass hammer; and this kind of leather may be easily distinguished from its being darker in the colour, in consequence of lying longer in the tannin.

A coarse kind of upper leather is also made from cow-hides, the weakest and thinnest being selected for this purpose. When taken out of the lime-water, and the hair scraped off, these hides are immersed in a solution of the ordure of pigeons, which has the effect of neutralising the lime. They are then stretched upon a board, and from the inner or fleshy side slices are taken with a sharp knife, until the operator thinks it is reduced to a proper thickness—an operation which is technically called 'shaving in the butt.' The skins are then put into the tan-pits, where they remain for about six months, after which they are sent to the currier. The skins of seals, calves, &c. are manufactured into upper leather in the same way, except that an equal extent of shaving is not required. Such was the old, and, till very recently, the only mode of procedure in this most important branch of our manufactures.

Several improvements, however, have recently been made in the manufacture of leather, by which the tannin principle is more readily admitted to the inner fibres of the skins. One of the improved methods is that of Messrs Herapath and Cox of Bristol, and consists in using a machine of two rollers, which is placed in the middle between two tan-pits. The hides having been previously divested of the hair, &c. are fastened together, and put into the tan-pit in regular folds. After lying in this for a certain time, the end of the belt of hides is laid upon the under roller, which, being set in motion, carries the belt over to the other tan-pit. This is done without pressure; but when the hides have become soft, the upper roller is pressed down against the under one. The hides are again passed through between the rollers, which press out the exhausted tannin, and prepare them for being submitted to a fresh infusion. By the old method, the hides were taken from one pit to another without receiving any pressure, and consequently a quantity of exhausted tannin must have remained in them when put into the fresh liquor. By using this machine, however, this is altogether obviated; and leather may now be tanned in four months, a process which formerly took from eight to twelve.

More recent improvements are those of Mr John Cox of Gorgie Mills, near Edinburgh, and for which he has obtained patents. He announces *six* improved processes of tanning, any of which may be adopted. His great object is to force the liquid tannin into the vesicles of the skin, and this he proposes to do as follows, in his *fourth* process, which he considers the most suitable in ordinary circumstances. The skin is to be sewed into the form of a bag, and immersed in tanning liquor, while the interior is also filled and compressed from a supply of liquor through a pipe from a cistern placed a few feet above the pit:—'The hide or skin bag being tied tightly at the neck-end to the feeding tube (which tube should be long enough to dip a little down amongst the liquor in the pit in which the bag is to be immersed), tanning liquor is to be supplied to the feeding cistern, when the bag will swell until it can contain no more liquor, when percolation will commence, and be continued with a vigour proportionally to the height of the liquor in the feeding cistern above the liquor in the pit of immersion. As the bag fills with liquor, the pit (having been previously full) will overflow, unless the liquor is supplied from the pit of immersion; and therefore a run-way must be made for the liquor to flow to a reservoir, from which it may be pumped or lifted again to the feeding cistern; and as the percolation goes on, the liquor will flow to the reservoir, again to be raised and circulated as before. In this process of tanning there is a double hydrostatic pressure exerted—a greater, which is exerted inside of the bag; and a lesser, which is exerted outside of the bag; and it is the surplus pressure (which is equal at all parts of the bag) of the one above the other that causes the percolation of liquor from within outwards.' By any of Mr Cox's processes we understand that a hide may be as effectually tanned in a week, as it was by the old tan-pit method in twelve months, while there is at the same time a saving of tanning material and gelatine.

More recently still, Dr Turnbull of London has patented a very ingenious process, depending upon the principles of *endosmose* and *exosmose*; and another, in which the forcing-pump is employed to expedite the impregnation of the hide with the tanning liquid. The theory of endosmose and exosmose was first broached by Dutrochet, who discovered that small bladders of either animal or vegetable membrane, if filled with milk, and securely tied, when thrown into water, absorbed a quantity of that fluid, and acquired weight; while, on the contrary, if the bladders were filled with water, and thrown into milk, they lost weight, from the water being attracted through the membrane into the milk. From these and other experiments, he concluded that if two fluids of unequal density be separated by a membrane, the heavier fluid will attract the lighter through that membrane. The attraction from the outside to the inside he called endosmose; from the inside to the outside, exosmose. Upon this principle Dr Turnbull fills his skins (sewed up in the form of bags) with a super-saturated solution of tannin, and places them in a reservoir filled with a sub-saturated solution (or *vice versâ*), upon which the permeation goes on with rapidity; and what formerly required months, can be effected more thoroughly in as many days.

Skins intended for the *manufacture of gloves* require in the first place to be washed with pure water. This is done in a cistern placed, if possible, near a running stream; and immediately after being washed, the skins must be worked, or they are liable to become marked with indelible spots. They are next rubbed upon a convex beam, and the rough parts removed with the fleshing-knife. The fleshy sides of the skins are then covered with a cream of lime, and piled together with the wool sides of each pair outermost. They are left in this state for from four to six days, or until the wool is found to come easily off. The skins are then washed in a running water, to free them from the lime, and the wool is taken off by means of small spring tweezers. After this they are fleeced smooth by a rolling-pin, or by rubbing with a whetstone.

The next operation to be performed is steeping the skins in a strong solution of lime, for the purpose of swelling and softening them. They are then put into weak lime-water, and drained upon inclined tables, which is repeated several times, the process occupying about three weeks. The outsides are then rubbed with a whetstone, to remove any wool which may still remain; and the skins are then fit for what is called *branning*. Into twenty gallons of water forty pounds of bran are put, and the skins are steeped in this mixture until they sink, which they will generally do in about two days in summer and eight in winter. During the branning process, the skins must be frequently stirred, that each may get a due share of the liquid. They are next steeped in a solution of alum and sea-salt, which is called the *white stuff*. From twelve to eighteen pounds of alum, and about three pounds of salt, are put into a copper with twelve gallons of water. This mixture is dissolved by heating the copper; and when about to boil, three gallons of the solution are poured into a basin, in which twenty-six skins are worked one after another. The twelve gallons are thought sufficient for one hundred skins; and when all have been worked, they are allowed to steep for about ten minutes. The skins are then taken out, and fifteen pounds of wheat flour are added to the solution. This is next run out of the copper vessel, and the yolks of fifty eggs put into it, in which the skins are worked, and afterwards allowed to steep for a day. They are then taken out, stretched upon poles, and allowed to dry. By this operation the leather is rendered very white and soft, which enables it to bear the working of the softening-iron. This consists of a plate of iron about a foot broad, mounted upon an upright beam thirty inches high, which is fixed to the end of a plank three and a half feet long. This plank is heavily loaded; and the skins having been previously wetted, they are rubbed with the iron upon a board. The skins are sometimes stretched upon the horse, and well rubbed with a blunt two-edged knife, and afterwards polished with pumice-stone. They are then worked upon the stretching-iron, and afterwards smoothed with a hot iron.

Sheepskins are frequently dressed for household purposes, and on this account are technically called *housings*. For this purpose, those skins are selected which have the longest and most beautiful fleece. They are first well washed and steeped in water, to render them soft, and then thinned with the fleshing-knife, after which they are put into the bran pit for four days. The same process as for glove leather, of steeping in alum water, and rubbing with paste, is then performed. The skins are next worked upon the horse, stretched upon the stretching-iron, and then dried in the sun with the fleecy side outermost.

Chamois leather is prepared by washing, steeping in lime-water, taking off the fleece, and then branning the skins as before described. The outer skin, or epidermis, is next cut off upon the horse, which removes all excrescences, and renders the skins equal in thickness. They are then branned for a short time, the liquid wrung out of them, and then well beat in a fulling-mill. The next process is to oil the skins, which is done by sprinkling and rubbing over them any cheap animal oil. The skins are afterwards oiled and beat several times, and are then subjected to a fermenting process; after which they are washed in potash lye, and then dried. The very thick and firm, but pliable sort of leather called *buff* (originally made of buffalo skins, but now also from cow-hides), is dressed in oil, and prepared much in the same way as chamois.

Morocco or *Turkey leather* is manufactured from goatskin, but a spurious article is frequently sold under this name which is made from sheepskin. The process is much the same as for glove leather, except that the washing is performed oftener, and the skins are salted previous to being dyed. Morocco leather is dyed with cochineal, about an ounce being required for each skin. The cochineal gives a scarlet colour to morocco leather; but other colours may be given to it, such as black, by using the red acetate of iron; blue, by indigo; yellow, from the roots of the barberry. The skin is next tanned in a decoction of sumach. The tanning is performed twice, the process requiring about twenty-four hours. The skins are then rubbed hard with a copper blade, and hung up to dry.

Russia leather, well known for its durable properties, is prepared by steeping in alkaline lye, and then in dogs' dung; after which it is fulled and tanned with birch bark. It is generally dyed of a pale orange colour, is roughened in the surface by an iron tool, and receives its peculiar odour from being rubbed with the empyreumatic oil of birch. *Maroquin*, commonly of a red or yellow colour, is another Russian leather similarly prepared. *Shagreen*, brought chiefly from Astracan, is prepared from the strong skin which covers the crupper of the horse or ass. Its peculiar granulated surface is produced by treading small round seeds into the skin when soft; these are afterwards removed, the leather dyed green, and the surface worked down by rasping, when it finally presents the appearance of white dots on a green ground.

Currying is the process by which the newly-tanned rough leather is converted into the soft, flexible, and jet-coloured article from which the upper leathers of shoes are made. The currier first steeps the leather, and then places upon it a piece of basket-work, upon which he treads, in order to soften it. He then shaves the leather by means of a double-edged knife, with a horizontal handle at each end. The edges of this knife are curved, and in cutting, it is held nearly at right angles to the leather, which is thrown over an upright beam. The currier stands behind this beam and scrapes downwards. By this means all inequalities are removed, the leather being rendered uniform in thickness and firm in the texture. What is called a stretching-iron is also used, which still further firms the grain; and cleaning-knives to make the surface smooth. The leather is then pommelled by an instrument grooved on the under side, and with a cross strap on the top, under which the hand of the workman goes. The leather is folded with its grain side in contact, and rubbed strongly with the pommel, which gives it a granular appearance and greater flexibility. It is then conveyed to the drying-house, where grease is applied to soften it. The grease employed is a mixture of tallow and cod oil, called *dubbing*, and is applied to the leather by means of hard brushes upon a large broad table. When well greased, the leather is hung up to dry, in order that it may thoroughly imbibe the oily matter. It is then well scraped, to free it from all superfluous oil, which would otherwise injure its appearance, and prevent it from receiving the colour readily. The leather is then rubbed on the flesh side with a brush dipped in a composition of oil and lamp-black, until it is thoroughly black. It is then black-sized with a brush or sponge, rubbed again with the oily matter, and afterwards scraped with glass. When coloured (that is, blacked) upon the grain side, a solution of sulphate of iron or copperas is employed. The leather is then wetted with stale urine, and afterwards rubbed with an iron, to render the grain as fine as possible. The bright shining varnish now common on dress shoes is called *enamelling*.

Cow-hides, when dressed for upper leather, are called *neat's* leather, and the shoes made from it are coarse. Common shoes are in general made from calf-skin, which is prepared in the same manner. The uppers of boots are all made from calf-skin, the best part for this purpose being the back and flank. This also applies to cow-skin leather. A considerable number of shoes are made from a description of leather called *kip*, which is prepared from the hides of young cattle, and is consequently intermediate in quality between calf-skin and cow-hide. Horses' hides were formerly much used for making leather, generally known as *cordovan;* but they are now almost entirely superseded by cow-hides, which are greatly preferred. *Parchment* and vellum, well-known preparations, we reserve for our article on BIBLIOGRAPHY.

Colours—Pigments.

There are, as is well known, two modes of imparting colours—dyeing and painting; the former applied to articles coloured by a liquid infusion, and the latter applied to the laying of a colouring substance on the surface. We *dye* cloth, and *paint* a house. The materials employed in dyeing are usually drugs, salts of some kind, or vegetable fluids; but in painting, the prepared colours are chiefly pigments. The preparation of dye-stuffs and pigments is one of the chief departments of practical chemistry.

According to the definitions of men of science, there is no such thing as material colour. The colour is not in the substance; it is only a result of the operation of rays of light on the peculiarly-formed particles in the mass. It is stated that when the rays strike upon the surface of a body, they are decomposed into their elementary tints, and some substances reflecting one colour, and some another, the impression is made on the eye accordingly. When the particles of the body do not reflect any of the rays, the body appears black; and when they reflect them all equally, it appears white. A piece of blue silk, for instance, absorbs six rays, and reflects one, the blue, by which a blue appearance affects our eye. What is the precise constitution or figure of the particles in a substance which produces the phenomena of colours, has never been ascertained. It is certain, however, as we have just mentioned, that colouring less or more depends on the well-known principle of the refrangibility of light. (See OPTICS.) Both dyers and painters require to be more conversant with chemical than optical science; yet there are cases in which a knowledge of the laws of light are of importance. It is a well-known truth that the common white ray of light can be refracted into three primitive colours—red, blue, and yellow—and that these can be recombined into the white ray. A dyer could not expect to dye white by employing an infusion of red, blue, and yellow drugs, but it is certain that the application of a little blue improves a white colour; and this is perfectly understood by paper-makers. Mixtures of Prussian blue and cochineal pink are likewise used to improve the whitening of silks. The colours resulting from a mixture of two primitive colours, as green from blue and yellow, are only a delusion of the eye. Both the component colours are present and distinct, but they are so blended, that we cannot separate them by the naked sight. For instance, a gray hair, when seen by a microscope, is not actually gray, but a composition of small black points on a whitish ground.

The substances used as *paints* are partly artificial, and partly natural productions. They are derived chiefly from the minerals by certain chemical processes; and even when animal or vegetable substances are used for colouring, they are always united with a mineral substance (an earth or an oxide), because by themselves they have no body, which they acquire only by a mixture with a mineral. In painting, the colours are ground to a great degree of fineness, and applied, by means of some liquid, with a brush or camel-hair pencil. Different fluids are employed for this purpose; and the difference of the material used, with the method of employing it, has given rise to the modes of painting in water-colours, oil-colours, in distemper, and in fresco (painting on damp plaster as an absorbent). Oil-paints are usually prepared with boiled linseed-oil, which is drying in its nature; the colours employed all consist of metallic oxides, or salts, or of combinations of sulphur. Among the metallic oxides used as pigments are minium and masticot, from lead; the ochres, burnt sienna, umber, from iron; smalt, from cobalt. Among the salts, or saline metallic combinations, are white-lead, cremnitz white, from lead; Prussian blue, from iron; verdigris, mineral green, Brunswick green, from copper. Metallic combinations containing sulphur are cinnabar, from quicksilver, and orpiment, from arsenic. The lake colours have tin or alum for their bases, and owe their tint to animal or vegetable colouring substances. Among these are the red or pinkish lakes prepared from cochineal, madder, and Brazil wood; the yellow, from fustic, &c.; the brown, from several other colouring barks; finally, indigo, which, however, is entirely vegetable. In staining porcelain and glass, the metallic colours which are not driven off by heat, and are not easily changeable, are used. Gold containing tin gives a purple, nickel green, cobalt blue, iron and manganese black, uranium yellow, chrome green. From the chromate of iron, or rather ferruginous oxide of chrome, one of the most beautiful yellow pigments is now prepared for the use of painters. Ultramarine, another of our most beautiful, and, till lately, one of the most expensive of our pigments, is now prepared cheaply and abundantly by a process strictly chemical. Originally obtained from the lapis-lazuli, a mineral of unrivalled azure-blue, it became the duty of the chemist to discover the constituents of that mineral, and thereafter to endeavour to imitate the natural product. 'The analysis of lapis-lazuli,' says Liebig, 'represented it to be composed of silica, alumina, and soda, three colourless bodies, with sulphur, and a trace of iron. Nothing could be discovered in it of the nature of a pigment, nothing to which its blue colour could be referred—the cause of which was searched for in vain. It might therefore have been supposed that the analyst was here altogether at fault, and that at anyrate its artificial production must be impossible. Nevertheless this has been accomplished, and simply by combining in the proper proportions—as determined by analysis—silica, alumina, soda, iron, and sulphur. Thousands of pounds weight are now manufactured from these ingredients; and this artificial ultramarine is as beautiful as the natural, while for the price of a single ounce of the latter we may obtain many pounds of the former!'

The material principally employed by respectable house-painters to give consistency to their paints, is white-lead or ceruse. This substance is an oxide of lead saturated with carbonic acid. It is prepared by exposing thin plates of lead in a closed vessel to the vapours arising from hot vinegar. The vapours of the acetic acid become saturated with the metal, and change the latter into a whitish substance, which is scraped from time to time off the plates. The whitish substance is afterwards pulverised, and mixed with properly prepared oil. Much of the white-lead in common use is adulterated with whiting—that is, purified and ground chalk—which is much less durable, and may be easily washed off by an alkaline solution.

Oil or spirit of turpentine is also largely used by house-painters, chiefly for the purpose of imparting a drying quality, or of deadening the glitter of the paint. Turpentine is a fluid extract from certain kinds of fir-trees, from which it exudes, and being distilled, the oil or spirit of turpentine is obtained; the residuum is resin. Turpentine is of a powerful acrid quality, and is now employed for certain purposes in medicine. All the *varnishes* used by painters are of the class of gums or resins, properly prepared—such as copal, mastic, sandarach, lac, gum-lac, dragon's blood, &c. All are extremely inflammable, and great caution is necessary both in their preparation and general use.

Inks, either for writing or printing, are as much the result of chemical operations as paints or dyes. Black ink is a decoction of partly vegetable and partly metallic substances, the basis of the latter being iron. The ingredients commonly used are Aleppo galls in powder, logwood, gum-arabic, and sulphate of iron, in certain proportions; but latterly the art of manufacturing the article has been greatly improved, chiefly with the view of giving great fluidity as well as colour. *Printing-ink* is quite a different substance, being a thick viscid body, resembling a black paint. Its ingredients are boiled linseed or nut oil and lamp-black, in the proportion of two and a half ounces of black to sixteen ounces of oil. The preparation of the oil is one of the most dangerous processes in the arts, and great care is required to prevent conflagration of the oleaginous material. There are various qualities of ink to suit different kinds of work. The prime object of attainment in making printing-ink is to give it a deep black colour, which will endure after exposure on the pages of a book. Unless very great trouble be taken in grinding and mingling the materials in exact proportions, the ink, on being used, will gradually become brown, by the spreading of the oil. The French printing-inks are much superior to those made in Britain. *Indian ink* is used in China for writing with a brush, and for painting upon the soft flexible paper of Chinese manufacture. It is ascertained, as well from experiment as from information, that the cakes of this ink are made of lamp-black and size, or animal glue, with the addition of perfumes, or other substances not essential to its quality as an ink. The fine soot from the flame of a lamp or candle, received by holding a plate over it, mixed with clean size from shreds of parchment or glove-leather not dyed, will make an ink equal to that imported. The science of chemistry having, as it were, at its command the production, change, and reproduction of colour, by the use of its numerous compounds, a variety of what are called *sympathetic* inks have been invented, and others attempted, which might withstand all chemical obliterants. Some of these are made to remain invisible till some re-agent be applied, others require chemically-prepared papers, and others again can be rendered visible or invisible at pleasure.

Dyeing.

A remarkable circumstance connected with dyeing, is the different degrees of facility with which animal and vegetable substances imbibe the colouring matters applied to them. Tissues composed of the former, as silk and wool, receive more brilliant colours than those composed of the latter, as cotton and linen. The cause of this difference has not hitherto been discovered.

Although in the most numerous class of cases it is easy to impart colour to various tissues, yet when these become exposed to moisture, the dye-stuff is removed. It has therefore been found necessary to employ certain chemical substances, which shall have the property of permanently fixing the colour upon the body which is dyed. These substances have obtained the name of *mordants* (from the Latin word *mordere*, to bite), because they were supposed at first, figuratively speaking, to bite the dye into the cloth. The same name has also been applied to those preparations which possess the property of altering the shade, or of heightening the colour, as it is called. The latter, at the suggestion of Berthollet, are sometimes termed *alterants*. The principal mordants are alumina, employed universally, we believe, in the form of a salt, as that of alum; the oxides of tin, employed like the former in the shape of salts, which are prepared by dissolving tin in muriatic acid. Silk and woollen dyers, however, employ nitric acid or aqua-fortis for forming the salts of tin which they use. The salts of lead and copper are likewise had recourse to as mordants; and the gall-nut, which contains two very peculiar vegetable substances—tannin and gallic acid—is not only employed as a mordant, but also as a simple and powerful dye-stuff.

By varying the mordant, a great variety of shades may be derived from the same colouring matter. Indeed, the mordant itself, in many instances, supplies a colour. For example, in dyeing with cochineal, when the aluminous mordant is employed, the colour produced is crimson; but when oxide of iron is substituted for the alumina, a black colour is the result. The whole phenomena are accounted for on the principle of chemical affinity or attraction. The mordant employed should have an attraction both for the stuff to be dyed and the colouring matter, and act, as it were, like a third party, in reconciling two inimicals. The way in which it is used must depend entirely upon the degree of affinity exerted between the stuff and the colouring matter. Where that is slight, the former should be saturated with the mordant before the latter is communicated. A knowledge of the nature and chemical affinities of the substances used is necessary, before mordants can be had recourse to as a medium of union in imparting colour to cloths, or other stuffs which we wish to dye; for, by an indiscriminate use of them, results the very opposite of those anticipated may take place.

Calico-Printing.—In impressing the representation of figures on calico goods, the object generally held in view is the fixing of mordants on the cloth, which is afterwards dyed in the usual way, those parts which have received the mordant only retaining the colour, the rest remaining white. In some cases the colour is removed from certain portions of cloth already dyed, so that they may either remain white, or receive some new colour afterwards. Sometimes it is applied to cloth before it is dyed blue, in order to prevent the indigo from being fixed on those parts to which it is applied, that they may remain white, or receive other colours afterwards. Substances possessed of this property are called resist-pastes. Lastly, it is frequently employed to communicate mordants and colouring matter at once to cloth. The thickening of the mordants is of considerable importance towards the successful practice of the art. The application, or the bringing out of the colours, is an ingenious chemical process. Madder is the substance commonly used for red by the calico-printers, and the addition of sumach, fustic, or quercitron bark, will produce a variety of tints with the various mordants at one operation. 'Suppose,' says Dr Ure, 'we wish to produce flowers or figures of any kind, containing red, purple, and black colours, we may apply the three mordants at once by the three-colour cylinder-machine, putting into the first trough acetate of alumina thickened; into the second acetate of iron; and into the third a mixture of the two; then drying in the air for a few days to fix the iron, dunging, and dyeing up in a bath of madder and sumach. If we wish to procure the finest madder reds and pinks, besides the purple and black, we must apply at first only the acetate of alumina of two densities, by two cylinders; dry, dung, and dye up in a madder bath. The mordants of iron liquor for the black, and of iron liquor, mixed with aluminous, for the purple, must be now grounded in by blocks, taking care to insert these mordants into their precise spots; the goods being then dried with airing for several days, and next dunged, are dyed up in a bath of madder and sumach. They must be afterwards cleared by branning.' (See No. 22.)

After the cloth is dyed, it is washed either with soda, potash, soap, or fresh water, according to the nature of the ingredients used in the dyeing process. Great care is necessary in this department; for if the washing liquor be too strong, the mordant may be injured. Cow-dung diffused through hot water, is applied to calico goods in a particular stage of the manufacture. This is done in order to dissolve and carry off from the cloth a portion of the thickening matter, and also to prevent any undissolved mordant or acetic acid from injuring the blank parts of the piece. The dunging, as it is called, is performed several times, generally between the washings. The piece should be immersed, if possible, without folds, and to secure this it is made to pass through rollers. As soon as it comes out of the dung-bath, it is washed in the dash-wheel as in bleaching. The cloth is then finished by being passed through a calender, which greatly improves its appearance. The action of the solution of cow-dung in cleansing from impurities is both mechanical and chemical; as respects the chemical part of the operation, it will be understood when we mention that cow-dung contains muriate of soda, sulphate of potash, sulphate of lime, carbonate of lime, and other detergent matters.

Bleaching.

Bleaching is the art by which various articles may be deprived of the colours which they naturally possess, and so rendered white. Formerly, it was the custom to submit textile fabrics in a moist condition to the free action of the atmosphere and sun's light; but this process of bleaching was not only imperfect, but tedious; and the substitution of a chemical effect, as suggested by the celebrated chemist Berthollet (1787), was a great improvement, such as the state of manufacturing industry required. Berthollet's plan consisted in employing chlorine, which possesses a wonderful power of removing vegetable colours. The bleaching-powder, or chloride of lime, as it is usually called, is manufactured by exposing slaked lime (hydrate of lime) to the action of chlorine gas, till as much of the latter is absorbed as the lime is capable of combining with under these circumstances. The chlorine in the bleaching-powder, which is not applied till after sundry preparatory washings of the cloth, acts upon vegetable substances, by dissolving their hydrogen, which is the colouring agent; the air would have the same effect, but would require a much longer time than can be allowed. The cloth is left in a cold solution of the bleaching-powder for about six hours, and is then taken out and washed with water. The next part of the process is called *souring*, which is immersing the cloth in a solution of sulphuric acid, so diluted that it does not injure the texture of the goods, whilst it improves their colour. The sulphuric acid dissolves and removes the oxide of iron with which the cloth is always contaminated; it also removes the lime which may have attached itself to the cloth during its previous treatment with that substance. It is again washed, boiled in an alkaline lye, and once more carefully washed in cold water. Another solution of bleaching-powder, two-thirds the strength of the former, is then prepared, in which the cloth is immersed, and left for five or six hours; it finally undergoes another process of souring, by which means it is rendered perfectly white. The acid is carefully removed by washing; and after each piece of cloth has been stretched to its full length, it undergoes a process of mangling, by being passed successively between cylinders forced towards each other by levers, to which a considerable weight is attached. The cloth being thus stretched, smoothed, and wound upon a roller, is rendered fit for *starching*. The starch is that of flour, deprived of its gluten by remaining for twenty-four hours in water, and then passed through a sieve, which retains the bran, and allows the starch to pass. A little indigo is mixed with it, and sometimes porcelain clay. The starch is applied in the state of a pretty thick paste whilst the cloth is passing between a pair of rollers. The goods are then dried, and passed through a calender, for the purpose of giving them a gloss and texture.

Such is the process of bleaching, as practised in the large bleaching establishments on the common class of goods. The number of processes which the cloth undergoes amounts to about twenty-five, but some of the earlier ones are occasionally omitted. The expense of bleaching and finishing a yard of cotton cloth is about one halfpenny, and the time required is trifling. A bleacher in Lancashire, we are told, received fourteen hundred pieces of gray muslin on a Tuesday, which, on the Thursday following, were returned bleached to the manufacturers, at the distance of sixteen miles; and on the same day they were packed up and sent to a foreign market. But for this new process of bleaching by chlorine, it would scarcely have been possible for the cotton manufacture of Britain to have attained its present enormous extent. Chlorine is easily and chiefly obtained from the muriatic acid generated in the process of extracting soda from sea-salt. In liberating the chlorine from the compound acid, the main expense is caused by the employment of manganese; but it is more than likely that the use of this substance will shortly be superseded by one or other of the processes which have lately been patented for the purpose. We may remark, in conclusion, that the common prejudice against stuffs bleached by chlorine is groundless; they suffer less in the hands of skilful workmen than those bleached in the sun. (See No. 22.)

Combustibles.

The class of combustibles in the manufacture of which a knowledge of chemistry is more particularly required, includes gunpowder, gun-cotton, fulminating powders, the material of Congreve and skyrockets, bombshells, percussion-caps, rapidly-igniting matches, and of fireworks generally. The term *Pyrotechny* (from *pyr* fire, and *techné*, art) has been applied to the art of making and compounding those substances.

The leading ingredients in most explosive combustibles are charcoal, saltpetre, or nitre, and sulphur. In making fireworks of a varied kind, however, numerous other substances are employed. The chief are chlorate of potass, fulminating silver, and mercury, preparations of steel, copper, and other metals, with various oils, spirits, and resins. Charcoal, as is mentioned in the preceding sheet, is simply wood reduced to a charred condition (pure carbon), by being burnt to a kind of blackened cinder in a vessel closed from the atmosphere. For making gunpowder, light woods, such as the willow and alder, are the best, and the pieces are stripped of their bark before being used. In preparing this kind of charcoal, it is important that the vapours be allowed freely to escape, otherwise its combustibility will be impaired. The preparation is usually effected by iron retorts over furnaces; and by a connecting tube the vapour escapes, and is condensed into a tarry acid, from which pyroligneous acid is afterwards distilled. After being thus prepared, the charcoal is reduced to a fine powder.

Saltpetre, nitre, or nitrate of potass, is abundant in nature, but may be also compounded by the artificial union of its two ingredients—nitric acid and potass. It is procured largely from India, and also from Egypt, Spain, and other countries, where it is found on the surface of limestones, marls, and chalky strata, being spontaneously generated and reproduced there by some atmospheric influence not well understood. The slight silky tufts of the nitre are swept up with a broom, and are lixiviated, allowed to settle, evaporated, and crystallised. In this state it is exported; but the impurities which it contains require its subjection to successive solutions and crystallisations, ere it can be employed in the manufacture of gunpowder. The last process is that of fusion, in iron pots at a regulated heat. It is tested by adding to its solution in distilled water nitrate of silver, with which it occasions no perceptible opalescence.

Sulphur is procured in many volcanic countries, but the great emporium for it is Sicily. It can also be obtained from the metallic sulphurets as from iron pyrites. At the gunpowder works it is purified for use either by distillation or by fusion. In the first instance, the pure part is distilled over, and in the second, skimmed off, the impurities being left behind.

Gunpowder.—The three ingredients, charcoal, nitre, and sulphur, being duly prepared by trituration, and passed through fine sieves, they are ready to be mixed. There appears to be a great difference of opinion and practice in determining the relative proportions of the ingredients. The following is a scale of proportions in 100 parts, adopted by different gunpowder makers:—

	Nitre.	Charcoal.	Sulphur.
Royal mills at Waltham Abbey, -	75	15	10
French, for war, - - - -	75	12·5	12·5
... for sportsmen, - - -	78	12	10
... for mining, - - -	65	15	20
Chaptal's proportions, - - -	77	14	9
Mr Napier's ditto, - - -	80	15	5

The mingled ingredients are now carried to a mill, to be properly blended, by the pressure of a revolving stone on edge; the stone is of a calcareous quality, and goes round on a bedstone of the same nature; no metal or sandstone is employed either about the machinery or the mill-house, in order to avoid the danger of sparks. 'On this bedstone,' says Dr Ure in his history of the manufacture, 'the composition is spread, and moistened with as small a quantity of water as will, in conjunction with the weight of the revolving stones, bring it into a proper body of *cake*, but not of *paste*. The line of contact of the edgestone is constantly preceded by a scraper, which goes round with the wheel, continually scraping up the cake, and turning it into the track of the stone. From fifty to sixty pounds are usually worked at once in each mill-wheel. When the cake has been thoroughly incorporated, it is sent to the corning-house, where a separate mill is employed to form the cake into grains or corns. Here it is first pressed into a hard firm mass, then broken into small lumps; after which the graining is executed by placing these lumps in sieves, on each of which is laid a disk of lignum-vitæ. The sieves are made of perforated parchment. Several such sieves are fixed in a frame, which, by proper machinery, has such a motion given to it as to make the lignum-vitæ runner in each sieve move round with considerable velocity, so as to break the lumps of the cake, and force the substance through the sieves, forming grains of several sizes. These granular particles are afterwards separated from the finer dust by proper sieves and reels. The corned powder is next hardened, and the rougher edges taken off, by being revolved in a close reel or cask turning rapidly on its axis. This vessel somewhat resembles a barrel-churn: it should be only half full at each operation, and has frequently square bars inside, parallel to its axis, to aid the polish by attrition. The gunpowder is now dried, which is done generally by a steam-heat, or by transmitting a body of air, slightly heated in another chamber, over canvas shelves covered with the damp gunpowder.'

Gun-cotton.—Much interest and excitement (we abridge from the English edition of Knapp's 'Chemical Technology') have been recently caused by the announcement of a substitute for gunpowder, which is said to be four times more powerful than that substance, weight for weight, to ignite at a much lower temperature, to be uninjured by water, and to burn without smell, smoke, or residue. This substance is the gun-cotton of Dr Schönbein, to whom the credit is due of discovering and making known the various useful purposes to which this remarkable body may be applied, although its actual discovery dates from a period prior to that when Schönbein published his experiments. Without entering upon either its history or its theoretical composition, as manifested in what are called xyloidine and pyroxyline, we shall merely advert to the plan adopted for the preparation of gun-cotton in the laboratory of the chemist—no minute description of its manufacture upon a commercial scale having yet been published:—Well-cleansed cotton is immersed in a mixture composed of equal parts* of concentrated nitric and sulphuric acids, for about ten or fifteen minutes; and to prevent accidents, no portion of the cotton should be above the level of the liquid. The acid should then be pressed out, and the cotton which remains impregnated with it is well washed with water, until no acid reaction is perceptible to the tongue; it is now dried at a temperature not exceeding 212° Fahrenheit. Care should be taken in drying this substance to allow a free current of air to pass over it, and to spread out the cotton as much as possible, to prevent its forming into dense masses, which are said to be much more liable to explode.

The properties of the substance so prepared are very extraordinary, and create a greater degree of astonishment, in consequence of its outward appearance bearing the strictest resemblance to ordinary cotton wool, which, however, is not so harsh to the feel. It is insoluble in water both hot and cold; and when removed and dried, is found to have lost none of its original properties. It explodes violently when heated to 356° Fahrenheit, or on ignition, leaving scarcely any residue, and creating very little smoke. The temperature at which it is thus decomposed is so much below that at which gunpowder explodes, that the cotton may be lightly placed upon the surface of gunpowder, and detonised by a red-hot wire without setting fire to the powder. Friction of the ordinary kind will not explode gun-cotton; but when placed on an anvil, and powerfully struck with a hammer, the heat generated by the stroke causes it to detonate. With reference to the projectile force of gun-cotton as compared with gunpowder, no authoritative statements have yet been made; but there appears reason to apprehend that its action in its present form is too rapid, and resembles too much that of fulminates, to render it applicable to the purposes of artillery. The gaseous products from its combustion are also such as cannot be altogether resisted by firearms, although, if air be absent, no great amount of corrosion can ensue; and as it has been found that gun-cotton impregnated with chlorate of potash or nitre has a still more powerful effect than that prepared in the usual way, the addition of these substances would at the same time tend to modify the corrosive action of the acid products of combustion. As a substitute for gunpowder in all mining and blasting operations, however, the superior local force of the cotton will be highly valuable; and it has indeed been found to effect as much as four times its weight of powder.

Rockets.—The common modern rockets, which are generally employed as signals or tokens of rejoicing, may be described as tubular cartridges of paper, pasteboard, wood, or metal, filled with combustible substances, which, on ignition, cause the cartridge to shoot rapidly through the air. The movement may be irregular, parabolic, or perpendicularly upwards, according as a small stick or guide is attached, or otherwise, to the cartridge, to direct its movements. The principle on which rockets rise in the air is simple, and may be explained here, once for all, as it applies to all varieties of flying fireworks. A vessel containing a fluid which tends to expand, will be motionless so long as the vessel is closed on all sides, because the pressure is then equal everywhere; but if an opening exist, the pressure will not be equal, and the vessel will then tend to move in the direction in which the pressure exists. If the opening be below, the tendency will be to rise; and if the expansive force be great enough, and the vessel sufficiently light, the vessel will obey the pressure, and ascend. When the expansive force is exhausted, it will again descend, by the ordinary influence of gravitation. In the case of the rocket, the combustion, commencing below, creates the expansive gas, and the pressure forces the rocket upwards. The cartridge or tube, commonly of pasteboard or pasted paper, must be very strongly formed, if large, and intended to ascend high. Inside of it is a second tube, called the *soul* or *fusee* of the rocket, the purpose of which is to leave a vacant space round the axis, that the volume of elastic gas which the ignition produces may act on a vacant space. On account of its somewhat conical form, hollow rods, adjustable to different broaches or skewers, are used in packing the charge, the cartridge being sustained by a copper mould or cylinder at the time. The charge of sky-rockets varies according to the bore of the cartridge. Nitre 16, sulphur 4, and charcoal 7, are the contents and proportions of the charge when the bore is three-fourths of an inch; and the charcoal is merely increased a very little when the bore is enlarged. This is the common rocket, with the usual light of gunpowder. When a rocket with a *brilliant* light is wanted, 3 parts of fine steel-filings are added; and when the light called the *Chinese-fire* is desired, 3 parts of fine borings of cast-iron form the addition to the three ingredients first mentioned. These are the common rockets: the sources of other kinds and colours of light will be noticed immediately.

* Schönbein recommends the use of 3 parts sulphuric acid, and 1 nitric acid of the specific gravity 1·5.

The *garniture* of a rocket, as the crackers, showers of fire, stars, serpents, &c. are called which are commonly attached to it, with what is termed the *pot*, are of course added before igniting the charge in the central tube or fusee. 'The pot is a pasteboard tube, wider than the body of the rocket, and one-third of its length. After being strangled at the bottom like the mouth of a phial, it is attached to the end of the fusee by means of twine and paste: these are afterwards covered with paper. The garniture is introduced by the neck, and a paper plug is laid over it. The whole (for still greater strengthening) is enclosed within a tube of pasteboard terminating in a cone, which is firmly pasted to the pot. The quick-match is now finally inserted into the *soul* of the rocket, and a light rod or stick attached to the end of the whole, to keep it in a perpendicular ascent.' The beauty of the rocket depends much on the style of the garniture. These, whether stars or serpents, are charged fusees, stronger or weaker, formed into the shape wanted, and giving kinds of light modified by the ingredients. Stars which give golden showers are formed of nitre, 16; sulphur, 16; charcoal, 4; gunpowder, 16; lamp-black, 2. *Petards* are sealed cartridges, which burst in the air; and *crackers* are square boxes of pasteboard, hooped, and charged with gunpowder. But the finest accompaniment of the rocket is the Roman candle, which is a fusee so formed as to throw out in succession, as the combustion reaches them, very fine stars. These stars are small cylindrical masses of nitre, sulphur, and gunpowder, steeped in spirits and gum. The variety of rockets of course depends on the difference of size and garniture.

Congreve rockets, first used in the attack of Boulogne, 1806, are of various dimensions, and are differently armed as they are intended for the field or for bombardment. Those of the first sort carry shells or case-shot; the others are armed with a very combustible material, and are called *carcass rockets*. Their form is cylindrical, and they are composed of strong metallic cases. The sticks employed for regulating their flight are of different lengths, according to the size of the rocket. The carcass rockets are armed with strong iron conical heads, pierced with holes, and containing a substance as hard and solid as iron itself, which, when once inflamed, is inextinguishable, and scatters its burning particles in every direction. When this substance is consumed, the ball explodes like a grenade. The rocket is projected horizontally, and whizzes loudly as it flies through the air. The ammunition is divided into three classes—heavy, medium, and light: the heavy including all above forty-two pounds; the medium, those from forty-two to twenty-four pounds; and the light, from eighteen to six pounds inclusive. The Congreve rockets were used at Leipsic and Copenhagen; but experience has proved them to be much less efficacious than common artillery, and, besides, the secret of their manufacture is now known everywhere.

Bomb-shells are spherical cases of metal, fitted to be discharged by cannon, and containing a central charge of gunpowder, with an external charge of substances fitted to spread and inflict injury on the explosion of the powder, which is ignited by a fusee. The bombs also spread combustion where they alight. The experience of the late sieges of Antwerp by the French, and Acre by the British, has shown that this species of warlike machine is calculated to rise into greater importance than it has hitherto done, rendering forts and cities untenable when it is well used.

Of *fixed fireworks*, or those whose motion is confined to a spot, as jets, wheels, suns, trees, lances, spirals, revolving suns, double or Catherine wheels (two suns in one axis, revolving opposite ways), and many other beautiful contrivances, are now common exhibitions. In all preparations of a pyrotechnic nature, nitre, sulphur, charcoal, and gunpowder, are the chief ingredients. By means of spirits, gums, resins, and oils, the quality and duration of the light are modified, and the principal articles of that description in use are alcohol, bitumen, camphor, wax, turpentine, lard, and the like. Again, the colour of the fire, on which so much of the splendour rests, is modified by employing other articles. Copper-filings and sal-ammoniac give a greenish tint to flame; zinc, a fine blue; amber, and very dry common salt, a yellow; lamp-black produces a deep red with gunpowder, and a pink with nitre in excess; camphor gives a fine white; lycopodium gives a rose colour; and sulphate of strontia, a beautiful purple light. Many other substances are at the command of the pyrotechnist, which produce variations of colour.

Instantaneous Matches, commonly known as *Lucifers*, are nearly all made of one substance—the chlorate or oxy-muriate of potass. Dr Ure's formula for making the matches is as follows:—Thirty parts of the chlorate, in fine powder, are to be mixed gently with a knife upon paper with ten parts of very fine sulphur, eight of sugar, five of powdered gum-arabic, and enough of powdered vermillion to give a rose tint to the whole. The chlorate, gum, sugar, and vermillion are then gently but well mixed, after which as much water as will make a thin paste is added, and then the sulphur is thoroughly mixed with the whole. A great improvement, however, has lately taken place in the use. The matches were dipped formerly in sulphuric acid; but by adding a little more of the chlorate and sulphur than is in Dr Ure's recipe, they are lighted by friction on sand-paper, or any other rough substance.

Of the numerous *fulminating powders* known to chemists, none, comparatively speaking, has any economical importance, except the fulminate of mercury, which is used for *percussion-locks*. We believe that a report to the government of Great Britain in 1831, made by Dr Ure, had the effect of introducing the improvement of percussion-locks into the public service. The formula which that report gives for the manufacture of the fulminate is as follows:—Dissolve 100 parts of mercury in 1000 parts of nitric acid, and add the solution to 830 parts of alcohol, a large vessel being used. A gas rises, which must be allowed to escape, and at a distance from flame. When the effervescence ceases, the contents of the vessel are to be poured out on a large double paper filter in a glass funnel, and cold water thrown over it till the drainings no longer redden litmus paper. The powder adhering to the vessel is also to be placed on the filter, with a little water. The superfluous acid thus washed away, the powder of fulminate of mercury, adhering to the filter, is lifted away, and opened out on plated copper or stoneware heated by steam. The powder, when dried, is in the form of small gray crystals, and is then to be packed in small parcels, and kept close from the air in bottles or boxes. Dr Ure examines several other modes of making the fulminate, but points out defects in all; and his own, though not free from them, was the one adopted most generally we believe. Two and a half pounds of the fulminate, when prepared for the purpose, will charge 40,000 percussion-caps, according to the calculation of French manufacturers. The preparation consists in grinding the fulminate upon marble with 30 per cent. of water, adding six parts of gunpowder for every ten of the fulminate. A dough is obtained, which, when dried in the air, is introduced in small fixed portions into the bottom of the percussion-caps. The fulminate was formerly placed dry in the bottom of the cup; but of late a most important improvement has taken place, in so far as an alloy of copper is made for the purpose, which contains the fulminate within itself, so that there is now no chance of injury by wet, or danger from the mixture.

When combustibles are ignited, they *explode* with a loud noise, and with an extraordinary degree of force. The explosive sound is caused by the rapid resolution of the combustibles into gaseous products, and the shock of these striking upon the volume of the external atmosphere. The explosion is indeed a chemical process, in which a tangible material suddenly vanishes into gases, and is no more seen; its force depending on the strength of the charge—that is, the quantity of elastic vapour to be expanded.

FICTILE MANUFACTURES.

We employ the term *fictile*—from *fingo*, I fashion—to comprehend all those arts which, like that of the potter, involve the moulding or fashioning of crude materials into determinate forms. Thus, with some degree of latitude, earthenware, porcelain, glass, bricks, tiles, mosaic tesseræ, cements, artificial gems, and the like, may be designated Fictile Fabrics, in contradistinction to those of woollen, linen, silk, cotton, and other vegetable and animal fibre, which are strictly textile. The subjects thus embraced are numerous and important; of scientific importance, as involving at every step the deductions of chemistry and the principles of taste; and economically so, as elaborating from the crude and apparently worthless materials of the soil an almost infinite variety of articles of utility and elegance. Our limited space precludes the idea of a minute account, and restricts us merely to the leading features of the manufactures in question.

EARTHENWARE.

Pottery may be generally defined as the art of making vessels from clay, or from other mineral substances ground and rendered plastic like that body. The manufacture of porcelain or china is not included in this definition, inasmuch as it is semi-vitrified, and becomes translucent in the kiln. The fabrication of earthenware—that is, mere sun-dried or fire-dried vessels of clay—seems to have been one of the earliest of human arts; but pottery with a painted glaze was unknown till about the ninth century, when it was first attempted by the Arabs in Spain. Soon after, it found its way into the island of Majorca, where considerable progress was made in the art. From Majorca it was introduced into Portugal, Italy, and France, and thence into Holland. In the seventeenth century a pottery was established at Burslem, in Staffordshire, at which, however, only the coarsest articles of brown ware were manufactured. Subsequently, the glazing of this ware by the vapour of salt—obtained by throwing handfuls amongst the heated articles in the kiln—was introduced by Mr Palmer; and in this state the manufacture continued till 1690, when two Dutchmen of the name of Elers commenced at the same place the fabrication of red unglazed porcelain, of black or Egyptian ware—the tint of which was produced by manganese—and of brown ware of a higher glaze and finish than had hitherto been produced in England. Some years afterwards, Mr Astbury was led by accident to attempt the admixture of ground flint with the finest white clay—a composition which yielded not only a finer and whiter, but a more durable ware than had previously been manufactured. It is to the late Josiah Wedgewood, however, that Britain is mainly indebted for the vast improvements which have taken place since the middle of last century in this department of her manufacturing industry. It was he who erected the first large factories in Staffordshire, and who, from his extensive chemical and mechanical knowledge, conjoined with correct taste, has made the stoneware manufactures of this country superior to those of every other.

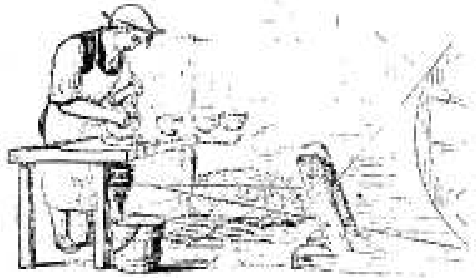
The best clay for pottery manufacture is obtained in Dorsetshire, and another of a quality somewhat inferior is found in Devonshire. These clays are both well suited for the potter, being easily worked, standing the fire well, and becoming very white when burnt. When dug, the clay should be cleansed as much as possible with the hand, and freed from stones. At the factory it is cut to pieces, and put into a cast-iron cylinder about four feet high and twenty inches in diameter. An upright shaft or axis revolves in this cylinder, from which knives radiate in all directions, being so placed, that the shafts with the knives attached somewhat resembles a screw. In the sides of the cylinder knives are also fixed, which reach nearly to the shaft, and remain inactive. When the shaft moves round, the active blades cross the passive, and operate like shears in cutting the clay, which is by this process reduced to a fine pulp. When well ground in this manner, the clay is of the consistence of cream, and is run off through sieves of wire, lawn, and silk, so that none of the grosser parts may enter into the composition of the ware. This clay-cream, or *slip*, as it is termed, is then diluted to a standard density, and set aside in cisterns, to be used as required.

Vessels made from clay alone, however, are found to crack upon being put into the kiln; and to prevent this, it is necessary to add some siliceous substance, incapable of contraction, to the clay. Ground flint is most commonly used for this purpose. It is prepared by cleaning the flint found imbedded in chalk, subjecting it to a red heat, and throwing it in this state into water, by which it becomes comparatively soft. It is then broken by being placed under an upright shaft, which moves up and down in a frame, and is called a *stamper*. The broken flint is next transferred to the flint-mill, which consists of a strong wooden tub, built round a circular bottom, composed of flat pieces of hornstone. On the top of these, similar flat stones are laid, which are attached to, and driven by, strong wooden arms projecting from an upright shaft in the centre of the box. Into this tub the flint is put, and a stream of water is constantly running in, which greatly facilitates the grinding. When the flint is reduced to about the consistence of cream, it is passed through sieves, in a manner similar to the clay. The story of the accidental discovery of this material by Astbury is worth recording:—While on a journey to London, this potter was compelled to seek a remedy for the eyes of his horse, which seemed to be rapidly going blind. The ostler of an inn near Dunstable burned a common black flintstone, pulverised it, and blew a little of the dust into the eyes of the horse, by which they were made to discharge copiously. Astbury having observed the white colour of the calcined flint, and the ease with which it was then reduced to powder, immediately conjectured that it might be usefully employed to improve the colour of his pottery. On his return home he availed himself of his observation, and soon produced a kind of ware superior to any that had hitherto been fabricated. The flints were at first pounded by manual labour in mortars; but an increased demand soon compelled the invention of grinding-mills as above.

The flint and clay liquids being properly prepared, they are next mixed together in such proportions that the flint powder will be to the dry clay as one to five or six, according to the plasticity of the clay. Sometimes a little Cornish stone is also added; and the following are the proportions generally adopted in one of the principal Staffordshire factories for what is designated *cream colour*:—Silex, or ground flint, 20 parts; clay, 100 parts; and Cornish stone, 2 parts. This mixture is put into oblong stone troughs called *slip kilns*, bottomed with fire-tiles, and placed above a furnace flue. Heat is then applied, and the water gradually evaporated, the liquid being constantly stirred during the operation. By this process the mixture is formed into a fine uniform doughy mass, which is cut into pieces, and heaped together in a damp cellar, where they lie for the space of about six months. The clay here becomes black, exhales a fetid odour, and is supposed to undergo a slight degree of fermentation. The longer the clay-paste is kept, the finer it becomes in the grain; and vessels made from it when old, are not so apt to crack as those formed from newer paste.

Another operation, called *slaying*, or *wedging*, greatly assists in forming a fine quality of clay. This consists in seizing a mass of clay in the hands, tearing or cutting it into two pieces, and striking them together again with a force sufficient to make them adhere. This is repeated about twenty or thirty times, by which the parts of the clay are completely intermingled. In large establishments, this operation is performed by means of a tub, with an upright revolving shaft, on which blades are fixed, the machine being similar to that used when the clay comes first from the pit. The clay is forced, by the downward pressure of the blades, through a pipe, and is cut into equal lengths, and again returned to the cylinder, until the parts are blended together. It is sometimes the practice to beat the clay with wooden mallets; this practice is common in France, and the stuff is afterwards trodden by the feet on a clean floor. In China and Sweden, oxen are made to tread upon the clay, to form it into a proper dough. A process called *slapping* is performed by cutting a large mass of clay with a wire, and striking the two pieces together with considerable force. This is generally done as the clay is to be used, either in the same apartment in which the manufacturing or moulding process is performed, or in an adjoining one.

The clay being thus completely kneaded, is put upon the potter's lathe, where it is formed into articles of various shapes. This lathe consists of an upright iron shaft, the lower point of which turns in a socket, and the upper is fixed in a broad wooden disk. Near the top the shaft passes through a socket attached to the framework of the lathe. In the centre is a pulley, with grooves of different circumferences, by which the speed of the shaft can be increased or lessened as circumstances require. This shaft is driven by a fly-wheel, from which an endless belt passes to the pulley. The clay is weighed out and handed to the workman at the



lathe, called the *thrower*, who dashes the mass upon the revolving wooden disk. He then dips his hands frequently into a dish of water placed beside the lathe, and pressing the clay with both hands, it gradually assumes an irregular conical form. By pressing one hand upon the top of this cone, it is again flattened down to a cake, by which operation all air-bubbles are extricated. He next lessens the speed of the shaft by shifting the belt from a small to a larger groove in the pulley, and forms the clay into the shape of the vessel required. This operation is called *throwing*; and when performed, the vessel is cut off from the disk by a wire attached at each end to a piece of wood. The vessel is then allowed to dry gradually, until it arrives at a certain point called the green state, after which it is put upon a turning-lathe, similar to that used by the worker in wood. Here it is turned to its proper shape by a sharp tool, which also smoothes it, and after this it is burnished with a steel surface.

In the green state, also, are attached handles and other appendages to vessels, this being the point at which the clay possesses its greatest tenacity, till it is burned. Handles of teapots, &c. are formed by squeezing the dough through different shaped orifices, which, as it issues, is cut into proper lengths, and bent into the desired forms. These being formed, are attached to the vessels by a paste called *slip*, and the seams are smoothed off with a wet sponge. The ware is next placed in an apartment heated to about 90° Fahrenheit, and fitted all round with shelving. When completely dry, they are rubbed over with hemp, and are then ready for the baking kiln.

The articles made in the manner above-described are all of a round form; but there are many which are of a different shape, and require a different process in the manufacture. Oval-shaped vessels are formed by what is called press-work, which is done in moulds made of plaster of Paris. One-half of the pattern is made in the one side of the mould, and the other half in the other side. The parts are formed to fit each other exactly, and are joined in the same manner as the handles are to vessels. Imitations of flowers and foliage are executed in moulds of plaster of Paris. The clay is poured into the mould in a thin state, and is there left for a certain time. The plaster soon absorbs the water, which renders the clay tough; and its thickness depends upon the time it is allowed to stand in the mould. These *furnishings*, as they are called, are then dried to the green state, and fastened on with slip.

When the ware is ready for the kiln, the articles are placed in baked fire-clay vessels called *sags*, or *saggers*. These vessels are made of inferior clay by the workmen during the intervals of their work, and are from six to eight inches deep, and from twelve to eighteen in diameter. The sags are packed full of the dry ware, and are then piled above each other in the kiln, the bottom of one sag forming the cover of another. These rude dishes are necessary, to prevent the ware from being suddenly and unequally heated, and also to protect it from the smoke and dust of the kiln.

The body of a pottery kiln is generally of a conical shape, and inside of this is the fire-kiln, which is circular and round at the top. When the kiln is filled with the sags, the doorway is built up, and fire applied to the furnaces. The heat is increased gradually, from the time the fire is put on till the ware is found to be properly burnt. To ascertain this, the workman draws from the kiln what is called a *watch*, and if this is found to resemble in colour a previously-burned vessel, he allows the kiln to burn a little longer, and then opens the doors of the furnaces carefully, so as to lower the heat by slow degrees. The burning, or *baking*, as it is called, usually lasts from forty to forty-two hours, after which the kiln is allowed to cool very slowly. When the ware is taken out of the sags, a child makes the pieces ring with the handle of a brush, used for dusting them, and then immerses them in the glazing material. The glaze is kept in a large tub, into which the articles are put by the child, and lifted out by a man, who shakes them in the air, and places them on a board, to be conveyed to the glazing kiln.

'Three kinds of glazes,' according to Dr Ure, 'are used in Staffordshire—one for the common pipe-clay, or cream-coloured ware; another for the finer pipe-clay ware, to receive impressions, called *printing body*; a third for the ware which is to be ornamented by painting with the pencil. The glaze of the first, or common ware, is composed of 53 parts of white lead, 16 of Cornish stone, 36 of ground flints, and 4 of flint-glass; of the second, 26 parts of white felspar, fretted with 6 parts of soda, 2 of nitre, and 1 of borax; to 20 pounds of this frett, 26 parts of felspar, 20 of white lead, 6 of ground flints, 4 of chalk, 1 of the oxide of tin, and a small quantity of the oxide of cobalt, to take off the brown cast, and give a faint azure tint, are added. As to the ware which is to be painted, it is covered with a glaze composed of 13 parts of the printing colour frett, to which are added 50 parts of red lead or litharge, 40 of white lead, and 12 of flint; the whole having been ground together.'

The above compositions make a very clear, hard glaze, which is not affected by vegetable acids, and preserves its lustre for an indefinite time. When covered with the glaze, the vessels are put into sags, which have been previously glazed, with a composition of 13 parts common salt, and 30 parts potash. They are then put into the glazing kiln, which is usually smaller than the biscuit kiln, the sags being piled in the same manner as at the first burning. The heat of the glazing kiln is very low at first, but gradually increases until it reaches the melting-point, when great care is necessary to prevent the temperature from suddenly falling. To ascertain when the temperature is high enough, balls of red clay, coated with fusible lead-enamel, are employed. When these balls become of a slightly dark-red colour, the temperature is sufficient to glaze ordinary pipeclay ware. The fire is kept on for about fourteen hours, after which very little fuel is added, and the kiln is gradually allowed to cool. The vessels are again tried by being slightly struck by a small wooden hammer, when, if they ring freely, they are sound.

The colouring of pottery is performed either by what may be called painting, or by printing. The colours used in producing the *dipt* or *sponged* ware are of a very cheap kind, as it is only for common purposes that this material is employed. In dipt ware, the colours are dropped on before the ware is burned; and in sponged ware, when it is in the biscuit state. A black dip is made from manganese, ironstone, and clay-slip; a drab by nickel and slip; a blue by cobalt and slip; a yellow by yellow clay alone, or by a compound of red and white clay; and a red by a natural red or brown clay, which will burn red.

The colours used for painting and printing on ware are similar to one another, excepting that the colours for printing are more expensive; both, however, form an important and extensive part of the materials of a pottery. The manufacturers of earthenware are much occupied with the improvement of the variety and beauty of the colours, as well as of the patterns or styles that are produced, and hence a great emulation exists among those employed in the trade. The blue colour in *printing* is produced from cobalt, which is used with flint, ground glass, pearl-ash, white lead, barytes, china clay, and oxide of tin in reducing its strength; the brown by ochre, manganese, and cobalt; the black by chromate of iron, nickel, ironstone, and cobalt; the green by chrome, oxide of copper, lead, flint, and ground glass; and the pink by chrome, oxide of tin, whiting, flint, ground glass, and china clay, which are mixed in various proportions, fused together at a high temperature, then pounded and mixed with oil. The colouring matter is ground upon a porphyry slab, with a varnish prepared from a pint of linseed oil boiled very thick, 4 ounces of rosin, half a pound of tar, and half a pint of the oil of amber. This transfer varnish is very tenacious, and requires to be liquefied by heat before being used.

The figure or design to be fixed upon the vessel is engraved in the usual way upon copper-plate, which is rubbed over with the colouring matter prepared as above, and the impression is taken upon a thin unsized paper made for the purpose. The printed paper is placed upon the vessel, and is rubbed with a roll of flannel about an inch and a half in diameter. After this the vessel is set aside for a little, to allow the figure to become fixed, when it is dipped in water, and the paper washed off with a sponge. The impression being transferred, the vessel is dipped in alkali to destroy the oil, and then immersed in the glazing matter. Printing above the glaze is performed by covering the copper-plate with the colouring matter as before, and brushing off what is superfluous. A cake of glue, stiff enough to be handled, is then laid upon the plate, which receives the impression of the figure. The glue cake must be very cautiously lifted off from the plate, and transferred to the surface of the glazed ware which it is intended to print. The same cake will answer for transferring a number of impressions, by simply washing its surface.

It is but recently since a new method has been applied to cause the colours to flow or spread over the surface of the ware. This object is effected by washing the saggars in which the ware is placed, previous to its being fired in the glost-kiln, with a mixture of lime, common salt, and clay slip. Dry flows are also used, which answer equally well, the mixture being sprinkled on the bottom of the saggar. The following are some of these flows:—Lime, sal-ammoniac, and red lead or litharge; lime, common salt, and soda; and whiting, lead, salt, and nitre.

The ornaments on common stoneware vessels are made in relief in France, and hollow in England, by means of a mould in relief which is made to pass over the article. These hollows are filled with a clay paste of the colour required, while the vessel is turning upon a lathe. Network and variegated decorations are made in this manner by passing different layers of coloured clay over each other.

Metallic lustres, from gold, platina, copper, iron, &c. are produced by dissolving any of these metals in aqua regia, and applying it to the vessels. Over the metallic solution a glaze composed of 60 parts of litharge, 36 of felspar, and 15 of flint, is put, and the vessels burned as before. These *lustres*, as the wares so coated are called, have a rich metallic appearance, and would be highly prized if they were not so cheap and common.

STONEWARE.

This is a ware intermediate between common earthenware and porcelain, and may be described as a coarse kind of porcelain, made from sandy clay, containing oxide of iron and a little lime, to which it owes its fusibility. The glazing is performed by throwing common salt into the heated furnace; this is volatilised and decomposed by the joint agency of the silica of the ware and of the vapour of water always present; hydrochloric acid and soda are produced—the latter forming a silicate which fuses over the surface of the ware, and gives a thin but excellent glaze. The salt is not thrown in until the kiln has been raised to its greatest necessary temperature. Ware of this kind, we have said, is generally made of sandy clay and a little sand, to keep the body open, or less compact; but for large vessels, potsherd (which is ware that has been fired, and then ground) is employed, to render the body still more open and porous, and also to give it a capability of withstanding sudden heats or colds. This ware is much used in public works for chemical purposes; it is exposed to the action of the flame during burning, whereas other kinds of ware are protected by saggars.

Stoneware of the Wedgewood colour is a semi-vitrified ware, which is not susceptible of a superficial glaze. It is composed either of barytic earths, which act as a flux upon the clay, and form an enamel, or by the clay being rubbed over with a compound-vitrifying paste. Semi-vitrified ware undergoes an operation called *smearing*, by which the vessels do not require to be immersed in glaze. They are merely put into the glazed sags, which communicate by reverberation a lustre nearly equal in brilliancy to glaze itself. 'About the year 1805,' we quote the Encyclopædia Britannica, 'an article was produced called *ironstone-ware*, in which, however, not a particle of ironstone was introduced, it being a compound principally of the Cornish materials above-mentioned. This ware has nearly all the properties of the Japan porcelain; it possesses great hardness and density; is sonorous, but is deficient in whiteness and transparency, although the vitrification is as complete as in that of the Japan. It continues to be made in great quantities; and being more durable, is perhaps, though higher in price, as economical as earthenware. It is a cheap substitute for porcelain, but does not admit of those fine paintings and splendid decorations which are applied with so much success on that more elegant production.'

In connection with this department of pottery, we may briefly allude to the manufacture of *crucibles*—vessels alike indispensable to the chemist, the worker in glass, and the metallurgist. In this branch of the art we are indebted to Wedgewood for numerous important improvements. 'Crucibles,' says Brande, 'composed of one part of pure clay mixed with about three parts of coarse and pure sand, slowly dried, and annealed, resist a very high temperature without fusion, and generally retain metallic substances; but where the metals are suffered to oxidise, there are few which do not act upon any earthen vessel, and some cause its rapid fusion, as the oxides of lead, bismuth, &c. Where saline fluxes are used, the best crucibles will undoubtedly suffer; but platinum may be employed in these cases, and the chemist is thus enabled to combat many difficulties which were nearly insurmountable before this metal was thus applied. Whenever silica and alumina are blended, as in the mixture of clay and sand, the compound softens, and the vessel loses its shape when exposed to a long-continued white heat, and this is the case with the *Hessian* crucibles; consequently the most refractory of all vessels are those made entirely of clay, coarsely powdered burnt clay (potsherd) being used as a substitute for the sand. Such a compound resists the action of saline fluxes longer than any other, and is therefore used for pots in glass furnaces. A Hessian crucible, lined with purer clay, is rendered much more retentive; and a thin china cup, or other dense porcelain, resists the action of saline matters in fusion for a considerable time. Plumbago is a very good material for crucibles, applicable to many purposes; when mixed with clay, it forms a very difficultly-fusible compound, and is protected from the action of the air at high temperatures; it is well adapted for small table furnaces.'

PORCELAIN.

Porcelain or china * is a fine-grained, compact, very hard, faintly-translucent ware, of which there are two kinds; one called hard, and the other tender. *Hard* porcelain is composed of a clay containing silica, which is infusible, and preserves its whiteness in a strong heat, and of a flux consisting of silica and lime. The glaze of this ware is earthy, and admits of no metallic substance or alkali. *Tender* porcelain consists of a vitreous frett, which is rendered opaque by the mixture of a calcareous clay. It is glazed with artificial glass, into the composition of which silica, alkalies, and lead enter.

Kaolin clay is the largest ingredient in porcelain ware. It is composed of alumina and silica, and is obtained in large quantities in China, Germany, France, and in the county of Cornwall in England. Kaolin is very friable in the hand, and is with difficulty formed into a paste or dough which will bear to be worked. That found in Cornwall is whiter than the foreign clays, and more unctuous to the touch. It is a decomposed felspar—one of the constituent minerals of granite—which has accumulated in vast quantities in certain localities, having been no doubt washed down by rains from the weathered and exposed surface of granitic rocks. At one time the use of this substance was unknown in England; but now about 38,000 tons, worth about £50,000, are annually exported from the south of England to the Staffordshire potteries, and for the manufacture of mosaic tesseræ, buttons, artificial gems, and the like. In some localities, the kaolin is found in the form of a fine sediment; in others, it is mingled with coarser alluvia, and requires to be prepared by running a stream of water over it—the water carrying off the finer particles, which are received into catchpools or ponds, and there allowed to subside. The water is next run off, leaving a fine sediment, which is removed, and exposed to the atmosphere for four or five months, when it is ready for export. In France, the clay is washed at the pit, which is repeated after it arrives at the manufactory, and it is also passed through fine sieves. When in this state, felspar rock is added, by the addition of which it is rendered fusible. The felspar is calcined, broken with stampers, and afterwards ground in a burrstone mill, to render it as fine as possible. This mixture is poured into shallow plaster pans, which absorb the water, leaving a thick paste, which is placed in damp cellars for some months to ripen. The paste is again put into the plaster pans, and cut into small pieces, which are thoroughly dried and ground to a fine powder. It is then moistened and trodden by workmen, who walk over it in every direction. The clay is now ready for working, which is done either upon the lathe or by casting in moulds. The materials for making porcelain ware are much less plastic than those of other pottery ware, and consequently greater care must be bestowed on its manufacture. When vessels are made upon the lathe, the operations are exactly the same as for earthenware, but they must be performed with greater caution. It is stated by Dr Ure that a good workman at Sevrès, in France, makes no more than from 15 to 20 porcelain plates in a day; whereas an English workman, with two boys, will make from 1000 to 1200 plates of stoneware in the same time.

When formed, the vessels are allowed to dry very slowly, and are then put into the kiln, which is nearly the same as that used for burning pottery. In this kiln they receive a certain degree of heat, by which the vessels are rendered capable of being handled, and the clay loses its property of forming a paste with water. The vessels are then dipped in the glaze, which consists of felspar rock ground to a fine powder, and formed into a paste with water mingled with a little vinegar. When taken out of the glaze, the vessels are inspected, and the glazing matter applied with a hair-brush to any parts which may remain uncovered. A quality peculiar to porcelain is, that it softens in the fire, for which reason one piece cannot be piled above another in the saggs, as is done with stoneware. Every porcelain vessel requires a sag for itself, with a piece of level stoneware in the bottom, covered with sand. This prevents the vessels from warping. The sags are piled above each other in the kiln, and wood put into the furnaces. The heat is gradually increased for fifteen hours, at the end of which time the inside of the kiln has a cherry-red colour. The temperature is then greatly increased by putting small chips of aspen wood into the furnace, which is continued for from thirteen to fifteen hours. The whole firing occupies from thirty to thirty-six hours, when the porcelain is baked. The kiln is allowed to cool gradually for three or four days; and when taken out, the bottoms of the vessels are covered with the sand put into the sag, which is removed by friction.

Unglazed porcelain has the appearance of white marble or alabaster, and presents none of that shining glassy surface which it acquires by the application of those vitreous compositions called *glaze*. In this state it is known by the name of *biscuit*, and is now employed for many ornamental purposes—such as the formation of small figures or statuettes, vases, medallions, and other imitations of sculpture. The celebrated manufactory at Sevrès in France has long been distinguished for works in porcelain biscuit; and of late years, so many improvements have been made in the English manufactories, that they are probably not inferior in the delicacy and accuracy of execution in this department of ornament. We have now before us some Staffordshire specimens which have all the sharpness and distinctness of the finest sculptures in marble, with a degree of translucency which reminds one of alabaster or picked specimens of Parian marble. In point of durability and non-liability to get tarnished

* The term *china* is evidently derived from the name of the country which originally produced the first specimens of this ware; but the etymology of the word *porcelain* is not so obvious. One authority says, 'The Portuguese traders were the means of introducing the fine earthenwares of China into more general use in Europe; and the name assigned to the fabric, as distinguishing it from the coarser kinds of pottery of domestic manufacture, was most probably given by them—*porcellana* signifying, in the Portuguese language, a cup.' Another authority states, 'It has been satisfactorily shown by Marsden that the word porcelain, or *porcellana*, was applied by Europeans to the ware of China, from the resemblance of its fine polished surface to that of the univalve so named; while the shell itself derived this Latin appellation from the curved or gibbous shape of its upper surface, which was thought to resemble the raised back of a porcella, or little hog.' The reader may decide.

or discoloured, ornaments of porcelain biscuit are vastly superior either to marble or alabaster.

In painting on porcelain, the same colouring materials are used as those employed in colouring glass or earthenware. In all the more delicate patterns, they are laid on with a camel-hair pencil, and generally previously mixed with a little oil of turpentine. Where several colours are used, they often require various temperatures for their perfection; in which case, those that bear the highest heat are first applied, and subsequently those that are brought out at lower temperatures. This art of painting on porcelain, or *in enamel*, is of the most delicate description; much experience and skill are required in it, and with every care, there are frequent failures; hence it is attended with considerable expense. The gilding of porcelain is generally performed by applying finely-divided gold mixed with gum-water and borax; on the application of heat, the gum burns off, and the borax vitrifying on the surface, causes the gold to adhere; it is afterwards burnished with bloodstone, agate, or other polishers.

Porcelain vessels are very brittle, and are easily damaged, which accounts in some degree for the high price at which they are sold. It is calculated that after being manufactured, one-third of the articles are damaged, most of which takes place in the kiln. English and foreign porcelains differ considerably in their composition, which accounts for their difference of transparency, brittleness, and fitness for chemical purposes. Thus an average of five analyses shows English porcelain to contain about 40 per cent. of silica, 24 alumina, 12 lime, 20 protoxide of iron and phosphate of lime; 3 of alkali, and a trace of magnesia; while Chinese and Berlin specimens yielded about 70 silica, 25 alumina and protoxide of iron, 2 lime, and less than 2 of alkali. The German manufacturers do not employ phosphate of lime or bone-earth; but use felspar instead, the alkali of which supplies the place of the phosphate. Their porcelain is thus better adapted for chemical purposes, as it is more vitrified, and less liable to be acted upon by acids, as well as being capable of withstanding a very high degree of heat. The principal materials employed by the Chinese are known to be *kaolin*, or decomposed felspar; *petuntze*, or quartz reduced to fine powder; and the ashes of fern, which contain carbonate of potash. From these materials the Chinese have long prepared a ware of the highest qualities—remaining perfectly white after exposure to heat, being able to withstand a very high temperature without fusing, exhibiting a semi-vitreous texture, and a peculiar degree of transparency and toughness. English and French manufacturers can produce the same degree of whiteness and translucency, but their ware is more fusible, is more apt to crack under sudden changes of temperature, and is altogether more brittle.

The extent to which the fabrication of pottery and porcelain wares is now carried on in Britain, together with its usefulness, and generally-acknowledged excellence, has rendered it a subject of great national importance. 'The raw materials,' says a recent writer, 'are of home production, and of little intrinsic value, the transport of which affords to the coasting-trade a freightage of from 40,000 to 50,000 tons annually. The manufactured articles are almost wholly produced by manual labour, which is not likely to be superseded by machinery, while the export of the bulky article of earthenware to all parts of the world, gives employment, to an immense extent, to the shipping of this and other countries. 'Nor is this interesting manufacture without some claim in furthering the progress of the fine arts, by the cultivation of painters, engravers, and modellers, many of whom have displayed talents of a superior order in their respective lines. In flower-painting, and in decoration generally, the work of English artists cannot be excelled; and in figure-painting it is to be hoped that the lately-instituted Schools of Design will soon raise them to the same superiority. There are some considerable manufactories of pottery-ware in the north of England, and one or two in Yorkshire; but the principal site of both porcelain and pottery-wares is in the modern borough of Stoke-upon-Trent, which contains a population of about 70,000 persons, engaged directly or indirectly in these manufactures.' The principal seats of porcelain manufacture in continental Europe are Sevrès near Paris, Tournay in Flanders, Dresden, Berlin, and Florence; the wares of Sevrès being as yet unequalled in their translucency, glaze, and gilding, and in the elegance and taste displayed in their shape and figure-paintings.

BRICKS—TILES.

The common superficial clay, which is so liberally spread over our island, must be familiar to every one. It is of various colours—yellow, red, or bluish, according to the amount of iron oxide which it contains—is more or less mixed up with sand and fragments of rock—and when softened, becomes plastic and tenacious. It is this variety that is ordinarily used for the manufacture of bricks, tiles, chimney-tops, flower-pots, drain-pipes, and the coarser sorts of earthenware. It will at once be perceived that the quality of the manufactured products must therefore depend upon the purity of the raw material, and upon the care with which it is wrought and tempered. Stones and other extraneous impurities can be readily separated by washing and screening, but admixtures of calcareous or magnesian earths cannot be so got rid of; and thus it happens, that what may appear a fine and available clay, is utterly worthless to the brick and tile-burner. What is chiefly necessary is a due admixture of alumina and silica—that is, clay and sand; for though pure clay may be made into extremely hard bricks, they are apt to shrink and crack in the burning; while too much sand renders them brittle and friable. Excellent natural brick-clay occurs in many localities; and where there is any deficiency of either ingredient, it can in general be cheaply supplied. As to the presence of a little lime, magnesia, or oxide of iron, it is rather liked than otherwise, these materials giving agreeable colours to the finished article. Thus the presence of iron confers on common bricks their red hue; magnesia a dullish gray; and lime a light cream or *malm* colour. These adventitious colours, however, cannot be procured without deterioration of quality, there being nothing so durable as the pure mixture of clay and sand, carefully tempered, and gradually but strongly fired. For bricks, slabs, crucibles, &c. which have to resist the action of fire, some of the coal-measure or stratified clays are generally had recourse to; these, from their greater purity, and a certain per centage of silica, being susceptible of a more thorough baking. In England, the Windsor, Stourbridge, and Welsh fire-clays are esteemed the best—the latter yielding those large square slabs employed in the construction of drying-kilns, brewers'-coppers, sugar-boilers, smelting-furnaces, and the like.

Bricks, formed of the materials above described, may be termed artificial stones; at least they have been used as substitutes for stones from the earliest periods, and often with greater advantage as to strength and permanency. *Sun-dried* bricks, though not durable, were formerly used in many places, as Egypt, Babylon, &c. and are still used in the East. There, under a dry and equable climate, they serve the purpose intended; but under the rains and frosts of our northern region they would be utterly useless. We have now before us a fragment of Egyptian brick in all probability more than three thousand years old, with a figure in fresco upon it as fresh and brilliant as that day it was painted by the artist. It is composed of an earthy clay, mingled with chopped straw, to give it greater consistence, and has evidently been subjected to no higher heat than that of the sun. Exposure in Britain for as many years as it has endured centuries in Egypt, would have reduced it to its original elements. *Kiln-drying*, or *baking*, is therefore necessary to render bricks sufficiently durable in Northern Europe; and according to the material of which they are composed, and the degree of heat to which they are subjected, so in general is their hardness and durability. The following is the ordinary process of manufacture:—'The clay is usually dug in September, and exposed in heaps of a few feet in height to the action of the frost of winter, which pulverizes and mellows it. The small stones are then separated by grinding it in water, and passing it through a grating. The clay thus reduced to paste is now mixed with chalk, ground with water to the consistence of cream, if any calcareous ingredient is to be added. After remaining till it has acquired sufficient consistency, it is finally tempered by working it in a pug-mill, when it is ready to be moulded. Before the pug-mill was invented, the clay was thrown into a shallow pit, and trodden by the feet of men or oxen. When the clay has been properly tempered, it is taken to the moulder's bench, and separated into small pieces. The mould is a box of a size fixed by act of parliament, but with the bottom loose. It is placed on the bench, sprinkled over with sand, to prevent the clay from sticking to it, a lump of the prepared clay is dashed in, and the top or superfluous portion scraped off with a flat stick. The newly-moulded bricks (with a little additional dressing where necessary) are carried on a wheelbarrow to a shed or open square, as the case may be, where, arranged on each other diagonally, with interspaces for the free passage of air, they are allowed to dry for a few days. When sufficiently firm to bear handling, they are removed to the kiln.' A clever workman, with proper assistance, will mould and dress about five thousand bricks per day.

The burning is performed either in *kilns* or in *clamps*—the latter being large square piles of bricks skilfully built up, with layers of fuel between, called *breeze*, and also with flues filled with coal, cinders, and wood, to facilitate still more the process of combustion. Baking in kilns, however, is preferable, as there is not only less waste, and less fuel consumed, but the bricks are sooner ready for the market. 'The kiln,' says Dr Ure, 'is usually 13 feet long by 10½ feet wide, and about 12 feet in height. The walls are one foot two inches thick, carried up a little out of the perpendicular, inclining towards each other at the top. The bricks are placed on flat arches, having holes left in them resembling lattice-work; the kiln is then covered with pieces of tiles and bricks, and some wood put in, to dry them with a gentle fire. This continues two or three days before they are ready for burning, which is known by the smoke turning from a darkish colour to transparent. The mouth or mouths of the kiln are now dammed up with pieces of bricks piled one upon another, and closed with wet brick earth, leaving above it just room sufficient to receive a fagot. The fagots are made of furze, heath, brake, fern, &c. and the kiln is supplied with these until its arches look white, and the fire appears at the top; upon which the fire is slackened for an hour, and the kiln allowed gradually to cool. This heating and cooling are repeated until the bricks are thoroughly burned, which is generally done in forty-eight hours. One of these kilns will hold about twenty thousand bricks.'

Bricks, whether clamp or kiln-burned, are of different qualities, according to the degree of baking they have been made to undergo. The most thoroughly burned are termed *stocks;* the inferior *samel*, or sandel bricks; and those vitrified, or over-burned, *burrs*. As in every other manufacture, there are numerous local designations, having reference either to the quality, colour, shape, or purposes to which the bricks are to be applied. Thus the *malms* of the London bricklayer are of a yellowish uniform colour and texture, prepared, as already stated, by an admixture of ground chalk; *seconds* are those less uniform in colour and texture; *cutters* are those made so soft, as to be cut into form for arches of windows; *fire* bricks are prepared to withstand the heat of fires and furnaces, and of such there are varieties known as *Welsh lumps*, *Windsors*, &c.; *paving* bricks, made for the purpose their name implies; *compass* bricks, of a circular shape, for lining walls and chimneys; *Dutch-clinkers*, at one time imported from Holland, but now made in England, a compact variety often used in stables, about 6 inches long, 3 broad, and only one in thickness; and *Bath-brick*, a soft variety, the powder of which is much employed in scouring bright many articles of furniture—as knives, forks, brass candlesticks, &c.

The *floating* bricks known to the ancients, and recently revived by M. Fabroni, are composed of a siliceous or infusorial earth, commonly known as fossil or mountain-meal. This substance is of organic origin, and consists of 55 parts siliceous earth, 15 magnesia, 14 water, 12 alumina, 3 lime, and 1 of iron; it is infusible in the fire, and though it loses about an eighth part of its weight, its bulk is scarcely diminished. 'Bricks composed of this substance,' according to the authority already quoted, 'either baked or unbaked, float in water; and a twentieth part of clay may be added to their composition without taking away their property of swimming. These bricks resist water, unite perfectly with lime, are subject to no alteration from heat or cold, and the baked differ from the unbaked only in the sonorous quality they acquire from the fire. Their strength is little inferior to that of common bricks, but much greater in proportion according to their weight; for M. Fabroni found that a floating brick 7 inches in length, 4½ in breadth, and 1 inch 8 lines in thickness, weighed only 14¼ ounces; whereas a common brick weighed 5 lbs. 6¾ ounces. The use of these bricks may be very important in the construction of powder magazines and reverberatory furnaces, as they are such bad conductors of heat, that one end may be made red-hot while the other is held in the hand. They may also be employed for buildings that require to be light; such as cooking-places in ships, and floating batteries, the parapets of which would be proof against red-hot bullets.'

Tiles are prepared much in the same way as bricks; only, from their being thinner, and of a more intricate form, they require to be made of finer and tougher materials, and are always burned in kilns. They are of different kinds, according to the use to which they are applied; as *plain* and *pan* tiles, *ridge* tiles, &c. In some instances they are glazed like brown ware; in others they are merely coloured red, blue, or cream-yellow, according to the taste of the purchaser. Tiles in many districts form cheap and durable materials for roofing, being less expensive than slates; and in reference to fire, a decided improvement upon thatch. For roofing, it has been proposed to lessen their weight by grooving their surface, whereby additional strength is also gained, and their appearance much improved. What are called *drain* tiles are of recent adoption, and are peculiarly available in districts where there is a scarcity of stones. These tiles are of very simple construction—consisting of flat soles, from 10 to 14 inches in length, with a highly concave tile placed above, so as to form a channel of 4 inches in width and 6 in height. From the highly concave shape of the cover, they are able to resist almost any degree of downward pressure; and the openings between each allow the water to percolate into the channel. As drain-tiles are not exposed to the action of the weather, the most common field-clay, if well worked and burnt, may be used in their manufacture. Besides clay, glass and various concretes (as mentioned under these heads) have been recently employed in the fabrication of tiles and water-pipes; but as yet, the data are too scanty to say with what degree of success.

Tiles and bricks, at one time made solely by the hand, are now extensively formed by machines which press and fashion the prepared material with wonderful rapidity. Thus the drain-tile machine invented by the Marquis of Tweeddale, throws out, when worked with one horse, from 1000 to 1500 per hour; and others have since been invented which exceed that rate; at the same time that the articles so moulded are greatly superior in shape and construction. In France, as well as in England, attempts have been made to produce bricks from dry pulverised clay by hydraulic pressure; but unless for mosaic tesseræ, and other ornamental purposes, the operation is said to be too tedious and expensive. In America, a common moulding machine will turn out about 30,000 bricks a day, not only of improved shape and compactness, but so dry, as to be ready for immediate burning.

The manufacture of tiles and bricks was, till recently, placed under the control of the Excise, and subject to a duty of 5s. 10d. per thousand; but now, only the latter are charged—producing an annual revenue of upwards of £450,000. We have no data as to the amount of roofing and drain-tiles produced in Britain; but England and Scotland manufacture upwards of 1,550,000,000 bricks per year, independent of Ireland, upon whose produce there is no duty. Makers of bricks must give notice of their intention to begin the manufacture, under a penalty of £100; and all bricks made for sale must be 8½ inches long, 2½ thick, and 4 wide. But for this absurd restriction and interference, vast improvements would speedily be effected both in the quality, shape, and appearance of British bricks; 'and when we consider,' laments an authority, 'the durability of the material, and the facility with which it may be moulded into any required form, it is much to be regretted that means are not found for preserving the revenue, without depriving the public of the advantages which might be derived from the inventions of architects.'

It seems almost unnecessary to advert to the fabrication of *flower-pots, chimney-tops, drain-pipes*, &c. which, in their usual forms, are manufactured from common clay, treated much in the same way as that for the finer sorts of tiles. It may be observed, however, that vast improvements have recently taken place in the preparation of these articles, not only in fashioning them into more elegant forms, but in constructing them of more varied materials, whereby they acquire colours and glazes, or are rendered compact or porous, according to the purpose they are destined to serve. For architectural decorations, figures, vases, &c. on a large scale, a variety of argillaceous compounds are now in use, the principal of which is known by the name of *terra cotta*—literally, baked clay. This composition consists of pipe or potters' clay, a fine colourless sand from Ryegate, and pulverised potsherds. These are worked into a homogeneous paste, which is modelled or cast into the figure required, then slowly dried in the air, and ultimately fired to a strong hardness in a proper kiln. We may also here allude to the manufacture of *tobacco-pipes*, which, from the too prevalent practice of smoking, has now become a considerable branch of national industry. These pipes are made of a finely-ground white plastic clay (to which they have given the name), chiefly found in the Isle of Purbeck and Dorsetshire. This clay being worked into paste and dough, in the same manner as the finer sorts of potters' stuff, is next rolled into cylinders for the stems and into balls for the bowls. These are then pressed to the desired form in metallic moulds, and pierced with a wire; dried for a day or two; scraped, polished, and dipped; and ultimately fired in a baking kiln for ten or twelve hours. A clever workman, aided by a boy, can easily make from five to six gross of plain pipes per day.—For *Meerschaums*, see No. 23.

MOSAIC WORK.

The term *Mosaic* is said to be derived from the Greek word *mousaikon*, elegant or polished; and is now applied to the art of imbedding or inlaying in a cement fragments of different coloured substances, so as to produce the effect of a picture. This art was practised at a very early period, and was introduced into Italy by the Byzantine Greeks. Magnificent specimens are to be seen in St Peter's at Rome, and in the chapel of St Lawrence at Florence, where precious marbles, agates, jaspers, avanturines, malachites, &c. constitute the coloured tesseræ. This art is now admirably imitated by the potter, tile-maker, and fabricator of pastes; thus bringing it fully within the scope of our present treatise.

Among the ancients, mosaic appears to have been confined to pavements, for which it is admirably adapted; since, notwithstanding its being frequently trodden upon and washed, it is not injured. At a later period, mosaics were executed upon walls; and more recently, extremely minute mosaics, either for the cabinet or for personal ornament, have been fabricated chiefly in Italy. For pavement, the tesseræ may either be individually coloured, and then so arranged as to produce a pleasing effect, or each tessera may be variously coloured and figured, and thus produce an independent effect, or an effect only when in combination with others, like the separate figures of a carpet. Till within the last ten or twelve years, tesselated pavements in Britain were generally very tame affairs, but now tesseræ of great beauty and delicacy are being fashioned at our potteries, and the laying of them in halls, and other public buildings, is greatly on the increase. The usual method of preparing them is thus intelligibly described by Mr Dodd:—'The tesselated tiles are formed of two differently-coloured clays, one imbedded in the other, and disposed so as to form an ornamental device. The tile is first made in clay of one colour, with a depression afterwards to be filled with clay of the other colour, and this depression is formed by the aid of a mould. In the first place, the modeller models in stiff clay an exact representative of one of the tiles, about an inch thick, cutting out to the depth of about a quarter of an inch the depression which constitutes the device. When this is properly dried, a mould is made from it in plaster of Paris, and from this mould all the tiles are produced one by one. The ground colour of the tile is frequently a brownish clay, with a yellow device; but this may be varied at pleasure. Let the colour be what it may, however, the first clay is mixed up very thick, and pressed into the mould by the aid of a spring press. On leaving the press, it presents the form of a damp, heavy, uni-coloured square tile of clay, with an ornamental device formed by a depression below the common level of the surface. The second coloured clay, so far from being made stiff like the first, has a consistence somewhat resembling that of honey; and herein lies one of the niceties of manufacture, for it is necessary to choose clays which will contract equally in baking, although of different consistence when used. The tile being laid on a bench, the workman plasters the honey-like clay on it, until he has completely filled the depressed device, using a kind of knife or trowel in this process. The tile in this state is then allowed to dry very gradually for the long period of eight weeks, to accommodate the shrinking of the clays to their peculiar natures. After this, each tile is scraped on the surface with an edge-tool till the superfluous portion of the second clay is removed, and the two clays become properly visible, one forming the ground, and the other the device. In this state the tiles are put in a "biscuit-kiln," where they are baked in a manner nearly resembling the baking of porcelain, but with especial reference as to time and temperature, to the quality of the two clays. From the biscuit-kiln they are transferred to the dipping-room, where they are coated on the upper surface with a liquid glaze by means of a brush. Lastly, an exposure to the heat of the glaze-kiln for a period of twenty-four or thirty hours, causes the glaze to combine with the clay, and the tiles are then finished.' Another mode of producing the tesseræ is by hydraulic pressure of pulverised clay, either uni-coloured or variegated.

The fabrication of those pretty ornaments generally known by the name of Roman mosaics, is altogether a different art. It is thus described by Mr Wyatt in a recent communication to the Society of Arts:—'A plate, generally of metal, of the size of the picture to be copied, is first surrounded by a margin about three quarters of an inch from its surface. This is then covered over with a coating of perhaps one quarter of an inch in thickness of mastic cement, composed of powdered travertine stone, lime, and linseed oil. This is, when set, entirely covered with plaster of Paris, rising to a level with the surrounding margin, which is intended to be exactly that of the finished mosaic. On this is traced a very careful outline of the picture to be copied; and with a fine chisel, just as much is removed, from time to time, as will admit of the insertion of the little pieces of glass, or, as the Italians call it, "smalto." This smalto is composed of glass, and is made in rounds about six or eight inches in diameter, and half an inch thick. The workman then proceeds to select from the great depository—wherein are preserved in trays nearly 10,000 varieties of colour—those he may require, which he works to the necessary shape. This is done by striking the smalto with a sharp-edged hammer directly over a similar edge placed vertically beneath. The concussion breaks the smalto to very nearly the shape required; and it is then more perfectly ground, by application to a lead wheel with emery powder. The piece thus shaped is then moistened with a little cement, and bedded in its proper situation; and so on until the picture is finished; when the whole is ground down to an even face, and polished.' Several regularly-trained artists are now constantly employed in the fabrication of these mosaics at the Vatican.

GLASS.

The origin of glass manufacture is involved in the greatest obscurity, and has given rise to much ingenious speculation, upon which little or no dependence can be placed. Glass beads have been found on the bodies of Egyptian mummies, which are known to have been embalmed three thousand years ago. Pliny says that the art of glassmaking was accidentally discovered by some shipwrecked Phœnician mariners, whose vessel was laden with fossil alkali, a component part of glass. On kindling a fire on the sand to prepare some food, and placing their cooking vessels on pieces of the substance just named, the sand, by the agency of the fire and its union with the alkali, became vitrified; hence, according to this authority, the discovery of the art.

The first glass manufactory of any note was established at the village of Murano, near Venice. The glass produced here was superior to any in Europe, and for a long time the principal supply was obtained at this place. The Venetians were long celebrated for making mirrors, which they brought to considerable perfection. Window-glass appears to have been made in England in the middle of the fifteenth century, but it was of an inferior description. In 1557, the finer sort of window-glass was manufactured at Crutched Friars in London. The first flint-glass was made at Savoy House in the Strand; and the first plate-glass for mirrors, coach-windows, and the like, was fabricated at Lambeth in 1673, by Venetian workmen, brought over by the Duke of Buckingham.

A glass-house is usually built in the form of a cone, from 60 to 100 feet high, and from 40 to 80 feet in diameter at the base. The furnace is placed in the centre of the building, and is generally of an oblong figure, although sometimes circular. Below the furnace is an arched gallery, extending right across the building, and terminating in folding-doors, large enough to admit a barrow for carrying out the ashes. In the sides of the furnace are apertures called working-holes, through which the materials are put into the pots, and the blowing tubes inserted. In a crown-glass manufactory, the furnace generally contains from four to six pots; but this will altogether depend upon the size of the building. The stone used in constructing glass furnaces must be of the finest quality; that called fire-stone, got from Coxgreen, in the neighbourhood of Newcastle, is considered the best for this purpose.

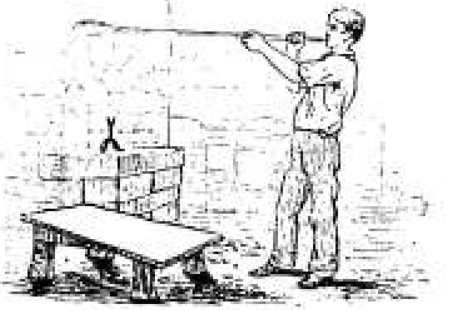
Crown-Glass.

Crown or window-glass is usually composed of pearl-ash, or other alkalies, and fine white sand. The best sand for glassmaking is that which contains most transparent particles, and this is found in large quantities in that brought from Lynn Regis in Norfolk, and the western coast of the Isle of Wight. The sand is put into a large vat, and boiling or cold water poured upon it until the water runs off clear. It is then subjected to a red heat for twenty-four hours, and immediately on being taken out is plunged into cold water, which divides the particles of sand, and makes it unite more readily with the alkali. Some put nitre amongst the sand during this process, which consumes any sulphur or other extraneous matter which may be present. The sand and kelp are next mixed together, in the proportion of eleven parts of the former to seven or eight of the latter. Since the manufacture of soda from common salt, the use of carbonate of soda and lime, instead of kelp, in the manufacture of crown-glass, is almost universal; and from these alkalies being much purer, a better article is produced.

When the sand and alkali are properly mixed together, the compost is put into the calcining arch, or reverberatory furnace, where it is reduced by heat to a semi-fluid state. This process requires from three to four hours, and the *frett*, as it is now called, is taken out, placed upon an iron plate, and cut into cakes before it becomes quite cold. The calcining furnace is generally about ten feet long, seven feet wide, and two feet high. The sides and top are built of fire-brick, and the rest of common brick; and the bottom must be carefully cemented, to prevent the frett from oozing through the seams. It is the opinion of most glass manufacturers that the frett should be kept for about six months before it is used. If glass is made from new frett, it is full of what are called seeds, the presence of which depreciates the quality of the ware.

The frett is next put into the melting-pot, along with a proportion of what is called *cullet*, which is nothing more than broken crown-glass. The melting-pot is formed of the finest clay, that obtained at Stourbridge, in Worcestershire, being considered the best adapted for this purpose. The clay is freed from all extraneous particles, which, if allowed to remain, would injure the pot, and about a fourth part of old crucibles ground into a fine powder is added. Pots made from this mixture resist heat much better than when altogether formed of the virgin clay. The pots are very gradually dried, being generally kept for nine or twelve months at a temperature of about fifty degrees. They are afterwards tested in a furnace before being used, and last upon an average for from eight to ten weeks.

When the frett and cullet are put into the pots, the furnace is heated to as high a temperature as possible, until the metal is reduced to a liquid state. It is then skimmed of all extraneous substances which may be floating on the surface, and is fit for the operations of



the workmen. An iron tube, six or seven feet in length, thicker at one end than the other, is heated and dipped into the liquid metal. A portion of glass adheres to the end of the rod, which, being allowed to cool a little, is again dipped in, and gathers more. The rod is then taken out and hung perpendicularly, that the metal may be equally distributed on all sides, and also that it may be lengthened out beyond the rod. The metal is next rolled upon a smooth iron plate called the *marver*, and afterwards blown out slightly, so as to resemble a pear in shape. The blower then heats the metal twice, blowing it out between the heatings, when it is brought to a globe shape. The glass is then allowed to cool a little, and a rod of iron, called the *punty rod*, is attached to the side immediately opposite to the tube. This is done by dipping the end of the rod in the liquid metal, which adheres readily to the half-cooled glass, and the tube is detached by touching it with a piece of iron dipped in cold water, leaving an aperture in the glass about two inches in diameter. The glass is again put into the furnace until it has become sufficiently ductile to yield readily to any impression. The workman then twirls the globe round, slowly at first, but afterwards with great velocity, during which the aperture formerly mentioned gradually widens, until it reaches a certain point, when the globe suddenly flies open with a loud ruffling noise, and becomes a plane or circular sheet of glass, about fifty inches in diameter. This is an exceedingly beautiful operation, and requires considerable skill on the part of the workman. The circular motion is still continued, until the sheet is sufficiently cool to retain its form, when it is carried to the annealing arch to be tempered. The punty rod is detached by means of large shears, and the sheet of glass is lifted on a wide-pronged fork, and set up edgewise in the kiln. A kiln will hold from four to six hundred sheets. When full, the mouth is built up, the fire withdrawn, and the kiln allowed to cool as gradually as possible. This process of gradual cooling is known by the name of *annealing*—a process without undergoing which, glass, as well as several of the metals, would be so brittle, as to break on the application of the slightest force. The glass is then taken out, the circular sheet cut into halves, and assorted into different qualities, known by the names of *firsts*, *seconds*, and *thirds*.

Sheet-Glass.

The process we have described is altogether applicable to crown or window-glass, but the manufacture of sheet-glass is somewhat different. In making sheet-glass, the same materials are used as in crown-glass, the difference being in the manner of forming the sheet. When the metal is melted, the workman dips his tube into the pot, and when he has gathered a sufficient quantity of the liquid glass upon it, he places it in a horizontal position upon a hollowed block of wood. He turns the rod round in his hand, with the metal resting upon the hollowed block, which forms it into a solid cylindrical mass. Water is poured upon the block during this operation, the action of which upon the glass gives great brilliancy to its surface. If the glass was only red hot, on coming in contact with the water it would crack; but at the great heat at which it must be kept so as to be ductile, no injury takes place. When the metal is sufficiently formed and cooled, the workman blows into the tube until he perceives the diameter to be of the dimensions required, which depends upon the size of the sheet to be made. The metal is again put into the furnace, and when softened, the workman swings it round his head, reheats, and continues to swing it, until the cylindrical mass has attained what he thinks a sufficient length. He then fills the tube with air, and closes up the hole, so that none may escape; after which the metal is again put into the furnace, and as it becomes soft, the air bursts from the end opposite to the tube, leaving an aperture. The cylinder is then turned round very quickly, which renders it perfectly straight; and then, by applying cold iron to the end of the glass next the tube, a sudden contraction takes place, which separates the cylinder of glass from the iron tube. The cylinder thus formed is allowed to cool for about five seconds, and it is then split up lengthwise by drawing a red-hot iron rod along the inner side. The glass has next to be flattened, which is done by softening it in a furnace upon a smooth plate, where, as it begins to melt, it gradually opens, and is smoothed with a piece of charred wood. It is then carried to the annealing furnace to be tempered, in the same manner as crown-glass.

Sheet-glass may be made of any thickness, and possesses considerable advantages over crown-glass. It has none of that wavy appearance too often seen in crown-glass, and a larger square can be obtained when the sheet is formed. It is difficult to get a sheet of crown-glass which will yield a square 34 inches by 22, whereas the common size of sheet-glass is 40 inches by 30.

Plate-Glass.

The manufacture of plate-glass requires greater care than either of the two preceding kinds, and the process is different—the plate-glass being moulded, and not blown, as is the case with other kinds of glass-ware. The sand made use of must be the finest that can possibly be obtained, and requires to be well washed, to free it from impurities, and passed through a fine sieve, previous to being mixed with the other ingredients. At St Gobin, in France, crystallised carbonate of soda is used as the alkali; and at Ravenhead, near St Helen's, Lancashire, the soda is obtained by treating sea-salt with pearl-ash, the result of which is carbonate of soda and muriate of potash. The latter body is easily got rid of, as it crystallises at a higher temperature than the carbonate of soda. The soda thus prepared is exceedingly pure, and well adapted for glass manufacture. To these are added dry slaked lime carefully sifted, and cullet, as in crown-glass-making. The following proportions are stated by Dr Ure to have uniformly yielded a beautiful glass:—'Sand, 7 cwt.; quicklime, 1 cwt.; dry carbonate of soda, 2 cwts. 37 lbs.; and about the same quantity of cullet as there is sand.' Mr Parkes somewhat varies the formula—namely, siliceous sand, washed and sifted, 720 lbs.; alkaline salt or soda, 450 lbs.; quicklime, 80 lbs.; nitre, 25 lbs.; and broken glass, 425 lbs.—in all, 1700 lbs.; from which about 1200 lbs. of good plate is generally obtained.

These materials are usually fretted before being melted; but at St Gobin, in France, this is sometimes dispensed with. Two kinds of crucibles are required in the manufacture of plate-glass; namely, the pots in which the materials are melted, and the basins from which it is poured upon the moulding plate. These crucibles are made from a clay entirely free from iron and lime, and which is dried, ground, picked, washed in water, and passed through a fine hair sieve. Old crucibles ground to a powder are mixed with the clay in proportions according to its quality. This composition, when prepared, is called *slip*, and is also used for cementing the furnaces.

The materials of which the glass is composed are first put into the pots to be fused, which occupies about sixteen hours, and then transferred to the basins. The transfer of the melted glass from the pots to the basins is called *lading*, and is performed by ladles of wrought iron furnished with long handles. This second melting is called *refining*; and the glass is allowed to remain other sixteen hours, which is necessary for the disengagement of the air-bubbles introduced by the transferring, and for giving the metal the proper consistence for casting. For three hours previous to the casting, all the openings in the furnace are closed—an operation called *stopping the glass*, or *performing the ceremony*. The glass is tried; and if found of the proper consistence, and free from air-bubbles, the basins are carried to the casting table.

This table was formerly made of copper or bronze, but cast-iron is now found to answer the purpose better. It is about ten feet long, five feet broad, and from six to seven inches thick, supported by a wooden frame which rests on iron wheels. Along the sides of the table are two parallel bars of bronze, which support the roller in its progress, and determine the thickness of the glass. The roller is made of bronze, and is run along the table after the glass is poured on, to spread it equally. When the liquid glass is poured upon the table, two men run the roller slowly and steadily from one end to the other; and after two plates have been formed, the roller is allowed to cool. The plate of glass is next inspected, and if any air-bubbles appear, it is cut through, and is then put into the annealing furnace, where it remains for fifteen days.

When tempered and cooled, the rough edge is cut off the glass by means of a diamond, and the plates are sorted according to their sizes; it being necessary, when air-bubbles occur, to cut a larger piece from one than from another. The next step is the grinding of the surface, which is done by cementing the glass upon a horizontal table made either of freestone or wood. One plate is then reversed and suspended over another, and ground flint or sand is introduced between them. The suspended plate is fastened upon a conical stone, with a ball at the top for the workman to hold it by. When machinery is used for this process, the upper plate is fastened to a square of cast-iron, which receives a rotatory motion similar to that communicated by the hand. When one side has been sufficiently ground, the plates are reversed, and the same operation performed upon the other. By this grinding, the plates have been rendered perfectly level, but they have still to be smoothed before receiving their polish. For this purpose, they must be again ground with emery powder, of increasing degrees of fineness. The glass is then polished on both surfaces, by means of wooden blocks covered with layers of woollen cloth. The glass is fixed, as before, upon the stone table, and a quantity of the red oxide of iron (the colcothar of commerce) is laid on, and the surface rubbed with the covered blocks till a perfectly smooth and transparent plate has been obtained.

Plate-glass is not always fashioned by casting. The process of *blowing* a plate of this kind is very similar to the mode of blowing sheet-glass; the differences observable in the manipulation in these processes being chiefly occasioned by the weight and bulk of the mass of glass operated on. It is very difficult to blow a plate of glass of sufficient thickness for grinding to a level surface, and polishing of a size larger than fifty inches by forty; whereas, by the process of casting, plates are produced one hundred and sixty inches by eighty—this, we believe, being the largest attempted at Ravenhead.

Plate-glass is extensively manufactured into *mirrors*, which has hitherto been done by applying a layer of tinfoil, alloyed with mercury, to the posterior surface of the glass. The workshop for executing this operation is provided with a number of smooth tables of fine freestone or marble, truly levelled, having round their contour a rising ledge, within which there is a gutter, or groove, which terminates by a slight slope in a spout at one of the corners. The glass-tinner, standing towards one angle of his table, sweeps and wipes its surface with the greatest care, along the whole breadth to be occupied by the mirror-plate; then taking a sheet of tinfoil adapted to his purpose, he spreads it on the table, and applies it closely with a brush, which removes any folds or wrinkles. The table being horizontal, he pours over the tin a small quantity of quicksilver, and spreads it with a roll of woollen stuff; so that the tinfoil is penetrated, and apparently dissolved by the mercury. Then taking the plate of glass, he lays it carefully on the smooth bed of tin and mercury, which adheres to the glass in obedience to the law, that bodies contract a close adhesion when they touch at all points. The glass is then removed from the table, and placed under heavy weights for twenty-four hours, so as to make the adhesion more perfect and durable. Even after this, a portion of the superfluous lackering remains on the glass, and has to be gradually drained off by placing the plate on a frame sloped like a writing-desk. This is a very nice and difficult operation, and requires the most minute care to prevent the glass from contracting during the operation, in which case the whole process must be recommenced. Moreover, the bed of tin is easily cracked, and every one knows with what rapidity the action of the sun, or the least humidity, spoils the best looking-glasses. Such, till within a recent period, was the tedious and expensive mode of 'silvering' plate-glass for mirrors.

Towards the end of 1843, Mr Thomas Drayton, of Brighton, sealed a patent, the subject of which was a mode of silvering looking-glasses without the employment of quicksilver; and this by chemical instead of mechanical means. The material used is composed of coarsely-pulverised nitrate of silver, spirits of hartshorn, and water. This, after standing for twenty-four hours, is filtered, and an addition is then made of spirit of wine and a few drops of oil of cassia. The glass to be silvered with this solution must have a clean and polished surface; it is to be placed in a horizontal position, and a wall of putty or other suitable material formed around it; so that the solution may cover the surface of the glass to the depth of from an eighth to a quarter of an inch. A deposition of the silver then takes place in two hours or less, and when the required deposit has been obtained, the solution is poured off; and as soon as the silver on the glass is perfectly dry, it is varnished with a composition formed by melting together equal quantities of bees' wax and tallow. This serves as a protection to the residuum which adheres closely to the glass, and affords a more clear and brilliant reflection than the old process; besides being done in infinitely less time, and with no risk of failure. The term 'silvering' looking-glasses is rendered by the new plan quite correct, for it is silver, and nothing but silver, which converts the glass into a mirror. M. Tournasse has lately improved the minutiæ of Mr Drayton's process, so that mirrors may be now made in half an hour, and this in any shape or form—a result rendered impossible by the old pressure system, which could be applied only to flat or plane surfaces.

Still more recently (August 1847), Mr T. Fletcher of Birmingham has patented a process for silvering mirrors, or rather for coating, by the electrotype, mirrors already silvered, whereby the quicksilver is protected from injury, and a stronger reflecting power given to the speculum. The silvered plate is lightly and carefully coated on the back, or silvered side, with a varnish composed of two ounces of shellac, half a pint of highly-rectified spirits of wine, and half an ounce of the best lampblack; this varnish protects the quicksilver from damp, and from the acid used in the subsequent process. Before the varnish is quite hard, shake over it, from a muslin bag, finely-pulverised plumbago, black oxide of manganese, or any other metallic powder, or cover it with metal foil, so that the whole surface may receive a perfect but thin metallic coating; after which it is submitted to the electrotyping process, and by this means a thin coating of copper, or other metal, will be precipitated over the entire back of the mirror.

Flint-Glass.

Flint-glass, or crystal, is composed of Lynn sand—which is calcined, sifted, and washed for the purpose—red lead, or litharge, and refined pearl-ash. It was formerly made of calcined flint, but the finest Lynn sand has been found to produce a clearer ware, and is therefore preferred. The proportion of these materials varies in almost every manufactory; but the following proportions were long ago recommended by M. Loysel, the fuel employed being coal:—Fine white sand, 100 parts; red lead, 80 to 85; pearl-ash, 35 to 40; nitre, 2 to 3; and manganese a little more than $\frac{1}{6}$ a part. The mixture used by most manufacturers of the present time does not differ greatly from the above. With a coal fire, the following may be taken as the average:—White sand, 9 parts; red lead, 6½; and pearl-ash, with a little nitre, 4½. An excellent crystal may be obtained, however, with a much smaller proportion of red lead, but a higher temperature is then required for working the glass. A mixture of this description, recommended by Mr Aikin, consists of—White sand, 100 parts; purified pearl-ash, 40; red lead, 35; nitre, with a small quantity of manganese, 13 parts. When a flint-glass of first-rate quality is required, purified carbonate of potash is always employed instead of pearl-ash. We may also mention that a considerable quantity of cullet or broken crystal is in most cases made use of—to the extent perhaps of a fourth of the whole weight of the melting.

A flint-glass furnace varies little from those described for other kinds of glass, except that it is round in the top. The pots in which the glass is melted are larger at the top than the bottom; and the top is arched over, that no dust may fall in, with a hole at the side for the insertion of the tube. When the glass is sufficiently melted, the tube is inserted, and a quantity lifted out upon its point in the same manner as for crown-glass. After being rolled upon the marver, the glass is blown out to a globe shape, when the punty rod is attached, and by means of an instrument resembling a pair of sugar-tongs, the glass is moulded to the form required. The shapes into which flint-glass is manufactured are so numerous, that it would be almost impossible to describe them all. The operations are extremely simple and beautiful, and are performed with a rapidity which is truly astonishing. The workman is furnished with a pair of compasses, and a graduated scale, to measure the articles which he is making, by which they are kept of a uniform size. When finished, the articles are all weighed, to see that the right quantity of glass has been used in their manufacture, and after this they are put into the annealing furnace.

Optical glasses are made from crystal, in which case the utmost care is necessary to keep the metal entirely free from waves, otherwise the glasses will be useless. An *achromatic* object-glass for a telescope or microscope; that is, an object-glass which does not produce coloured fringes around the edge of the image—distinguished as chromatic aberration—must consist of two lenses made of different kinds of glass, differing in the proportion which their refractive bears to their dispersive power. Flint-glass and crown-glass are well adapted for being formed into such a compound lens, the dispersive power of the former being nearly double that of the latter, while the mean refractive powers of the two kinds are nearly the same.

Bottle-Glass.

Bottle-glass is composed of the coarsest materials, generally soap-boilers' waste and sand. The following receipt is recommended by Dr Ure as producing a fine dark-green glass:—Dry glauber salts, 11 lbs.; soaper salts, 12 lbs.; half a bushel of waste soap ashes; sand, 56 lbs.; glass skimmings, 22 lbs.; green broken glass, 1 cwt.; basalt, 25 lbs. The composition of bottle-glass, however, is by no means uniform, it being varied not only in different establishments, but in the same establishment at different times. The basis of the manufacture, nevertheless, is always a triple silicate of soda, alumina, and lime, the place of a portion of the lime being generally occupied by some magnesia and protoxide of iron, and that of a part of the alumina (clay) by peroxide of iron. A very worthless and deleterious article is occasionally produced, with a view to facilitate the formation of 'crust,' in port-wine bottles. This is said to be managed by an over-proportion of lime, or sulphate of lime, upon which the free acid of the wine acts, and forms a crust in a very short period. The practice is highly reprehensible, as is the introduction of soluble silicates in any form.

The furnaces for preparing bottle-glass are similar to those used for crown-glass; and the raw materials are treated much in the same way—being generally fretted, before they are introduced into the glass pots, in arches attached to the principal furnace. As the mixture always contains a very small relative proportion of the alkaline ingredient, its vitrification requires a high temperature; but it is usually complete in eighteen or twenty hours. After the undissolved matter has subsided, the sandiver skimmed off, and the glass cooled down to blowing consistency, the mass may be worked up into bottles. For this purpose the workman introduces his tube, and when sufficient is gathered upon the end, he rolls the glass upon a stone, blowing into it at the same time. He then puts the metal into a brass or iron mould of the shape of the bottle to be made, and blows through the tube until it comes to the desired form. This mould is so contrived as to open down the middle by means of a spring which the blower works with his foot. The mould is open when he puts in the metal at first; it is then immediately closed, and opened again when the bottle is formed, which is handed over to the finisher. The finisher detaches the tube from the mouth of the bottle, and fixes the punty rod to the bottom. He then warms the bottle at the furnace, and takes out a small quantity of metal, which is turned round the upper part of the neck, and forms the rim usually seen on bottles. The finisher next employs a pair of shears to give the right shape to the neck: on one of the blades of the shears is a piece of brass resembling a cork, by which the inside of the neck is formed. The bottles thus finished are sent to the annealing arch, which is kept a little below melting-heat until full, when the fire is allowed to die out.

Cutting—Grinding—Etching.

The instrument universally employed in *cutting* window-glass is the diamond, which is set into a metal socket attached to a wooden handle for this purpose. The cutting point of the diamond must be a natural one; artificial points, as well as those produced by breaking the diamond, only scratch the glass, without producing the deep cut which is necessary. The best diamonds for cutting glass are called *mother sparks*, which are sometimes cut down into a number of small sparks, with a natural point to each. It is thought better that a cutting diamond should be made of a large spark, for when one point is worn out, it can be turned and reset, when another fresh point is obtained. The diamonds used are known by the technical name of *bort*—that is, all such pieces as are too small to be cut, or have a bad colour, and are consequently unfit for ornamental purposes.

What is called glass-cutting, or *grinding*, is a separate trade from blowing in all glass manufactories. The cutting-wheel is driven by means of a belt proceeding from a large drum attached to an engine or other moving power. Above the cutting-wheel is a conical box, from which wet sand drops upon it, while another is placed below, to receive the sand as it falls from the wheel. The wheels used are three in number; the first is made of cast-iron, by which the rough glass is ground; the second of Yorkshire stone, by which the vessel is smoothed; and the third of willow-wood, by which the final polish is communicated. For this latter purpose, the wooden wheel is dressed with rotten-stone or pumice-stone; and for imparting the highest degree of polish, putty powder is used. These wheels are of various forms, according to the shape of the vessel to be cut. They may be broad or narrow, flat-edged, two-edged, concave, convex, &c. The cutter holds the glass to the wheel while it is revolving, and the most beautiful and regular figures are engraved in this manner with astonishing rapidity. Imitations of cut-glass vessels are made by blowing the soft glass into a polished metallic mould, the form of which it acquires with as much faithfulness as wax.

As stated under CHEMISTRY, the vapour of hydrofluoric acid acts energetically on glass, and is sometimes employed for the purpose of *etching* on this material. 'The art,' says Parnell, 'may be practised on all kinds of glass, but the most proper description is good crown-glass. The facts on which the art is founded are, that glass becomes powerfully corroded by exposure to the acid in question, and that certain parts of the glass may be easily protected by a resist varnish, on which the acid exerts no action, except at a high temperature. The varnish usually employed by artists for this purpose is either common turpentine varnish, mixed with a little white lead, or a strong aqueous solution of isinglass. In performing the process on a small scale, purified bees'-wax will be found to form a convenient varnish. The piece of glass to be etched is first of all warmed in a convenient manner, and one of its surfaces is then rubbed over with the wax—the temperature of the glass being high enough to cause the wax to melt, and be distributed uniformly over the entire surface. The glass is then set aside to cool; and when the wax has become quite solid, the design may be traced with a pointed, but not very fine instrument, such as a bodkin. Care must be taken to cut through the entire thickness of the wax, so as to lay the glass quite bare through the whole length of the line. The next part of the process consists in the application of the acid vapour. The vessel employed for this purpose is a shallow basin of lead, or of Wedgewood's ware (no glazed vessel should be employed), large enough to include within its area every part of the design when the prepared glass is placed over it. The materials for generating hydrofluoric acid, consisting of one part powdered fluor-spar, and two parts highly concentrated oil of vitriol, are introduced into the basin, and well mixed; the glass plate is then laid over the basin, with the waxed side undermost, and a moderate heat (generally a spirit-lamp) applied to disengage the vapour. Care must be taken to prevent the heat becoming high enough to melt the wax. After being exposed to the acid fumes for a few minutes, the glass plate may be removed and cleaned, when the design will be found perfectly etched upon the surface of the glass—the depth of the lines being proportional to the time the glass was exposed to the acid vapour.'

Staining—Colouring—Enamelling.

The art of staining or colouring glass is believed to be coeval with the discovery of the article itself. It is certain that it was known in Egypt several thousand years since, and tradition gives the honour of the discovery to an Egyptian king. The art of combining colours so as to produce pictures is of more recent date. The early specimens of stained glass exhibit a series of different pieces of various colours, joined together like mosaic work, so as to bring out the representation desired. This can now be done on one entire sheet. For a long period, the pictured glass used in cathedrals, &c. was merely painted on the surface, and was consequently liable to be rubbed off. The colours now are incorporated by fusion, and cannot be obliterated but by the destruction of the glass itself. The discovery of this art is ascribed to a painter in Marseilles, who went to Rome during the pontificate of Julius II. It was afterwards greatly improved by the celebrated Albert Durer and Lucas of Leyden.

All the pigments used in painting on or staining glass are oxides of metals or minerals—as gold, silver, cobalt, manganese, &c.—which, after being laid on, are subjected to a strong heat, until they penetrate into the body of the glass, or become fixed on its surface, and thus give out their fullest brilliancy and transparency. Animal and vegetable matters, which are freely used as colouring in ordinary painting, are wholly excluded in this, as the operation of the fire would entirely destroy their colouring properties. The colours that are meant to penetrate into the glass for the purpose of staining it, are wholly transparent, while those which are merely fixed upon the surface are only semi-transparent. Any colour or tint can be communicated to the glass in this way, and the art is at present practised with great success. The description of glass best adapted for painting upon or staining, is the finest crown or window-glass.

Thus the black oxide of copper imparts either a bright blue or a full green, according to the manner in which it is applied, while the red oxide of the same metal tinges glass with a beautiful ruby-red, the intensity of which is increased by the addition of peroxide of iron. Several different colours may be communicated by means of the protoxide and peroxide of iron: the former alone yields a dull green, which may be made so deep as to appear black; while the latter affords a variety of hues, from yellow to dark red. The greenish colour of common bottle-glass is due chiefly to the presence of protoxide of iron, introduced as an impurity in the materials. Oxide of cobalt is the principal vitrifiable colouring matter employed for the production of blue glass. 'No other metallic oxide,' says a chemical authority, 'possesses so intense a colouring power as this—one part being sufficient to afford a deep blue to one thousand parts of glass; and if the oxide is applied in a little larger proportion, the colour becomes so deep as to appear black. All kinds of glass may be coloured blue by this oxide with equal facility, and the colour is not in the smallest degree deteriorated by exposure to the highest temperature of a wind-furnace.' Oxide of chromium, which is the natural colouring matter of the emerald, imparts a beautiful and delicate grass-green; oxide of manganese, which is now extensively employed, a variety of shades, from a delicate amethystine to a deep violet, or even black. The delicate lemon-yellow, at present so fashionable, is produced by the peroxide of uranium; a good yellow by the chromate of lead, or by the oxide of silver, which is now, however, seldom employed. The splendid ruby, purplish-red, and rose-coloured hues are generally imparted by the oxide of gold, in combination with the oxide of some other metal—as lead, tin, bismuth, antimony, or zinc; gold by itself imparting no hue to the glass.

'The substances employed,' we quote from Parnell's Applied Chemistry, 'for rendering colourless and some coloured glasses more or less opaque, like enamel, are phosphate of lime, fluor-spar, arsenious acid, peroxide of tin, phosphate of lead, and phosphate of antimony. Phosphate of lime, which is the only one of these materials commonly employed at present, with the exception of fluor-spar, is introduced in the form of finely-powdered calcined bones, to the amount of one-twentieth to one-thirtieth of the weight of the glass. A very beautiful opaline crystal is obtained in this way.

'To colour glass uniformly throughout its whole substance, it is essential that the colouring oxide be intimately mixed with the glass, and both be brought into a state of complete fusion. But glass vessels and panes for windows are coloured very commonly merely on their surface, the body being an ordinary colourless glass, such as good crown-glass, containing a small proportion of alkali. For this purpose the metallic oxides, mixed with vitreous bodies which are easily fused, and with certain fluid vehicles, as oil of turpentine, are applied to the surface of the pane, commonly where a design is required, by means of a brush; but the pigments may also be transferred from a metallic plate or wooden block by gentle pressure; the pane is then exposed in an oven, or muffle, to a temperature sufficient to fuse the vitreous flux, and dissolve the colouring matter. In another method of obtaining a sheet of glass coloured on one of its surfaces, the glass-blower first collects the proper quantity of colourless glass on the end of the blowing-iron, then dips this lump for a moment into a pot of melted coloured glass, and blows out the two together into a cylinder or globe, which is extended into a flat plate in the ordinary manner. This method has been long practised in Bohemia, and is now become very general for colouring crown-glass red by means of the red oxide of copper. Ornamental vessels of flint-glass are also coloured on their outside in a similar manner, and colourless facets may be produced on such vessels by cutting through the layer of coloured glass into the substratum of the colourless.

'A patent has been recently obtained for a method of ornamenting glass, as well as earthenware and porcelain, by a process similar to that for painting or staining glass. The glass vessel or plate to be coloured is first of all covered with a thin layer of some adhesive matter, for which purpose essence of lavender is said to be preferred by the patentee; and on this coating the colouring oxides, in a state of very fine powder, and mixed with proper fluxes, are carefully dusted. The colour is then permanently fixed by the usual process of "firing." Articles of flint-glass are sometimes ornamented with delicate white argentine incrustations, formed of dry porcelain clay, cemented into a solid by means of a little plaster of Paris. These figures being thoroughly dried, are placed on the red-hot bulb of flint-glass, and are immediately covered with a thin layer of glass in a very liquid state. The polished external layer of glass gives the white figures a very agreeable silvery appearance, and they may be easily coloured, if required, before being applied to the glass. Flint-glass vessels, with coloured enamel figures on their external surface, are sometimes prepared by placing the figure in its proper place on the mould into which the vessel is to be blown. The glass, at this stage, being very hot, the enamel figure becomes firmly cemented to the surface.'

The applications of glass prepared and ornamented as above, are almost innumerable. Its use for windows, mirrors, bottles, decanters, drinking-glasses, and other vessels of domestic utility; for optical lenses, and the construction of chemical and philosophical apparatus; for decorative mouldings, chandeliers, and articles for the boudoir; for beads, spangles, gems, and other personal ornaments—must be familiar to every British reader. Since the abolition of the duty in 1845, its use has been extended in horticulture and in the dairy; it has been proposed to use it in the fabrication of transparent roofing-tiles, and pipes for the conveyance of water; and it is not too much to predict its application, on a large scale, to other economical purposes for which, by its beauty and durability, it is so eminently adapted. The manufacture of glass, in all its departments, is one of high national importance, giving employment to many thousands of our population, and converting into sources of wealth, comfort, and civilisation, the crudest and commonest materials of our soil.

PASTES—ARTIFICIAL GEMS.

In gem sculpture, *paste* is the term for a preparation of glass, calcined crystal, oxide of lead, and other ingredients for imitating gems. This art appears to have been well known to the ancients, and after being lost, was restored, at the end of the fifteenth century, by a Milanese painter. The general base of artificial gems is a vitreous compound known as the 'Mayence base' or Strass (from the name of its inventor.) It is prepared, according to Fontanieu, in the following manner:—8 ounces of pure rock-crystal or flint in powder, mixed with 24 ounces of salt of tartar, are to be baked, and left to cool. The mixture is to be afterwards poured into a basin of hot water, and treated with dilute nitric acid till it ceases to effervesce; and then the frett is to be washed till the water comes off tasteless. This is to be dried, and mixed with 12 ounces of fine white lead, and the mixture is to be levigated and elutriated with a little distilled water. An ounce of calcined borax being added to about 12 ounces of the preceding mixture in a dry state, the whole is to be rubbed together in a porcelain mortar, melted in a clean crucible, and poured out into cold water. This vitreous matter must be dried, and melted a second and a third time, always in a new crucible, and after each melting poured into cold water, as at first—taking care to separate the lead that may be revived. To the third frett, ground to powder, 5 drachms of nitre are to be added; and the mixture being melted for the last time, a mass of crystal will be found in the crucible of a beautiful lustre. Another very fine white base may, according to the same authority, be obtained from 8 ounces of white lead, 2 ounces of powdered borax, ½ grain of manganese, and 3 ounces of rock-crystal mixed and treated as above.

A base being thus prepared, the peculiar colours are obtained from the metallic oxides. We transcribe the proportions given for the fabrication of a few of the more familiar gems:—*Yellow diamond*—1 ounce strass, and 24 grains of chloride of silver, or 10 grains of glass of antimony. *Colourless diamond*—3 ounces rock-crystal, 8 ounces white lead, 2 ounces borax, and ½ grain of manganese. *Oriental ruby*—to 16 ounces strass, add a mixture of 2 drachms, and 40 grains of the precipitate of cassius, the same quantity of peroxide of iron prepared by nitric acid, the same quantity of golden sulphuret of antimony and of manganese calcined with nitre, and 2 ounces of rock-crystal. Manganese alone, combined with the strass, is said to yield a ruby colour. *Sapphire*—24 ounces of strass, 2 drachms and 26 grains of the oxide of cobalt. *Emerald*—to 15 ounces strass add 1 drachm carbonate of copper, and 6 grains glass of antimony; or to 1 ounce of base add 20 grains glass of antimony, and 3 grains oxide of cobalt. *Common opal*—1 ounce strass, 10 grains chloride of silver, 2 grains calcined magnetic ore, and 26 grains of an absorbent earth (probably chalk marl). *Topaz*—10 lbs. strass, and 1½ ounce of calcined iron. *Garnet*—2 lbs. strass, 2 lbs. glass of antimony, and 2 drachms of manganese. *Amethyst*—5000 parts strass, 20 oxide of manganese, and 1 oxide of cobalt. The preceding proportions, under the hands of an experienced manipulator, are said to yield imitations so like the natural gems, that none but lapidaries or mineralogists could detect the deception. In general, the artificial products are softer, more readily scratched, and of less specific gravity than the real gems; while their power of refracting light is also different—a test that can be applied without unsetting them.

In the above preparations, it will be observed that the fabricator produces a mere amorphic mass, which must be subjected to the wheel of the lapidary before it assumes the ultimate polish and facets of the natural crystals. Attempts have been made, however, to produce regularly-crystallised products from aqueous solution, by the agency of electricity; and in several instances the result has been so satisfactory, as to induce the hope of accomplishing in the laboratory of the chemist what nature has produced in the crust of the earth. More recently, M. Ebelmen has adopted a method to effect crystallisation based on the property which boracic acid possesses of dissolving metallic oxides in the dry way, and the volatility of this acid at a high temperature. It occurred to him that, by dissolving alumina and magnesia, mixed in the proportions which constitute spinelle (for example) in fused boracic acid, and exposing the mixture in open vessels to the high temperature of a porcelain furnace, the affinity of the alumina for the magnesia might cause the separation of a crystallised aluminate, and the expulsion of the boracic acid. By this means he has succeeded in producing artificial spinelle, cymophane, emerald, and other minerals possessing nearly all the hardness, transparency, colour, &c. of the natural product. M. Ebelmen is now hopefully engaged in prosecuting experiments in this interesting department of chemical knowledge.

CEMENTS—CONCRETES—STUCCOES.

Under this section we rank those compositions generally known as cements, mortars, concretes, plasters, and stuccoes. Their preparation, for the most part, involves a knowledge of chemical principles, and their practical application as ornamental mouldings, substitutes for sculpture, and the like, is an art as strictly fictile as the fabrication of earthenware or porcelain.

The *mortar* or cement employed to unite stones and bricks into a compact mass in building, is composed of quicklime, sand, and water. Quicklime is procured by roasting or calcining limestone in kilns, into which moderate-sized fragments of the rock are placed in alternate layers with coal or turf. By this process, water and carbonic acid are expelled, and the limestone converted into what is called *shell* or unslaked lime. The shells are then reduced to powdery quicklime by *slaking*—that is, by pouring as much water upon them as will suffice to destroy the cohesion of their particles. When intended for mortar, the quicklime should immediately be incorporated with sand, and used without delay, before it imbibes carbonic acid from the atmosphere. Lime, thus mixed with sand, becomes harder, and more cohesive and durable, than if it were used alone. It is found that the sand used in common mortar undergoes little or no change; while the lime, seemingly by crystallisation, adheres to its particles, and unites them together. The cement formed in this manner continues to increase in strength and solidity for an indefinite period, the hydrate of lime being gradually converted into a carbonate. Such is the strength which mortar thus acquires by time, that in some old buildings the lines of cement remain entire, while the stones have decayed. Indeed, in the removal of many old ruins, it is found necessary to employ the explosive force of gunpowder; and in such cases the stones more frequently give way than the lines of mortar.

In making mortar, fresh sand from a pit is to be preferred to that taken from the sea-shore, the salt of which is liable to keep the building moist, and to weaken the strength of the cementing property. The sand most proper for mortar should consist of angular particles, not rounded by attrition. The proportions of the lime and sand to each other are varied in different places; the amount of sand, however, always exceeds that of the lime. The more sand that can be incorporated with the lime the better, provided the necessary degree of plasticity be preserved; for the cement becomes stronger, and it also sets or consolidates more quickly when the lime and water are less in quantity, and more subdivided. The purer the lime, and the more thoroughly it is beaten or worked over, the more sand it will take up, and the more firm and durable does it become. In many cases, modern builders pay little or no attention to the slaking and preparing of their mortar, which, from whatever cause, is very inferior to the ancient cements.

When common mortar is made so fluid with water as to be poured on a course of brick or stone-work, it is known by the name of *grout*. Where great strength and durability are required, the practice of grouting the hearting or packing of the walls is usually adopted; as by this means the interstices are filled, and the whole rendered, by the hardening of the lime, a solid compact mass. Foundation *concretes* are generally formed of small angular stones well packed and grouted. Such concretes are proof against all moisture and decay; and on indifferent subsoils form more resistant foundations than isolated blocks of stone, however large and heavy. A concrete of quicklime and well-sifted gravel, with a small proportion of some absorbent earth, has been applied with success by Lord James Hay to the fabrication of drain-tiles or drain-tubes—the chief merit of the invention consisting in the facility with which the object can be accomplished. The composition setting with great rapidity, it may be worked round a mould in the bottom of the drain, and almost immediately covered with the arable soil.

Hydraulic or water cements, also called *Roman cements*, are those which have the property of hardening under water, and of consolidating almost immediately on being mixed. Common mortar, although it stands the effect of water very well when perfectly dry, yet occupies a considerable time in becoming so, and dissolves or crumbles away if laid under water before it has had time to harden. It is found that certain rocks which possess an argillaceous as well as siliceous character, if mixed with lime or mortar, communicate to them the property of hardening in a very few minutes after the mixture has taken place, as well under water as out of it. Substances of this sort have therefore been made the basis of water cements. The ancient Romans, who practised building in the water, and particularly in the sea, to a great extent, first availed themselves of a material of this kind. They erected their villas, not only on the sea-shore, but in artificial quays and islands constructed in the water. To enable them to erect these marine structures, they fortunately discovered, at the town of Puteoli, a peculiar earth, to which they gave the name of *Pulvis puteolanus*, and which is the same as that called by the modern Italians *Pozzolano*, chiefly obtained from Pozzuoli, near Naples. This earth is a light porous friable mineral, various in colour, and evidently of volcanic origin; mineralogically, it may be designated a calcined ferruginous clay. When reduced to powder by beating and sifting, and thoroughly mixed with lime, either with or without sand, it forms a mass of great tenacity, which, in a short time, cements to a stony hardness, not only in the air, but likewise when wholly immersed in water. To give the composition greater tenacity, it is occasionally mixed with bullocks' blood and oil. *Dutch trass* is a somewhat similar substance, which used formerly to be imported from Holland, where it is extensively used in hydraulic works. It is made from a light vesicular lava found near Andernach, on the Rhine.

Of late, a vast number of compositions have come into use as hydraulic cements, many of them possessing all the properties of the old Roman cement, and procurable at much less cost. The precise composition of several is kept secret by the manufacturers; but it may be stated generally, that lime, such as the lias, which contains about 12 per cent. of clay and iron, 5 clean sand, and occasionally brick or pottery dust, constitute the chief ingredients. Thus Parker's cement, which is known under the name of *compo*, and much used for facing houses, water-cisterns, setting the foundations of large edifices, and the like, is described as follows in the 'Engineers' Journal:'—This valuable cement is made of the nodules of indurated and slightly-ferruginous marl, called by mineralogists 'septaria,' and also of some other species of argillaceous limestone. These are burnt in conical kilns, with pit-coal, in a similar way to other limestones, care being taken to avoid the use of too much heat, as, if the pieces undergo the slightest degree of fusion, even on the surface, they will be unfit to form the cement. After being properly roasted, the calx is reduced to a very fine powder by grinding, and immediately packed in barrels, to keep it from the air and moisture. For use it is tempered with water to a proper consistence, and applied at once, as it soon hardens, and will not bear being again softened down with water. For foundations and cornices exposed to the weather, it is usually mixed with an equal quantity of clean angular sand; for use as a common mortar, with about twice as much sand; for coating walls exposed to cold and wet, the common proportions are three of sand to two of cement; and for walls exposed to extreme dryness or heat, about two and a half or three of sand to one of cement. For facing cistern-work, water frontages, &c. nothing but cement and water should be employed. The same authority gives several recipes for the preparation of similar cements, of which we may transcribe a few by way of example:—*1st*, Good gray clay 4 parts; black oxide of manganese 6 parts; good limestone reduced to powder with water 90 parts: mix, calcine and powder. *2d*, Mix manganese iron ore 15 parts, with lime 85 parts: calcine and powder. Both this and the preceding must be mixed up with a little sand for use. A piece thrown into water will rapidly harden. *3d*, Fine clean sand 1 cwt.; quicklime powder 28 lbs.; bone ashes 14 lbs. For use beat up with water as quickly as possible. *4th*, Three gallons of clay mixed with one of slaked lime, and exposed for three hours to a full red heat, are given as the constituents of Bruyere's water-cement. *5th*, The following preparation, and the last which we shall quote, is said to yield a very durable artificial pozzolene:—Expose a mixture of clay or loam, broken pottery, flints, or siliceous sand, or broken bottle-glass, with wood ashes, to a considerable heat in a furnace, until it becomes partially vitrified. Next grind to a fine powder, sift and mix with one-third of its weight of quicklime, also in fine powder. Pack in barrels, to preserve it from the air and moisture. For use this composition must be mixed with water, and applied like Roman cement.

Plaster, or the material which is used to spread smoothly over walls, is of various kinds. That which is applied to inner walls or partitions, is formed of certain proportions of slaked lime, fine sand, and water, with mixture of cow hair, to assist in giving cohesion. The lime requires to be sifted finely, and the more free it is of small lumps the better, as such lumps are apt to swell in the walls, and cause blisters, it is usual to allow plaster to remain some time made before using. The best plaster is now prepared by the pug-mill, by which the ingredients are more thoroughly incorporated than by the old process of hand-beating. Spanish white, ochre, and other colouring matters, are added when any peculiar tint is wanted; but we may here remark, that the most durable of all plasters, and that which answers best, even for fresco-painting, is composed simply of well slaked lime and sifted river sand. The surface of plaster is now seldom finished with a view to permanent exposure—whitewashing, sizing in colours, oil painting, and, above all, papering, being the prevalent fashions of the day.

Stucco is the name ordinarily given to plaster of Paris, which is gypsum reduced to a powder by heat and grinding; but the term *stuccos* is further extended to embrace all those compositions with which walls are coated or ornamented, in imitation of stone. Gypsum, which is found in roundish hard masses, is properly a sulphate of lime; and like all other varieties of lime, it has a strong power of absorbing water. The practice is to put the masses into a heated oven, and when duly baked, to take them out and grind them to powder in a mill. This powder, when sifted, is a beautiful white substance, resembling flour. A quantity of powder being put in a vessel, water is poured upon it, and immediately the stuff thickens in a surprising manner, and becomes a hardened mass. While still thickening or setting, it is poured into a mould for any required shape; or it may be applied along with a little lime as a fine plaster, which it is desirable should dry speedily. It is used largely for all kinds of casts from pieces of sculpture, mouldings for cornices, and is indispensable in stereotyping. There are none of the artificial stuccos which yield so sharp or delicate a cast; but most of them excel it in hardness and durability. Of these we shall notice a few of the more important:—

Mastic is a resinous substance, obtained from incisions made in the branches of the *Pistacia lentiscus*, a small tree or shrub growing in the Levant, and other countries bordering on the Mediterranean. It abounds in Scio, where it has long been cultivated. The gum being chewed or used as a *masticatory* by women in Turkey, for the purpose of cleansing the teeth, and imparting an agreeable odour to the breath, hence its European name of *mastic*—a term by no means appropriately applied to certain architectural cements or mortars. One of the most durable of these is *Hamlin's mastic*, thus described in the 'Pharmaceutical Times:' 'To any given weight of well-prepared pit or river sand, or any other sand of the same nature, or pulverised earthenware or porcelain, add two-thirds of such given weight of pounded Portland stone, Bath stone, or any other stone of a like nature. To every 500 lbs. of these earths so prepared, add 40 lbs. of litharge, and 2 lbs. of powdered glass or flint. To this admixture add 1 lb. of minium, and 2 lbs. of gray oxide of lead. When this composition is intended to be made into cement, to every 605 lbs. there should be added 5 gallons of vegetable oil—as linseed, walnut, or pink oil. When applied to walls in imitation of stone, the surface of the building should be previously washed with oil.' *Martin's patent cement* is another composition possessing durable properties, and less expensive than Hamlin's. It is made to imitate Bath, Portland, and other kinds of stone, as well as marble. It is generally employed as a plain coating, but can likewise be formed into ornamental mouldings. *Chunam* is the term for a durable Indian stucco, the basis of which is obtained from calcined shells.

Keene's patent marble is a recent invention, which appears to be approved of. It is described in the proceedings of the London Society of Arts as a combination of sulphate of lime and alum. The gypsum undergoes the same preparation as for plaster of Paris, being deprived of its water of crystallisation by baking. It is then steeped in a saturated solution of alum; and this compound, when recalcined, and reduced to a powder, is in a fit state for use. The cement has been already extensively employed as a stucco; but the finer qualities (when coloured by the simple process of infusing mineral colours in the water with which the cement powder is finally mixed for working) being susceptible of a high degree of polish, produce beautiful imitations of mosaic and other inlaid marbles, scagliola, &c. The cement is not adapted to hydraulic purposes, or for exposure to the weather, but has been used as a stucco in the internal decorations of Windsor and Buckingham palaces. From its extreme hardness, it has been found serviceable when used for imbedding and setting the tiles of tesselated pavements, &c.; and has been adopted for this purpose in several of the public buildings in London. The coarser qualities are said to form an internal pavement not distinguishable from stone in colour and hardness, and at less cost.

Scagliola is the Italian term for a composition intended to represent various marbles, porphyries, serpentines, &c. It is composed of fine plaster of Paris, with colouring matters, cemented by glue or isinglass, and is sometimes studded with chips of alabaster, &c. to imitate verd-antique. It is laid on like common stucco, moulded into the desired forms, and allowed to set. When thoroughly set, it is smoothed with pumice stone, and washed; then polished with tripoli and charcoal; next with tripoli and oil; and finally with pure oil, laid on with cotton wool. The result is a surface of unusual richness; but from the nature of the ingredients, it is only fitted for internal decoration, and even then requires to be kept dry.

Another composition, under the name of *intonaco* (literally wall-plaster), has recently been patented by Mrs Marshall of Edinburgh. We have seen nothing beyond hand specimens of the cement, but judging from these, it has all the requisites of hardness, susceptibility of polish and colour, and capability of resisting either fire or water. A writer in 'Chambers's Journal' for March 18, 1848, has 'seen walls in sunk flats (done with it more than two years ago) which had been streaming with damp, noxious and offensive in its effluvia, so as to be quite uninhabitable, rendered perfectly dry, and the apartments offering a peculiarly comfortable sensation to the feelings on entering, as if a fire had recently been in them. This arises from the intonaco being such a remarkably slow conductor of heat, that the atmosphere in all apartments plastered with it is kept at an even temperature—warm in winter, and cool in summer; whereas common lime, being a very rapid conductor of heat, speedily robs the air of all warmth in winter, and throws in great heat in summer—effects which we but partially obviate by covering it with paint or paper. The cement,' continues the same writer, 'also resists fire to a very high degree. Half an inch depth of it has been known to protect lath from intense fire for two hours; and even when it reaches the wood, neither flame nor spark is ever emitted—it merely smoulders slowly into a light-white ash. The intonaco does not, even under a red heat, crack or fly off from the wall; but if water be thrown upon it at this time, its substance and cohesion are destroyed, and it requires removal.' It can be employed with equal facility as a cement or plaster, a paste for casts and ornamental mouldings, or a concrete for the fabrication of artificial marble and other stones.

Various *artificial stones*, besides those for ornamental purposes, have recently been brought under the notice of the scientific. Thus a French mechanic has proposed the running of iron dross into moulds, and thereafter subjecting it to the slow cooling process which is known to produce such a total change in the nature of glass—the object being to impart to the dross the compactness and hardness of granite, and at the same time to save the cost and labour which the hewing of the real stone requires. To this end he contrives to let the iron refuse, and while in a fluid state, run into iron forms, which are previously brought to a red heat by being placed so as to receive the superfluous flame which issues from the mouth of the furnace; and in order to insure the slow cooling, these forms are provided with double sides, between which sand is introduced, which is well known to be a bad conductor of heat; the whole is then brought to a glow of heat, and in like manner again cooled off. By this procedure, it is asserted, the ingenious discoverer has succeeded in forming paving-stones, flags, large building blocks, and even pipes, of any given form, of a degree of hardness and polish equal to the best hewn natural granite, and at the most trifling conceivable cost. A composition of the same class has also lately been invented by M. Möser of Berlin, and employed in the fabrication of statues, vases, and ornamental mouldings under the title of *cast-marble*. The nature of the composition is a secret, but from its cheapness (2s. 6d. per cubic foot), it must consist chiefly of very common materials. The figures exhibited at the factory of the inventor are of various ingredients, presenting gradations from a compact reddish sandstone to the finest translucent Carrara marble.

Moulding compositions for making architectural ornaments in relief are now extremely common, and in most instances well fitted for the object in view. A very cheap one is formed of glue, chalk, and paper-paste, the paper aiding the cohesion of the mass; another of paper-paste, finely-powdered plaster of Paris, and size, which requires to be used as soon as mixed. Both of these are extremely light, and receive a good polish, but will not stand exposure to the weather. *Papier-maché*—a substance to be more fully noticed under Paper-Making—is also much employed for forming ornaments, as a substitute for carving, and casts in plaster of Paris. It is made, as its name imports, from paper or rags reduced to a pulp with gum or size, pressed into moulds and afterwards dried. It is extremely light and durable; and from its susceptibility of being varnished and painted upon, is now coming largely into use, not only for architectural ornaments, but for the fabrication of finger-plates, door-handles, tea-boards, trays, fire-screens, work-boxes, and a variety of articles for the boudoir.

Asphalte, so called from its adhesive nature, has lately been adopted to a large extent, both in the formation of a pavement concrete, and as waterproof roofing for buildings. Asphalte, or asphaltum, is a bituminous mineral, allied in its nature to pitch, and is found in the form of rocky masses in different parts of the world. The chief quarries for it in continental Europe are in the Val de Travers, province of Neufchatel, the excavations being in the Jura range of mountains, which are calcareous in their nature. An inferior kind is a species of bituminous molasse, which exists in various parts in what must be called lakes, or vast semifluid masses. The true asphalte, or asphaltic cement of Neufchatel, is procured by boring and blasting the bituminous rocks, and the pieces being brayed and then melted in large boilers, the hot fluid is poured out so as to form conveniently-sized cakes. When needed for smearing on roofs, it requires to be only melted and spread; and when dry, it remains impervious to the weather, neither cracking in winter nor melting in summer. If designed for pavement, it must be mixed with sifted gravel, pounded iron slag, or river sand, which gives it more stability, and a degree of roughness that is not unnecessary. The composition is prepared in portable boilers or caldrons, and spread while hot on a properly-prepared bed; and being rendered smooth on the surface, it offers an exceedingly agreeable resistance to the foot, being not so hard as stone, nor so soft as a mud pathway. Wherever stone is expensive, asphaltic pavement may be advantageously employed, not only for streets, but floors of dairies and other out-houses, garden-walks, and terraces.

A cheaper and equally durable pavement may be formed of gas-tar and gravel, the following formula for the preparation of which we find given in the 'Builder,' by Mr Shearburn of Dorking:—'Take ten gallons of gas-tar, two bushels of gravel, sifted through a half-inch sieve, and two bushels of sharp washed sand; the whole of this composition to be heated in an iron furnace, and kept stirring until it is found to set quickly; after which it is taken out, and spread upon the surface intended to be covered about two inches thick, with a wooden handfloat, such as is used by plasterers for stucco work. A heated iron or spatula is passed over it, which brings the tar to the face; after this sift over it some smiths' ashes—refuse from the forge. In a short time it will set, and appear like cast-iron, and resist all impressions and wet. Gutters may be formed in a similar manner. Care should be taken the materials are dry before being added to the tar; for this purpose I have used an old hot-plate, and dried them at the same time and expense as heating the tar. All can be done by labourers, excepting one man handy with a trowel; and the material will cover a large surface, at a comparatively small expense. I have used it for the covering of bridges, terraces, stables, and sheds for feeding cattle; and also on an area of 300 yards, covering basement rooms to a nobleman's mansion in the north of England; no wet has penetrated. I have seen it used on roads, with the exception of the tar being heated, and the materials of a heavier metal. The best road that I know of is out of Nottingham to Lincoln, for about two miles, and is of this description.'

Adhesive cements and *lutes* have already been briefly noticed under the head of 'Applied Chemistry:' we may here observe generally, that they are exceedingly varied both in their composition and application. Thus the engineer, plumber, jeweller, cabinetmaker, and mender of broken china or glass, have their own peculiar compounds; and the manner in which they apply them, so as to combine strength with neatness, and at the same time make them appear like the material united, is often truly ingenious. As a general rule, it may be remarked, that the closer any two bodies can be brought together, consistent with the uniform distribution of the cement, the more firmly will they be united. A few of these compositions may be transcribed, merely by way of example:—4 parts of iron-filings, 2 of potters'-clay, and 1 of pounded potsherds, mixed into a paste with salt and water, if allowed to concrete slowly on iron joints, forms a very hard cement. Another used by coppersmiths and engineers to secure joints, consists of boiled linseed-oil and red-lead mixed into a putty. White of egg, thickened with finely-powdered quicklime, is employed to mend earthenware, china, glass, &c.; but it does not resist moisture. Isinglass dissolved in mastic varnish is often used for the same purpose; it resists moisture, and dries colourless. Glue, and the various cements into which it enters, are well known; the celebrated *marine glue*, the adhesive powers of which are invincible, is a totally different substance, said to be composed of caoutchouc dissolved in naphtha or oil of tar, with a certain proportion of shellac. So powerful is this compound, that the hull of a vessel might almost be constructed by its assistance, without the aid of bolt or trenail!

Caoutchouc and *gutta-percha*, two remarkable substances of vegetable origin—to be afterwards treated at length—can scarcely be omitted in any account of modern fictile fabrics. The former, being highly elastic, reducible by heat, soluble only in certain liquids, and capable of chemically uniting with several substances, is applicable to a thousand purposes of utility and ornament. The same remark may be applied with equal propriety to gutta-percha, which is also soluble only in certain liquids, is reducible by heat, and though inelastic, is much more ductile and plastic than caoutchouc. In our textile fabrics, both now occupy a prominent part; while as fictile materials, they may be formed into ligatures and belts, tubes, bottles, springs, boots and shoes, waterproof vessels, knobs and handles, ornamental mouldings, and as ingredients in pavements and floorings of a very durable kind.

TEXTILE MANUFACTURES.

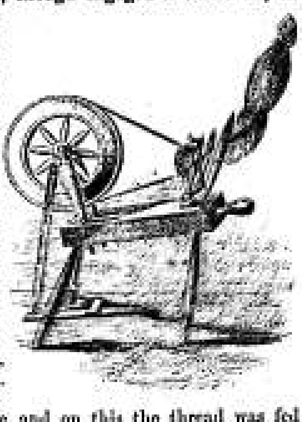
By *Textile Manufactures*—as generally defined—are meant those in which filaments of flax, of cotton, of silk, or of wool are wrought into linen, cambric, calico, muslin, silk, satin, flannel, broadcloth, and the numerous modifications of these now so well known to every British reader. In the present instance, we extend the definition so as to embrace every variety of fabric—as paper, felt, straw-plait, and the like—essentially composed of vegetable or animal fibre. In the preparation of these, from the rearing of the raw materials to their ultimate stage as articles of utility and luxury, there is involved a vast amount of labour, of mechanical and chemical skill, of capital and enterprise—so much so, that, as a class, they rank second to none of the manufactures which come within the scope of our national industry. In the following pages we aim at a very general account, seeing that details of any particular process would be not only inconsistent with our limits, but unintelligible without the aid of numerous diagrams, and also a certain amount of practical acquaintance with the subject under review.

LINEN.

The fabrication of linen cloth, which is of high antiquity, and to which we may first advert, commences by the preparation and spinning of the raw material—lint. Lint is the fibrous bark of the flax-plant (*Linum usitatissimum*), which grows in temperate climates to a height of from three to four feet. It is an annual, having a slender, smooth, hollow stem, rising undivided till within a few inches of its full height; its several branches are then terminated by small blue flowers, to which succeed roundish seed-vessels, each enclosing ten smooth shining seeds replete with meal and oily matter. As a crop, flax is cultivated less or more in most European countries, and succeeds best in a rich deep loam, with a good deal of moisture. That produced in Holland and Belgium is said to be best; but our chief supplies are obtained from Russia, Prussia, and other countries bordering the Baltic. Egypt, anciently so celebrated for its fine linen, is beginning to yield a portion of our supply, and promises well for the future. Owing to the cheapness of foreign flax, comparatively little is reared at home, notwithstanding the endeavours which have lately been made to extend its culture in Ireland, and in certain districts of England and Scotland. The seed is sown broadcast, and harrowed down early in April; and if in clean, well-prepared soil, requires no farther attention. When the crop is ripe, which usually happens about the end of summer, it is pulled and laid in bundles to dry. It is then *rippled*, or deprived of its seed-vessels, either by drawing the stalks through a kind of comb with iron teeth, or by beating them. The capsules are next thrashed and winnowed to obtain the seed, from which linseed oil is procured by pressure—the refuse forming the oil-cake of the cattle-feeder and farmer.

The next process is to obtain the flaxen fibre or lint free from the woody core, or *boon*, of the stem. This is effected by steeping the bundles in water till the boon begins to rot, in which state it is readily separated from the fibre. This operation is called rotting, or *retting*, and requires to be managed with great care, as by continuing it too long, decomposition might extend to the fibre, and render it useless; while by discontinuing it too soon, the separation could not be effected with sufficient ease. The time is generally determined by the nature and temperature of the water, and the ripeness of the flax—decomposition taking place more rapidly in soft stagnant water than in running streams, in which the retting is sometimes conducted. After being sufficiently steeped, the flax is spread out on the grass, to rectify any defect in the retting, and ultimately to be dried for the breaking. In some districts it is the practice to conduct the retting entirely on the grass—a process known as dew-retting, in contradistinction to water-retting. This is a safer and less offensive method, but it requires much longer time, and in a country where land is valuable, would become very expensive. On the whole, the mixed method of retting is preferable—that is, to steep till decomposition of the boon is well advanced, and then to complete the process on the grass. It has been attempted to separate the fibre by machinery, without subjecting the flax to retting; but the material so produced has hitherto been rejected as inferior in quality to that produced by the old process. Being retted and dried, the flax is now *skutched*, or bruised, to free the external fibres from the waste of the stalk. This was formerly effected, first by the *hand-brake*, which bruised or broke the dry brittle core; and secondly by the *skutch*, a sort of wooden knife with which the operator switched the waste from the fibre. A system of rollers to bruise, and flying arms to skutch, now constitute the preliminary dressing apparatus, which is moved by steam or water power. *Hackling* is the next process in flax-dressing, still partially performed by the hand, but chiefly, we believe, by machinery. The hackle is a strong comb composed of several rows of steel teeth, four or five inches in length, fixed upright in a block of wood as a base, and made fast to a bench. The workman taking a handful of skutched flax, strikes it against the pointed summits of the teeth, and draws it through—repeating the process till the requisite fineness is obtained. Coarser and wider-toothed hackles are first used, and then others progressively closer as the fibres become finer by separation. The fine lint so obtained is called *line*; the refuse left on the hackles, *tow*. Supposing the hackling to be performed by hand, the line is now ready to be spun into the finer sorts of yarn; the tow into the coarser sorts, for sacking and similar fabrics.

The mode of *spinning* is now very different from what it once was. In ancient times it was customary to spin by the distaff, an exceedingly simple apparatus, consisting of a spindle or bobbin, twirled by the twisting of the lint, as it came from a staff of lint held by the operator; the finger and thumb were the sole instruments for twisting. A female could not twist a spindleful of thread, though engaged a whole day in the labour. This rude process was at length superseded by the introduction of a machine called the *spinning-wheel*, a representation of which is given in the annexed engraving. A female sat with her left hand towards the *rock*, or staff, on which the lint was placed; her right foot moved the paddle-board below, and this affecting the upright crank, turned the wheel. A band communicated to the spindle, and on this the thread was fed from the rock. In drawing out the lint, the finger and thumb were frequently wetted by touching the lips, and this had an effect in consolidating and smoothing the thread, which no purely mechanical process has



since been able to imitate. An improvement on this, in point of celerity, was the double-thread spinning wheel, which was furnished with two spindles, the spinner forming a thread with each hand. Although the motion of the wheel was rapid in comparison of the feeble operation of the distaff, the process was very insufficient, except for home-made linens, and something very different was required for manufactures conducted on an extensive scale.

The introduction of machinery in the manufacture of cotton led to the application of similar mechanism in the linen manufacture; and for many years hand labour has been entirely abandoned. Hand-spinning may now be said to live only in the songs and ballads of our country, and spinning-wheels to be preserved merely as relics. All steps in the preparation and spinning of the flax are on a large scale. The flax is imported in vast quantities from the countries already mentioned, and is dressed and spun in factories at Leeds, Dundee, or some other great seat of manufacture. The machinery is extremely beautiful and ingenious, and the making of it alone is a principal trade. On being brought to one of these factories, the flax is from thirty to thirty-six inches in length, and the first step 'is to take a quantity of it'—we quote the Encyclopædia Metropolitana—'and divide it into three lengths; the part nearest to the root being coarse and strong, the middle part fine and strong, and the upper part still finer, but not so strong. Thus each length being divided into three, and all those of the parts from the bottom, middle, and top, being collected into separate heaps, three distinct qualities of yarn are to be formed. The separation of these first lengths into three is effected by a very ingenious machine, consisting of a number of vertical wheels, and a centre wheel, furnished with a kind of teeth. The length of flax is held transversely against these wheels, and is passed between two, one on either side, while the centre wheel tears it across by separating but not cutting the fibres. This cuts off the bottom part of the length of flax; the remaining part is then submitted to the same process, and the middle part cut from the top, each sort being collected in one heap, so as to effect a separation of the three qualities above named. Each division will be of course about ten or twelve inches in length.

'In the next stage—the dressing or hackling—these lengths are fixed in a sort of vice at one end, spread out to a breadth of six or seven inches; several of these are fixed on a sort of revolving drum, at distances of about a foot from each other, their unsupported ends falling on an internal drum covered with strong cards, the internal drum revolving one way with considerable velocity, and the external in the opposite direction rather slowly, and thereby the lengths of flax are rendered very smooth and straight; they are then dexterously removed by an attendant, generally a girl, and placed with their other side downwards in the next machine, and again removed. It should be remarked that these only pass over the upper part of the internal drum; for it is obvious, if they passed below, their weight would cause them to fall away from, and not upon the carding-roller.

These several operations being performed, the next step is to place these pieces of flax, one just reaching the other, on a feeding cloth, and by the hand slightly to combine their ends; the first end is then passed between two card-rollers, or rollers furnished with teeth, which carry the whole forward, while the extreme end passes between two rollers of iron, the latter moving with considerably greater velocity than the former, in some cases 30 to 1, and consequently the flax is now lengthened 30 to 1, and its thickness reduced accordingly. In passing from the roller the flax receives no twist, but comes out flat, and of about the breadth of narrow tape, and is caught in a cylindrical tin can placed below to receive it; when a certain length has been received sufficient to fill the can, a bell rings, an attendant breaks the flax, removes the can, and places another. The flax in the full can is then taken to another machine, where it is again lengthened, and so on, to different degrees, according to its intended fineness. After it is properly reduced in the flat state above described, it receives in its last stage a very slight twist, so as to reduce it to a round thread. It is then received on bobbins, and is in a proper state for spinning; the process of which differs only in degree from that described in relation to the cotton manufacture.' The yarn thus produced is now ready for the weaver, who converts it, either by hand or by steam power, into the various fabrics of linen, damask, cambric, &c. to be afterwards described.

Weaving is an art of great antiquity, and has undergone little improvement till recent times. The process is founded on a simple principle. A certain number of threads drawn out alongside of each other constitute the *warp*. This is evenly wound on the beam of a loom, and is thence extended to another beam at the opposite end. The warp is two threads in depth, and by means of heddles and other apparatus, these are caused to rise and fall, so as to cross each other vertically. Every time that the threads are opened, a shuttle, containing the *woof* or *weft*, is thrown across from one side of the warp to the other, and the thread of woof thus left is driven home by a lay, or properly by a comb-like process of reeds called a *dent*, which the lay brings forward. A reversal of the warp makes another opening, which is similarly crossed by the shuttle, and so on, the fabric gradually assuming the character of cloth. Plain cloth of all descriptions is formed by this simple species of operation, whether the loom be driven by hand or by steam power. In preparing *warps* and *woofs* on an extensive scale, machinery has also been called in to supersede that of manual labour. The former are now prepared by the *warping-mill*, an apparatus consisting of a number of spindles on which the bobbins containing the yarn are placed, and a drum or reel, round which they are simultaneously wound. The quantity of warp being determined, the warper proceeds to unwind from these bobbins the requisite amount, observing that none of the threads get broken, and taking care to supply the spindles with new bobbins as the first set are wound off. In filling the pirns for the shuttle, machinery also lends its aid; and though almost automatic—stopping when the thread breaks, or when the pirn is full—yet human skill is still, and ever will be, necessary to superintend and direct.

The only changes of pattern which can be readily produced by plain weaving are *stripes* or *checks*—the former generally depending upon the colours of the warp, and the latter upon the colours of both warp and weft. Thus stripes in the direction of the cloth may be produced by using warp of various colours, or a warp composed of threads of different sizes and substances; stripes across the web may be formed by using shuttles containing various colours and substances; chequered patterns by varying both warp and weft; and figures to a certain extent by raising and depressing alternately certain portions of the warp. *Twills* are formed by causing the thread of the weft to pass alternately over four and one of the threads of the warp, and performing the reverse in its return. Plain twilling is adopted in various linen fabrics—in silk it is called satin, in cotton fustian or jean, and in woollen serge or kerseymere. In ornamental or *figure* weaving, an expensive, or at least complex, harness is required, the warp being of various depths, several sets of heddles being also in requisition, and it may be a number of shuttles, each having its own system of thread or threads. It is easy to see how, by these means, a great variety of figures may be produced; and in order that the weaver may clearly understand the intended texture of his piece, all the threads are drawn on cards before he begins, in a manner peculiar to themselves; and these he reads as he proceeds, just as a musician plays from his sheet of music. Formerly, a number of boys or assistants were required in damask and other ornamental weaving; but now, by the aid of wheels, cranks, springs, and levers—in fact, by a system of clock-work—the weaver in general proceeds by himself. Looms of this kind, whether for linen, silk, cotton, or carpet fabrics, are known as draw-looms, the most perfect of which is that invented by M. Jacquard, a practical weaver at Lyons. With modifications adapted to the object in view, the Jacquard loom has now superseded all others for figure weaving—the skill and labour required to work it being little more than that necessary for plain weaving. *Pile* fabrics—as velvets, fustians, corduroys, &c.—are produced by using another set of threads besides the warp and weft. In the process of weaving, these threads are looped on one side of the fabric, and are afterwards cut and flushed into pile. For the weaving of ribbons, gauze, lace, and other fancy textures, a variety of ingenious machines are constantly being invented, some of which have little in common with the loom, and would require to be examined minutely to be properly understood.

The *fabrics manufactured from flax*, or linen yarn, are known in commerce by various names, according to their fineness, patterns, uses, and other particulars. Any of them may be bleached or unbleached, and bleaching may take place either in the yarn or in the fabric. In all of them the fineness and strength depend upon the original quality of the yarn, the closeness of the dent or reed, and the regularity with which the weaver drives the weft home. An excellent fabric may be left rough and unfinished in surface, while a worthless material may be made to assume the most captivating appearance by smoothing, starching, singing, watering, calendering, and other ultimate processes. Of *linen*, there are various subordinate sorts—as *Irish*, *Scotch*, and *English*; *Holland*, a fine kind brought from the Low Countries; *dowlas*, a coarse undressed fabric; *drill*, a stout twilled linen; *Silesia*, a fine brown holland, glazed for window blinds, &c.; and *Hessia* and *Forfar*, both coarse varieties used by upholsterers and others. *Linen damask* is the name given to twilled and figured sorts used for tablecloths and napkins, often of great beauty and intricacy of pattern; *diaper* is a damask of smaller figure and pattern used for napkins, towels, and the like; and *union*, a damask formed of linen and cotton, or even of linen and woollen. *Cambric* is the well-known finest fabric which can be produced from flax; and *lawn*, a variety intermediate between linen and cambric. *Tick* is the twilled and striped fabric used for bed, bolster, and pillow cases; *huckaback*, *dorrock*, *Osnaburgh*, &c. are coarse varieties of dowlas; and *canvas*, the general term for the coarsest fabrics produced from flax. Canvas of still coarser texture is manufactured from hemp and other fibrous material, to be afterwards noticed.

Bleaching and *calendering* are the processes which follow the weaving, and in both there are now great improvements. The principles of bleaching have been already explained under 'Applied Chemistry'—whether by the old process of sun-bleaching on the grass, or by the application of chemical detergents. We shall here merely allude to the process adopted by the Irish manufacturers, as detailed in 'Hall's Ireland,' premising that the cloth in this case is woven of unbleached yarn; it being perhaps now the more common plan to submit the yarn to perfect or to partial bleaching before committing it to the hands of the weaver. 'Being first unfolded from the firm and compressed shape in which each *piece* or web is received from the manufacturer, the cloth is cast, loosely knotted, into a wooden boiler, capable of containing some two or three hundred pieces, and nearly filled with a weak solution of potash or barilla. After it has been boiled in this liquid for several hours, it is removed from the boiler by a crane and network of rope, and almost immediately transferred, in separate quantities, to the *wash-mills*. Here it is placed in a trough, through which jets of spring-water are constantly passed, and kept fully exposed to the action of the water by means of two large beams suspended above the troughs, and termed *feet*, the lower ends of which are alternately drawn back, and permitted to fall against the linen with considerable force. This motion is produced by the revolving of a cylinder situated directly beneath, and having projecting spars which catch and raise, at intervals, the extremity of the feet. From the wash-mills the linen is removed to the green, where it is carefully spread upon the grass, the several pieces being attached together, and their ends secured to the ground by small wooden *pins*. After remaining two or three days upon the grass, it is again brought to the bleach-house, to be boiled and washed as before. The operations of boiling, washing, and spreading upon the green continue, thus successively repeated, till the linen has fairly assumed a whitish hue, when two additional forces are introduced. The first is that of passing the linen through the *rub-boards*. These boards, which are fixed in a frame, and moved by simple machinery, have portions of their inner surfaces furnished with plates of *lignum-vitæ*, or other hard material, completely channelled with narrow parallel grooves, the plates of the upper board being placed immediately over those of the under. Between these plates the linen, having been first plentifully soaped, is slowly passed, so that the entire web is submitted to the friction. The second process is that of steeping, for a certain number of hours, in *kieves*, or cisterns, containing water acidulated with sulphuric acid. After the introduction of the additional processes, the earlier continue unchanged, excepting that the use of the former alkalies in boiling is abandoned, soap-lye being now employed.

'By these several means, the bleaching is at length completed, when the *finishing* or preparing for market immediately begins. The linen is first starched and blued, after which it is suspended in a *drying-loft*, where it is exposed to the air till completely dry. It is then taken down and stretched, and submitted to the *beetles*. These are a succession of weighty wooden billets, ranged in a frame, above a slowly-revolving cylinder, round which the linen is wound. The machinery being set in motion, the billets are raised and successively dropped, with great rapidity and force, on the cylinder beneath. This is continued for several hours, and the operation repeated till the fabric is sufficiently compressed, and the requisite smoothness obtained. The linen is then *lapped*, or folded, and sent to the assorting-room. Here each piece is carefully measured, again firmly lapped, and subjected to the pressure of a hydraulic press. The peculiar stamp of the merchant is finally applied, and the linen is ready for the market.' Of course every manufacturer has his own mode of 'finish;' some smoothing by heated cylinders, others using starch and similar ingredients to stiffen the fabric, and not a few employing more objectionable methods of stretching, smoothing, and producing an artificial gloss, with a view to make an inferior fabric assume the appearance of one of superior quality.

It may be here observed that new modes of bleaching have recently (July 1847) been patented by Mr Sandeman of Perthshire, which, from their simplicity, cheapness, and safety, are likely to supersede in a great measure the old hot or boiling processes. Mr Sandeman's methods are termed the 'cold,' 'thermal,' and 'binary,' and are founded on the peculiar property of hydrates of lime—a property possessed, we believe, by no other aqueous solutions whatever—namely, that the colder the water, the greater is the quantity of solid matter (lime) which they absorb. He employs in the main the same detergents that are used in the boiling process, but in different proportions; while he manages to dispense with several of the alkaline solutions, nearly all the expense of furnaces and fuel, and effects a considerable saving in point of time. 'Moreover,' to quote his own words, 'yarns, threads, or twist which have gone through this cold process, are found to retain more of their original strength, firmness, levelness, and weight, and to be much freer from oaziness of fibre, than those which have been treated according to the ordinary hot or boiling processes. In like manner, all cloth bleached by this process retains more of its original strength, firmness, elasticity, and weight, than that which is bleached by the processes heretofore pursued.'

The *Linen Manufacture* has been long prosecuted, especially in England and Scotland; but until of late years, its progress has been inconsiderable, compared with that of our other manufactures. No very accurate statistics of the trade can be obtained, in consequence of hand-power being employed to a large extent both in the spinning and weaving of the material. In 1839, there were 169 flax factories in operation in England, 183 in Scotland, and 41 in Ireland—employing respectively sixteen, eighteen, and nine thousand hands. According to Mr M'Culloch, the entire value of the linen manufacture of the United Kingdom does not exceed ten millions.

Hemp and other Ligneous Fibre.

Hemp is the fibrous bark of the *cannabis sativa*—a plant supposed to be a native of Persia or India, but which has long been naturalised and extensively cultivated in Europe, particularly in Italy, Russia, and Poland, where it forms an article of primary commercial importance. It is also cultivated to a considerable extent in many parts of America; but in Britain it is but little grown, except in a few districts of Suffolk and Lancashire. Its fibres are prepared for spinning in the same way as flax, and is made into yarn for the fabrication of canvas-bagging, sailcloth, ropes, and cordage. The common cultivated *hop*, some species of *nettle*, and other plants belonging to the same natural order (*Urticaceæ*), as the hemp, yield also a tough elastic fibre, from which coarse fabrics are occasionally woven. Indeed the elaboration of a tough elastic product seems to be characteristic of the whole order—making its appearance in the stem of the hemp, in the inspissated sap of the Indian-rubber tree, and in silk, the best of which is derived from silkworms that feed on the leaves of the mulberry. Several of the members of another natural order (*Liliaceæ*) yield fibre strong enough to be worked into cloth and cordage; but in these the fibre resides in the leaf, and not in the bark of the stem. Of these may be mentioned the *New Zealand Flax* (*Phormium tenax*), whose toughness rivals that of hemp, and the Sansevieras, from which is obtained the still stronger substance called *African* or *bowstring hemp*. *Coir*, which is extensively worked into mats and cordage, is the dry fibrous pericarp of the cocoa-nut. The inner bark of various trees is sufficiently tough in fibre to form material for fishing-lines, nets, rice-bags, a coarse kind of linen, and the well-known matting called *bast*. The linden-tree may serve as an example, its inner bark furnishing the Russian or bast mats so largely employed for commercial purposes. The most of the coarse fabrics so composed are either woven or plaited; ropes and cordage are twisted on the same principle as common thread, either by hand labour, or perhaps now more generally by machinery.

COTTON.

Cotton is the wool produced in the pods or seed-vessels of the cotton plant (*gossypium*), which is indigenous to all the tropical regions of Asia, Africa, and America. Three great distinctions are generally observed in treating of cotton—namely, the herbaceous, the tree, and the shrub species. The first and most useful is the *herbaceous*, which is an annual plant, cultivated in the United States, India, China, and other countries. It grows to the height of eighteen to twenty-four inches, and has leaves somewhat lobed, of a bright dark green, and marked with brownish veins. Its blossom expands into a pale yellow flower, like that of a mallow; and when the flower falls off, a three-celled, triangular, capsular pod appears. The pod increases to the size of a large filbert, and becomes brown as the woolly fruit ripens; the expansion of the wool then causes the pod to burst, when it discloses a ball of snow-white or yellowish down, consisting of three locks, one in each cell, enclosing and firmly adhering to the seeds. The seed is planted in March, April, and May, and the cotton is gathered by hand, within a few days after the opening of the pods, in August, September, and October. In America, it is planted in rows five feet asunder, and in holes eighteen inches apart, in each of which several seeds are deposited: careful weeding of the ground is necessary, and the plants require to be gradually thinned, so as ultimately to leave only one or two for each hole; they are also twice pruned, in order to make them put out more branches, and yield a larger quantity of blossom and fruit. The *shrub cotton grows* in almost every country where the annual herbaceous cotton is found. Its duration varies according to the climate: in some places, as in the West Indies, it is biennial or triennial; in others, as in India, Egypt, &c. it lasts from six to ten years; in the hottest countries it is perennial; and in the cooler countries where cotton is grown, it becomes an annual. The *tree cotton* grows in India, China, Egypt, the interior and western coast of Africa, and in some parts of America. As the tree only attains the height of from twelve to twenty feet, it is difficult to distinguish the tree cotton and the shrub cotton from the mention made of them by travellers.

The cotton plant, in all its varieties, requires a dry and sandy soil. This is the uniform testimony of travellers and naturalists. It flourishes on the rocky hills of Hindostan, Africa, and the West Indies, and will grow where the soil is too poor to produce any other valuable crop. A mixture of siliceous and argillaceous earth is the most desirable, with a preponderance of the former. A marshy soil is wholly unfit for the plant, and so little congeniality has it for moisture, that a wet season is destructive to the crops. The plant flourishes most, and produces cotton of the best quality, on the sea-coast, as is well known by the planters of South Carolina and Georgia, who raise the finest cotton known—namely, the 'Sea Island,' on the sandy coasts and low islands of the sea, and who find the same cotton degenerate in length of staple and in quality when grown inland.

After the cotton is gathered—which is done by degrees, as the pods do not get ripe all at once—it is exposed to the rays of the sun till it is perfectly dry; the seeds are then separated by a peculiar skutching apparatus; and being picked and compressed into bales, the wool is sent to Europe. The chief seats of import are Glasgow and Liverpool, where it arrives in large oblong bales, and in this state is carted off to the factories in which it is to be spun.

The relative value of raw cotton depends on the length of its staple, the delicacy of its fibre, and its freedom from dirt and seeds. The cleanest, we believe, is the American; but however careful its preparers have been, 'it never comes to England in a state fit for immediate use; some seeds remain after the most careful cleaning, and the pressure to which it is subjected in packing, forms hard matted lumps, and some of the coarser and heavier wool is unavoidably mixed with that of superior quality. The first operation in the process of manufacture is consequently the cleaning of the cotton. It is put into the blowing-machine, where the cotton is torn open by revolving spikes, and subjected to the action of a very powerful blast, produced by the rapid turnings of a fan; the light wool is thus blown to some distance from the heavier portions—the dirt, seeds, &c. This process is continued in the skutching-machine, where the cotton is beaten by metallic blades making from 3000 to 5000 revolutions in the minute; these completely open the fibre, and separate the fine wool from the waste, which falls to the ground through a frame of wire-work.

The cleaning process is generally called *willowing*, which is either a corruption of *winnowing*, or perhaps derived from the willow frames on which the cotton was cleaned by beating, before blowing-machines were invented. Previous to this improvement, the cotton was placed upon willow hurdles, or upon cords stretched over a wooden frame, and then beaten with smooth switches. This operation, technically called *batting*, though very fatiguing, and we believe unwholesome, from the dust, &c. which was scattered about, was usually performed by women; it is now very rarely practised, except when some remarkably fine cotton is required for the manufacture of lace, when it is of importance to preserve the length of the staple, which might be injured by machinery.

The Hindoos open the fibres of their cotton by a bow similar to that which hatters use in raising wool; the same contrivance appears to have been employed in America, for we find the term *bowed cotton* still employed in the language of commerce. Judging from its effects on wool and fur (see Hat-making), we should think that the bow is an effective machine for cleaning and opening the fibres, but it would be far slower and less productive than the willow.

When cleaned, the cotton is brought to the lapping or spreading machine, where a given weight of the wool is spread over a determinate surface of cloth; and being then slightly compressed by a cylinder, it is lapped round a roller, so as to be in a fit state for feeding the carding-machine. It is a singular fact, illustrating the accuracy with which machinery works, that the weight of the cotton spread on the cloth in this process regulates the fineness of the thread ultimately produced, and that there is rarely any great amount of error in the calculation.

The next process—that of carding—is one of the most beautiful in the whole of the cotton manufacture. An explanation of the object to be obtained, is necessary for those who have not paid some attention to the subject. In order that any material should be spun—that is, should have its fibres twisted together—it is essential that these fibres should be straight and parallel with each other. After having been subjected to the action of the willow, the fibres of the cotton are blown about in every direction, and if compressed, would be entangled with each other. This, which is the object to be gained for the process of felting, is precisely that which must be carefully avoided for spinning. In order to straighten the fibre, the cotton is made to pass between cards or brushes of wire, one of which is stationary, and the other in motion; the wire teeth catch the fibres, and by their continued action pull them into nearly parallel directions.

This process was anciently, and in some rural districts both of England and Ireland is still, effected by hand-cards, which might be described as two brushes with handles, having short wires instead of hairs. The labour was usually performed by women, who placed one of the cards on the knee, holding it firm with the left hand; and then spreading the cotton or wool in small quantities over the wire, drew the other card repeatedly over it with the right hand, until the fibres were deemed sufficiently straight. When thus prepared, the cardings were taken off in a roll by the hand, and laid so as to be united into a continuous roving by the spinning-wheel.

The first great improvement in this process was to fix one of the cards to a table, and suspend the other from the ceiling, so that the workmen could move it without having to sustain its weight. Such a contrivance allowed *stock-cards*, as they were called, to be made of double the size of hand-cards, and consequently to double the quantity of work produced. We have seen stock-cards in some rural districts, where there is still a domestic manufacture of woollens; but they are daily becoming of more rare occurrence. In nearly all manufactures they have been superseded by the cylindrical cards, which Mr Baines has shown to be the invention of Mr Lewis Paul of Birmingham, about the year 1748. About 1760, the process, which seems to have been either neglected or disused, was revived by Mr Morris of Wigan, and applied to the carding of cotton. The perfecting of the machine has been claimed for Sir Richard Arkwright, but the originality of his invention has been very fiercely contested. Without entering into the controversy, we shall proceed to describe briefly the machine in its present state.

The *carding-machine* has the appearance of a cylindrical box, into which cotton is given by the roller, round which it was wrapped in the spreading operation. Its wooden covering is a series of narrow panels; and if one of these be lifted, it will be seen that each of them is a card, and that a cylinder covered with cards occupies the interior of the box, between which and the panel-cards the cotton is rapidly passed. At the opposite side of the box is a second cylinder, the cards on which, instead of being placed horizontally, are wound spirally round the cylinder, which is called a *doffer*, so as to remove the carded cotton in a continuous fleece. The cotton is slipped from the doffer by the action of a slip of metal, finely toothed like a comb, which being worked against the cylinder by means of a crank, beats or brushes off the cotton in a fine filmy fleece. The cloud-like appearance of the carded cotton, as it is brushed from the doffer, or finishing cylinder, by the crank and comb, is singularly beautiful—a breath seems to disturb the delicacy of its texture, and to the touch it is all but impalpable. The filmy fleece is gradually contracted as it passes through a funnel, by which it is forced to assume the shape of a roll or sliver. It then passes between two rollers, by which it is compressed into the shape of a ribbon of considerable tenacity, in which state it coils itself up in a deep tin can—there to await the subsequent process.

Looking at the various parts of this interesting machine, the attention is first engaged by the feeding cylinder, which supplies the cotton to the cards more regularly and continuously than could be effected by hands. The successive cards on the concave and convex cylinder are seen to subject the wool to several successive cardings at each revolution of the wheel; and to prevent the necessity of stopping the machine to remove the carded cotton, it is stripped off by the doffer, which removes the cotton, not in successive portions, but in one continuous fleece. Again, the removal of this fleece from the doffer, which would be both tedious and imperfect if attempted by hand-cards, is completely accomplished by the simple agency of the crank and comb.

Carding is not the only operation employed to straighten the fibre of the cotton. It may easily be conceived that the teeth of the cards will frequently lay hold of a fibre by the middle, and thus double it together, in which state it is unfit for spinning. This evil is corrected in the *drawing-frame*—an important part of the spinning machinery, for it executes work which could scarcely have been effected by human hands. The essential parts of the drawing-frame may be easily understood from description. Each drawing-head consists of three pairs of rollers, the upper one of each pair being smooth and covered with leather, the lower being fluted longitudinally. They are placed at a distance from each other, which is regulated by the staple of the cotton; that is to say, the distance between each pair of wheels is generally a very little more than the length of the fibres subjected to their action. The loose ribbon formed by the carding-machine is pulled through these rollers, and as they revolve with different velocities, the fibres pull out each other, and reciprocally extend each other to their full length.

But a not less important object of the drawing-frame is to equalise the consistency of the cardings. One carding, notwithstanding all the precautions that have been taken, will be found to have more or less of substance than another, and it is necessary to counteract this inequality by combining several of the carded ribbons, technically called *card-ends*, into one sliver. Eight card-ends are usually brought to the first drawing-head, and after passing through the rollers, they combine to form one sliver of the same density as each of them separately, thus increasing eightfold the chances of uniformity in the sliver. Four of these slivers are again subjected to the same process, and thus the chances of uniformity are thirty-two-fold those of the original card-ends; and this is continued until the last sliver may be regarded as containing parts of

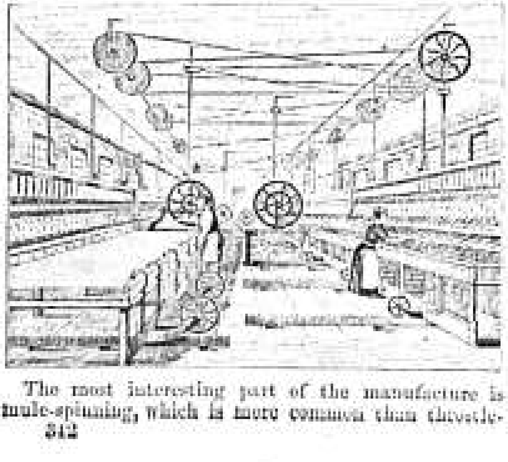
300 card-ends; but for very fine spinning, the doubling of the fibres, as the process is called, is multiplied more than 60,000 times.

The drawing-frames are fed from the tin cans containing the card-ends, and the chief duty of those who attend them is to mend or piece the feeding slivers when one of them is broken, or when one of the cylindrical cans is exhausted. A contrivance has been recently introduced to abbreviate this labour; a cylindrical weight is made to fall at intervals into the receiving can, and by pressing down the sliver, to force it to hold more than double the quantity which it would contain if the sliver were left to coil itself loosely. In the mills for fine spinning, great attention is paid to this process, because any defects left by the drawing-frame cannot be cured in subsequent operations. The labour of attending to the machines is the lightest in the cotton mill, but there are few parts which require more vigilance and care.

The next operation is the making of a roving or thin sliver about the thickness of candlewick, and giving it only so much of a twist as will enable it to hold together. The attenuation of the sliver is accomplished by rollers acting in the same way as in the drawing process, but various contrivances have been devised to give the roving just so much tension as is necessary, and no more. Arkwright invented the can-roving-frame, in which a slight twist was given to the roving by making the receiving-can revolve upon a pivot. It was necessary that the rovings, after this operation, should be wound off upon bobbins, a process injurious to their delicate texture; to obviate this evil, the jack-frame, or jack-in-the-box, was contrived, which wound the roving on a bobbin as it received its twist, instead of leaving it to coil in the can. At present, the process of roving is generally performed by the bobbin and fly-frame, an ingenious piece of mechanism.

It is not necessary to enter into any examination of the many ingenious contrivances which have been devised to render the roving-machines more perfect and automatic; the reader will best appreciate the difficulty of the operation, by bearing in mind that the process of twisting by the spindle, and winding on the bobbin, though connected in fact, are quite independent in principle, and that there is therefore a necessity for the nicest adjustment, in order that the one should be accommodated to the other.

Twist of low numbers, called *water-twist*, because it was originally worked in Arkwright's water-frame, is spun by the throstle, a machine probably deriving its name from its singing noise. It is in principle nearly the same as the drawing-frame which has been just described; it extends the rovings by the action of rollers into slender threads, and twists them by the rotation of spindles and flyers. The machinery, however, is far more simple, because the hard-twisted throstle thread does not require such tender manipulation as the delicate roving.



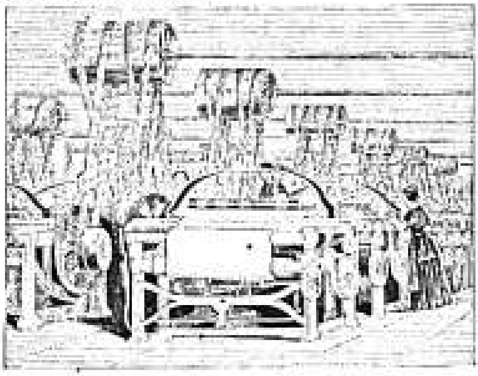
The most interesting part of the manufacture is mule-spinning, which is more common than throstle-spinning. 'Let the reader,' continues our authority, 'imagine himself in the room, a part of which is represented in the preceding cut, and it is probable that the circumstances worthy of his notice will present themselves in nearly the following order:—He will see a carriage about a yard in height, and of very considerable length, varying in different mills, bearing a row of spindles between its upper rails; it has generally three wheels, which traverse on the same number of iron guiding bars, so as to allow of its drawing out to a distance of more than four feet from the stationary frame; as it recedes from the frame, it draws with it and elongates the threads, or rather rovings delivered to it through rollers, by a series of bobbins in the creels or stationary rails. The threads, as they are elongated, are twisted by the spindles; and should any of them break, it is the duty of a boy or girl, called a piecer, to join the disunited ends as the carriage moves from the upright frame. A girl in the act of piecing the yarn is represented in the cut. When the carriage has receded to its full extent, the spindles continue to revolve until the requisite quantity of twist is communicated to the yarn. The spinner then causes the spindles to revolve backwards, until he has unwound the portion of thread which has coiled spirally round it from the point to the nose of the cop, and at the same time he lowers a faller wire, supported by hooks, as seen in the cut, so as to regulate the winding of the yarn on the cop in a proper spiral. There is great nicety required in regulating the pushing back of the carriage, for it is necessary that its rate of travelling should be commensurate with the revolution of the spindles. Three simultaneous and delicate movements have thus to be effected by the spinner as the carriage returns—he must guide the faller wire so as to insure the regular winding of the yarn on the cop; he must regulate the rotation of the spindles, of which there are often a thousand to one mule; and he must push the carriage at such a rate as to supply precisely the exact amount of yarn that the spindles can take up.

'The little piecers can only take up the ends when the carriage is within a foot or two of the delivering-roller, and they have therefore an interval of rest while the carriages traverse backwards and forwards.' The spinner, too, has a brief respite while the carriage is moving outwards from the frame. The time taken to make a stretch—that is, to draw out a thread equal in length to the range of the carriage—increases with the fineness of the yarn, and varies also according to the completeness of the machinery and the skill of the operative. The breaking of the threads depends not merely on the machinery, but to a very great extent on the atmosphere and temperature. We were in a mill during the prevalence of a sharp drying east wind, and found that it produced such an effect on the fibres of the cotton, that the threads broke faster than the piecers could mend them, and that the spinning of very high numbers at such a time was all but impossible. The rooms in which fine yarn is spun are kept at a temperature of from 70 to 80 degrees, which is not so high as to produce much inconvenience.'*

By the processes now described, the cotton has been attenuated into fine yarn on bobbins, and is now ready for being *warped*, or made into webs for the weaver. Formerly, all was wove by the hand; but the introduction of the power-loom, by which the work is altogether done by machinery, has superseded hand-loom weaving, except for some particular fabrics. 'In one respect,' observes the above authority, 'the power-loom has a very obvious advantage over the hand-loom; the batten, lathe, or lay, to which the reed is attached, drives home the weft to the rest of the web, after it has been shot from the spindle; now a weaker or stronger blow of this lathe alters the thickness of the cloth, and after any interruption, the most experienced weaver finds it difficult to commence with a blow of precisely the same force as that with which he left off. In the

* England in the Nineteenth Century—Lancashire. London: Howe and Parsons. 1842.

power-loom, the lathe is easily adjusted to give a steady certain blow, and when once regulated by the engineer, it moves with unvarying precision from the beginning to the end of the piece. Hence power-loom cloth is always of a more equable and regular texture than that woven by hand. Power-looms are generally placed in long apartments, and lighted from the top by a single range of windows to every row of looms. The weavers, or rather the tenters, have very little to do besides watching the machinery, and correcting any defects in the materials to be woven. As the labour is light, it is usually performed by women, or young persons; and we were informed that the business is so simple, as to be easily learned in a month or six weeks.' In the annexed engraving is presented a view of the interior of a power-loom apartment. All the looms are of iron, and moved by belts from shafts, the shafts being turned by steam or water power.



The subsequent processes of bleaching, dyeing, and printing have been already adverted to (pp. 311 and 339); and here we need only observe, that it is customary to *singe* the majority of calico fabrics, with a view to remove from their surface all loose and superfluous fibres. This is effected before printing by passing the web with rapidity over heated copper rollers, or by bringing it in contact with the flame of gas, as in Hall's beautiful singing apparatus. In printing, the reader will remember that the patterns are transferred to the surface of the fabric by blocks, copper-plates, or engraved cylinders, by which the colours are directly printed, or by which mordants are so applied, that when the calico is immersed in a colouring-bath, the colour only adheres upon the parts to which the mordant has been previously applied. Calico-printing in all its departments—from the preparation of the dyes and designs, to their ultimate finish on the fabric—is an art of the highest ingenuity and perfection. The old practice of *block-printing* by hand was slow, expensive, and imperfect; the new mode of *cylinder-printing* is rapid, cheap, and undeviatingly accurate. The one bears to the other the same relation that hand printing does to the steam printing-press; the one producing yards merely, while the other is throwing off miles! To be fully comprehended, the process would require to be seen—the original execution of the designs, the transferring and engraving of them on cylinders of steel, the multiplication of these engraved cylinders by Perkin's method, the mode of applying the colouring matter with such nicety and perfection, the subsequent processes of getting rid of all superfluous hues and stains, and the imparting of the ultimate gloss—are all triumphant manifestations of chemical and mechanical skill.

The *Cotton* manufacture, notwithstanding that the raw material can be obtained only in distant parts of the earth, has risen in Great Britain, during seventy years, from about two hundred thousand pounds of annual produce, to the enormous sum of thirty-six millions, of which about two-thirds is exported. Cotton goods are manufactured chiefly by means of machinery, in large factories, of which, in 1839, there were 1603 in England and Wales, 192 in Scotland, and 24 in Ireland; the chief seats of the manufacture being Manchester, Glasgow, and Paisley. These factories gave employment, in the same year, to two hundred and fifty-nine thousand persons, of whom upwards of twelve thousand were below thirteen years of age. Cotton goods are also manufactured by hand-loom weavers, of whom a considerable number continue to strive against the overpowering competition of machinery.

SILK.

This beautiful and unrivalled material is the produce of a plain-looking, greedy, leaf-devouring insect—the caterpillar of the silk-moth or *Bombyx mori*. It is thus directly of animal, though indirectly of vegetable origin; the glutinous caoutchouc principle of the leaves furnishing the insect with the basis of its silken fabric. The silk-worm is supposed to have been indigenous to China, at least the discovery was there first made, that the product of this little creature's operations could be elaborated into articles of human attire, richer and more beautiful than any to be derived from other sources. At an early period, a considerable commerce was established in silk between eastern and western Asia, from which latter quarter it was conveyed to Europe; but not until the sixth century of the Christian era, was it distinctly known by Europeans that the splendid tissues which they had worn for more than a thousand years, and which they had even partially manufactured from the raw transported material, were the product originally of a caterpillar. The first silk-worms seen in Europe were brought from China in the year 552, by two Persian monks, who had gone thither as Christian missionaries, and who contrived to secrete a number of the eggs in a cane, and to escape with them to Constantinople. From these few eggs have sprung all the successive generations of the insect which have supplied silk to Europe from that period to the present time.

Like many other insects, the silk-worm passes through the successive stages of egg, caterpillar, chrysalis, and moth. The eggs when dropped are about the size of a grain of mustard seed; their colour being then yellow, but afterwards becoming of a bluish hue. In temperate climes, and with proper precautions, these eggs may be preserved a long time without hatching or rotting. When first hatched, the caterpillar or larva has the appearance of a small black worm, about a quarter of an inch in length. On being brought forth, it almost immediately begins searching for its natural food (the leaves of the mulberry tree), which it devours with avidity. In about eight days, the head grows much larger, and the larva is attacked by its first sickness. This lasts for three days, during which time it refuses food, and remains perfectly motionless. It then begins to cast its skin, which it accomplishes after much pain and exertion. So complete is this moulting, that not only the covering of the body, but of the feet, the skull, the jaws, and even the teeth, are cast off. The insect then begins to feed with recruited appetite, and continues for five days, when a second moulting takes place, exactly like the first; and so on through a third and fourth course, the animal progressively increasing in size. After the last moulting, it feeds voraciously, and increases rapidly in size during ten days, when it has attained its full growth—being then generally from two and a half to three inches long. At this period it begins to leave off eating, and soon entirely ceases—becomes restless and uneasy, and looks out for a convenient place to commence its spinning labours. Its colour is now a light green; but as the material for forming the silk gets digested, it becomes glossy, and somewhat transparent. The silky substance is secreted in the form of a fine yellow transparent gum, in two vessels, which are wound, as it were, on two spindles in the stomach.

When the animal has found a suitable corner or hollow for the deposition of its silken ball, or cocoon, it begins to spin thin and irregular threads at first, the silk being drawn through two minute apertures beneath the jaws. In four days the cocoon is completed, the labourer remaining of course always on the inside of the sphere it is forming. The cocoon resembles a pigeon's egg in shape and colour, but is not quite so large. As may be imagined, the insect, from the continual emission of the gummy silk, together with the want of food, gradually contracts in size; and if the cocoon be opened after it is finished, the animal will appear in the form of a chrysalis, with a smooth brown skin—its former covering lying beside it. The silk-worm goes through all the transformations above-mentioned in the space of from twenty-two to thirty days, according to the temperature to which it is exposed. The cocoons containing the insects intended to be preserved for laying eggs are left undisturbed, and the chrysalis gradually undergoes a transformation into the state of a moth. This change is accomplished in the space of about twenty days; and the moth, by great labour and ingenuity, works its way through the cocoon. It then appears as a large moth, of a grayish-white colour, furnished with four wings, two eyes, and two black antennæ, or feelers, of a feathery appearance. This moth enjoys its existence only a very short time. It remains almost entirely fixed to one spot, the wings never being used for the purpose of flying, but only in assisting it in fluttering while seeking its mate. When this object is attained, the female deposits her eggs, and both end their being in the course of two or three days afterwards. The number of eggs laid by the female varies from 300 to 500; and these eggs, in about six months after, produce larvæ as before. It will scarcely be credited, but is nevertheless true, that in a few short weeks—that is to say, from its being hatched to the period of its full-grown size—the weight of the silk-worm is increased more than nine thousandfold.

The product of the silk-worm's labours, such as they have now been described, was a thing of too much value and importance not to attract the attention of man to the means of improving and increasing it. The Chinese have long pursued artificial modes of insuring the regularity of the silk produce; in Europe, and in many other parts of the world, for the last thousand years, it has also been the object of the most anxious and unremitting attention. It has been stated that these insects feed on mulberry leaves alone: the culture of the mulberry tree (*morus*) by pruning, grafting, and the like, is therefore an essential preliminary. Mulberry trees have often two crops of leaves in the year, and indeed, in very warm climates, the tree produces foliage all the year round, thus permitting the artificial breeders of silk-worms to obtain several crops of silk a-year. About thirty pounds of foliage may be procured from a healthy well-grown tree. Having an ample provision in expectancy of mulberry leaves, the silk-worm itself is the next object of care. The attention required in the management of these insects is indeed great and incessant. If the eggs, for example, from which the brood of the season is expected, be hatched a few days too soon, by a slight mismanagement of temperature, the whole hopes of the cultivator will be ruined. His leaves and his worms must be ready for one another to an hour almost. It is by confinement of the moths to particular spots that the eggs are procured, the insect being necessitated by situation to deposit them on paper or on cloths. They are then gathered, and placed in such situations as may prevent them from being hatched until the mulberry leaves are ready. When the proper season for bringing on the hatching arrives, the eggs are separated from one another by washing. They are then dried, and taken to the store-room, where they are exposed to a gradually increasing temperature, until they grow white, which is the signal of the approaching outbreak of the worm. Muslin is now laid over the eggs, and above this muslin a quantity of mulberry leaves. As soon as the larvæ are hatched, they crawl through the muslin, and attach themselves to the leaves.

The feeding-room is the place to which the worms are now conveyed. This apartment should be dry and well ventilated, but at the same time closed against the access of ordinary insects. It should contain proper shelves also for the reception of the worms. Young and tender leaves are given to the worms at first. Through the whole period of their transmutations, their food is chopped small, a great saving of leaves being thus effected. They are fed regularly three or four times a day, and consume, during the period of their moultings, a quantity of food which would appear wonderful, did not one remember the vast increase which takes place in their bulk. The same number of worms which will be satisfied with one pound of leaves previous to their first moulting, will consume one hundred and eighty-three pounds during their last feeding interval, before the commencement of their spinning. For their convenient performance of the latter operation, bushes of broom or brushwood are erected on the shelves, being usually bent over in an arched form. In clefts of these bushes the worms arrange themselves, and there they go through the process of manufacturing their cocoons. In three days their labour is finished, and in a few days afterwards the cocoons are carefully gathered from the bushes. One-sixtieth part of them is set aside for breeding, and the remainder are exposed to a strong heat, in order to extinguish the vitality of the chrysalis within, previous to reeling off the silk. When the moth breaks out, care is taken to make it deposit its eggs where they can be gathered, and laid aside for the next season. * The moth soon dies, having fulfilled its object—no mean one—in creation. It seldom exists beyond a couple of days, taking the while no food that can be observed.

It has been stated that one cocoon sometimes yields filaments a mile in length. More commonly, however, six hundred yards is about the extent of the largest cocoons. Twelve pounds of cocoons yield one pound of silk, by the ordinary computation. The silk differs considerably in quality, and the cultivators sort the cocoons, accordingly, into distinct lots, being guided by the observation of colour and other circumstances. The cocoons being prepared and assorted, the material is ready for being *reeled*. The great point in reeling is to make the thread of as even a thickness as possible: *perfect equality* is scarcely attainable. An experienced reeler, with the assistance of a girl to turn the wheel, can with ease wind off a pound of silk in a day. Six or eight pounds may be wound off in a day, but a coarse, foul, and ordinary silk will be the produce. The modes of reeling silk in Italy and France are very different, but that of the former is reckoned the best. The *floss*, or inferior silk, of the cocoons is not reeled, but spun, after being mixed with the silk of the injured or inferior cocoons.

After reeling, the next process for preparing the raw silk for the weaver is that of *throwing*. It has already been mentioned that this branch of the art was introduced by Sir Thomas Lombe into England in 1718, from models surreptitiously obtained by him at Piedmont. Considering the remarkable perfection now attained in this country in the science of mechanics, it will not appear strange that these throwing-mills have been long since superseded in Great Britain by subsequent improvements.

Raw silk, preparatory to weaving, must be made to take one of three forms—respectively termed *singles*, *tram*, or *organzine*. *Singles* is merely the raw silk twisted, in order to give more firmness to its texture. All raw silk, for whatever manufacture designed, must undergo this process. *Tram* is formed by twisting together, not very closely, two or more threads of raw silk, and this generally forms the weft, or transverse threads of the web. *Organzine*, which is principally used for warp, is produced by a very elaborate process, of which it would be impossible to convey any correct idea to the general reader without the aid of a diagram. The principle of the process, however, may be generally stated to be like that of making rope, where the combined strands are twisted in an opposite direction to that given to the separate threads, and this is accomplished by giving a reverse motion to the machinery; whereas singles and trams are twisted only in one direction, similarly to twine, or to the individual strands of which the larger rope is made. Silk thread intended for organzine is in the first process twisted in a left-hand direction. The organzine, when finished, is transferred to reels instead of bobbins, whence it is made up into skeins, and sorted for sale or use. Previously to this, however, the reels are subjected to a process of steaming for two or three minutes, in order to prevent any after-crinkling. The silk thus thrown is called hard silk, and must be boiled for some hours, with a quantity of soap, in order to discharge the gum, and thereafter well washed in a current of clear water to discharge the soap, after which the silk appears soft and glossy. Besides these varieties, there is another called *sewings*, which are compound threads of silk, wound, cleaned, doubled, and thrown, with especial reference to their ultimate use for sewing. *Marabout* is a peculiar kind of thrown silk, generally formed of three threads of raw silk; and being white as it comes from the cocoon, it takes the most delicate shades of colour at once without the discharge of its gum.

Silk is woven into various fabrics, plain and figured, by the Jacquard loom, and also into velvets. The fine soft pile of *velvet* is produced during the process of weaving, by inserting short pieces of thread doubled under the shoot or weft, and which stand upright in such a way, and so close together, as entirely to conceal the interlacings of the warp and shoot. In the production of every yard of velvet, six yards of pile at least are used. The loops of the doubled threads intended for the pile are supported by grooved wires, and the loops are afterwards divided by running a sharp instrument, called a *trevat*, along the groove. This is done by the hand, and of course requires great dexterity, as the slightest deviation from the proper line would infallibly injure, if not wholly destroy, the silk. It is considered a good day's work for one man to weave one yard of plain velvet, for which he is paid about five times as much as for weaving plain silks. *Damasks* of the most exquisite and elaborate patterns are of course produced by the Jacquard loom, and in some instances as many as 1200 or 1400 changes or cards are required for their completion. *Satin* and *satinette* are peculiar kinds of silk-twill, and exhibit in the most perfect manner the lustre of the material of which they are composed. *Brocade* is the general term for tissue of silk with gold or silver threads—a stuff of exceeding richness, and at one time much in fashion, but now seldom or ever sought after. *Lutestring*, *Gros de Naples*, *Persian*, &c. are names given to plain fabrics of silk, differing little from each other except in their thickness, or in the quality of silk. *Tabbaret*, *tabine*, *serge*, *levantine*, &c. are twilled fabrics, occasionally relieved with satin-stripes and checks; they are to be had of all qualities and colours. *Crape*, crisped or smooth; *gauze* in all its varieties; *ribbons*, of whatever fabric; and *bandanas*, are too well known to the English reader to require description. In fact, it is almost impossible to enumerate the various stuffs woven from silk, either for the purposes of clothing, upholstery, or ornament; but an idea of its importance may be formed from the fact, that scarcely an individual, even in humble life, but can boast of using it to some extent, either for the purposes of dress or of ornament.

In Britain, the annual value of the silk manufacture is estimated at nearly ten millions sterling—more than nine-tenths of which are for home consumption. We draw our chief supplies of the raw material from Bengal; from Italy, which produces about eleven million pounds annually; from China, where, next to tea, it is the staple article of export; from Turkey; and in smaller quantities from Holland, the United States, and other countries. The foreign states in which the manufacture chiefly exists are China, India, Italy, Switzerland, and France; the latter kingdom alone producing fabrics to the annual value of about eight millions sterling. There are no very accurate data as to the amount of silk stuffs consumed in the various countries of the world; but considering how generally they are worn in Oriental as well as in European countries, and reflecting upon the increasing demand by a civilised population in the Americas, we cannot be far wrong in stating that a million and a half of human beings derive their sole support from the culture and manufacture of silk, and that it creates an annual circulating medium of between thirty and forty millions sterling! So much for the importance of a humble insect which, if it had been shown to our ancestors a few hundred years ago, would have been as little valued as the earth-worm beneath their sandals.

WOOLLEN.

Wool, if we accept the definition of a recent authority, 'is a kind of soft hair which forms the external covering of several ruminating animals, particularly the sheep, llama, Angora goat, and the goats of Thibet. The distinction between wool and hair is rather arbitrary than natural, consisting in the greater or less degrees of fineness, softness, and pliability of the fibres. When the fibres possess these properties so far as to admit of their being spun and woven into a texture sufficiently pliable to be used as an article of dress, they are called wool.' The sheep, according to this definition, is the wool-bearing animal par excellence; different breeds yielding wools of different degrees of length and fineness, and this dependent, in a great measure, upon the food, climate, and other external conditions they enjoy. The finest of all wools is that from the goat of Thibet, of which Cashmere shawls are made; the finest of European wools is the produce of the Merino sheep—the Spanish and Saxon breeds taking the precedence; the Merino sheep, as now naturalised in Australia, furnishes also an excellent fleece; but all varieties of sheep-wool, reared either in Europe or Australia, are inferior in softness of feel to that grown in India, and also to that of the llama of the Andes. The best of our British wools are inferior in fineness to any of the above-mentioned (being nearly twelve times the thickness of the finest Spanish Merino); but for the ordinary purposes of the manufacturer they are unrivalled. Wool shorn from the living animal is known as *fleece-wool;* while that pulled from the skins of those slaughtered is termed *pelt-wool*. *Lambs'-wool* is generally softer than that of the full-grown animal, and is of course applied to finer purposes. The fineness of the fleece varies on different parts of the animal, and therefore requires to be 'sorted,' which may be considered the first process in the manufacture of woollen fabrics. The next step is to free it from dirt and foulness of various kinds, and in particular from the grease or oil with which it is naturally imbued. For this purpose it is repeatedly washed and combed, after which it becomes soft, clean, and elastic.

Independent of the quality of fineness, there are two sorts of wool which afford the basis of different fabrics, and are somewhat differently treated in the process of spinning, for which the combed material is now ready: these are the *long* wool and the *short*. Long wool is that in which the fibres are rendered parallel by the process of combing; it is also known by the name of worsted, and is the material of which camlets, bombazines, &c. are fabricated. Short wool is prepared by carding, like cotton, and is used in different degrees of fineness, for broadcloths, flannels, and a multitude of other fabrics. This wool, when carded, is formed into small cylindrical rolls, which are joined together (or by improved machinery into one continuous roll), and stretched and spun by a *slubbing* or *roving* machine, and a jenny or mule, in both of which the spindles are mounted on a carriage, which passes backwards and forwards, so as to stretch the material at the same time that it is twisted. On account of the roughness of the fibres, it is necessary to smear them with oil, to make them move freely upon each other during the spinning and weaving. After the cloth is woven, the oily matter is removed by scouring, in order to restore the roughness to the fibres, preparatory to the subsequent process of milling. In articles made of long wool, the texture is complete when the stuff issues from the loom. The pieces are subsequently dyed, and a gloss is communicated to them by passing them between heated metallic surfaces. But in cloths made of short wool, which is generally dyed before being spun, the weaving cannot be said to complete the texture. When the web is taken from the loom, it is too loose and open, and consequently requires to undergo another operation, called *fulling* or *milling*. This is performed by a fulling-mill, in which the cloth, being first freed from its oil by the use of fullers' earth and other detergents, is immersed in water, and subjected to repeated compressions by the action of large beaters, formed of wood, which repeatedly change the position of the cloth, and cause the fibres to felt, and combine more closely together. By this process the cloth is reduced in its dimensions, and the beauty and stability of the texture materially improved. This tendency to become thickened by fulling, is peculiar to wool and hair, and does not exist in the fibres of cotton or flax. It depends on the fibres or hairs being branched or serrated, which admits motion in one direction, but not in another. It thus promotes entanglements of the fibres, which serve to shorten and thicken the woven fabric.

The nap, or downy surface of broadcloth, is raised by a process which, while it improves the appearance, tends somewhat to diminish the strength of the texture. It is produced by carding the cloth with the barbed or hooked fruit-cone of the common teazle (*Dipsacus fullonum*), which is cultivated in England for the purpose. This operation extricates a portion of the wool, and lays it in a parallel direction on the right surface of the fabric. Machinery has been employed as a substitute for the teazle, but hitherto with very indifferent success. The nap thus formed is then cut off to an even surface by the process of *shearing*. This is performed in various ways; but in one of the most common methods, a large spiral blade revolves rapidly in contact with another blade, while the cloth is stretched over a bed or support, just near enough for the projecting filaments to be cut off at a uniform length, while the main texture remains uninjured.

The manufacture of cloth, as thus described, is carried on in three different modes in England—that of the master clothier, who buys his own wool from the importer, and afterwards gives it out to be manufactured, either in factories or at private houses; the factory system, by which every process of the manufacture is carried on under the same roof; the last is the domestic system, in which private weavers purchase wool from the dealer, and employ themselves, wives, children, and sometimes several journeymen, in the various manufacturing processes under their own roofs. The factory system is evidently the one best adapted for carrying the manufacture to its utmost extent. The mode of disposing of the various woollen cloths is different in Yorkshire and the west of England, but in both upon a scale in keeping with the magnitude of the manufacture and the commercial importance of the kingdom. In the west of England, the goods are exposed at periodical markets or fairs; in Yorkshire, in cloth-halls, of which there are three at Leeds, besides others at Halifax, Bradford, Huddersfield, Wakefield, &c. These halls consist of long walks or galleries, through the whole length of which the master-manufacturers have their stands in double rows. Between these the merchants pass, and make their purchases. At a certain hour a bell rings, and the market closes, those goods which are purchased being then carried to the merchants' quarters, and those unsold remaining in the stands. The goods are bought in their undressed state, the merchant afterwards getting them finished off himself. Dressing and finishing has of late years become a business entirely distinct from the manufacturing department, and in which, to attain perfection, has been the chief aim of the Yorkshire merchants. So proficient, indeed, have they become, as to defy any but experienced judges to distinguish their cloths from the more costly fabrics of the west of England.

Woollen fabrics manufactured as above are generally known by the name of *cloths*, of which there are several varieties in common use, as broad, narrow, and habit-cloths; all of which are worked plain, and only differ in width or in quality. When twilled, they are termed *kerseymeres, kerseymerettes, pelisse-cloths, &c.*; and when peculiarly finished—as, for example, with long, tufted, or velvet naps—they are known by such designations as *dreadnought, frieze, swanskin, plush*, and *duffle*. *Tweed* is a light structure, now largely used for trousering; *flannels*, of whatever variety, are all loosely woven; *baize* is a kind of flannel with a tufted nap; and *blankets*, of which there are many varieties manufactured in different parts of the country, are also loosely woven and finished with a long nap raised by rollers covered with brass pins. Besides the manufacture of cloths, blankets, and flannels, the department of woollen fabrics comprehends *carpets* and *hosiery*, two very distinct but important branches. Three kinds of carpets are usually made—Venetian, Kidderminster, and Brussels. Venetian carpeting is a plain fabric, composed of thick linen woof on a woollen warp, and is employed chiefly for stair or lobby coverings. The Kidderminster carpeting is by far the most common. It consists of two woollen webs, woven together, and intersecting each other at particular parts, so as to produce definite figures of different colours. The manufacture of this species of carpets has been long carried on with advantage in different parts of Scotland. Brussels carpets possess a basis of strong linen threads, on which the pattern in woollen is thrown up in loops, which are kept firm by small rods. When the web is woven, the rods are pulled out, leaving a soft surface of the closed ends of loops. Latterly, a great improvement has been made in Brussels carpet-weaving, and which has also been adapted for shawls. Instead of using threads of any particular colour throughout, and throwing up the threads as they were required to form the pattern, the custom is now to dye the threads with different colours, suitable to the pattern required. Thus a single thread may be dyed in patches of red, yellow, black, or any other colour, and it performs its part in the pattern through its entire length; the saving of material by this ingenious mode of dyeing is immense.

When long or combing wool is twisted to a certain degree of hardness, it receives the name of *worsted*; and the manufacture of certain fabrics of this kind is as extensive as that of soft woollen goods. Many of the variegated cloths called *tartans* are made of worsted; and so likewise are *tapestries*, and some kinds of *stockings*. The stocking or hosiery manufacture, generally, is conducted by means of stocking-frames and hand labour; the frame having been in universal use since it superseded knitting on the large scale about seventy years ago. Stocking-knitting or weaving is a distinct art from cloth-weaving, inasmuch as the fabric is not formed of a warp and woof, but consists of one continuous thread, which is formed into a series of loops in successive rows, the loops of each row being drawn through those of a former row, and so on. Besides stockings and socks, waistcoats, nightcaps, drawers, and other under-clothing are made in this manner—all coming under the general designation of *hosiery*, from the Saxon word *hosa*, hose or stockings. Though stocking-weaving has in a great measure superseded the old process of knitting, the latter is still largely prosecuted by females in Germany, in the Pyrenees, in the north of Scotland, and especially in the Shetland isles, whence shawls, plaids, hose, and other articles of exceeding softness and beauty, are exported to the large towns of the kingdom. In this list may be added what are termed *stuffs*—a term which properly includes all the thin fabrics of worsted, as shalloons, florenteens, moreens, calimancoes, camlets, merinoes, &c. They are woven either plain, twilled, or figured, and differ from other woollen cloths in having no nap or pile. After the operation of weaving, each side of the piece is drawn rapidly over a convex plate of red-hot iron, to singe off the superfluous fibres of the wool; it is then rolled tight, soaked in hot water, and boiled. Afterwards it is scoured, stocked, or milled, and pressed between rollers to take out the moisture; it is then dyed; dryed by passing between heated cylinders; and ultimately subjected to hydraulic pressure.

Of *ornamental fabrics*, such as tapestry, sewed-work, knitting, netting, and crotchet, our space will not permit any lengthened description. The first of these is more of a textile nature than the others, although still closely allied to the achievements of the needle. The following is given as the mode of fabrication at present practised in the celebrated manufactory of the Gobelins:—The frame or loom is formed of two upright pieces, at the top and bottom of which two large rollers are fixed horizontally: round the upper of these rollers are wound the longitudinal threads, or warp, composed of twisted wool—the work, as it is executed, being gradually wound round the lower. On the inner side of the upright pieces, several contrivances (here unnecessary to describe) are placed at different points, for separating these threads more or less from one another, in order to admit the cross threads or woof, which are to form the picture. As a sort of guide for the artist to introduce the cross threads in their proper places, he traces an outline of his subject on the threads of his warp in front, which are sufficiently open to enable him to see the painting behind.

For working the tapestry three instruments are required—a broach, a reed or comb, and an iron needle. The first is formed of hard wood, about seven or eight inches in length, and two-thirds of an inch thick, ending in a point with a small handle, round which the wool is wound, and serving the same purpose as the weaver's shuttle. The reed is also of wood, eight or nine inches long, and an inch thick at the back, whence it gradually decreases to the extremity of the teeth, which are more or less divided, according to the greater or less degree of fineness of the intended work. The needle is in shape similar to a common needle, but much larger and longer; it is used to press close the wool, when there is any line or colour that does not set well. The artist places himself behind the frame, with his back towards the picture he is about to copy; he first turns and looks at his design, then taking a broach of the proper colour, he places it among the threads of the warp, which he brings across each other with his fingers, by means of the coats or threads fastened to the staff; this he repeats every time it is necessary to change his colour. Having placed the wool, he beats it with his reed; and when he has thus wrought several rows, he passes to the other side to see their effect, and to properly adjust them with his needle, should there be occasion.

Knitting, netting, crotchet, and sewed work, now so universally practised by ladies as a light and elegant employment, depend upon the principle of looping one continuous thread, or system of threads, and not upon that of fabricating by warp and woof. The articles so produced admit of an almost infinite variety of design and pattern; and where the colours are in harmony, and the figures in keeping with the character of the piece, effects of a very wonderful kind—considering the simple nature of the materials—are not unfrequently obtained.

As to the *statistics* of British woollen manufactures, it is very difficult to arrive at anything like accurate data. The goods pass and repass through so many hands that the real amount is apt to be exaggerated; while knitting, both of useful and ornamental articles, is still too largely carried on to be altogether overlooked. In 1839, the manufacture was carried on by 86,411 persons; in 1738 factories, of which 1595 were in England and Wales, 112 in Scotland, and 31 in Ireland—jointly realising an annual value of about twenty-five millions. This amount includes of course all sorts of woollen and worsted stuffs—as broadcloths, tweeds, blanketings, flannels, carpets, hosiery—in fine, all articles into which wool enters as the main ingredient. Of such goods, to the value of eight and a quarter millions are now annually exported.

FELT—HATS—STRAW-PLAIT.

Felting is the process by which different kinds of hair, fur, or wool, are blended into a compact texture, without undergoing either spinning or weaving. It depends upon the serrated structure of the fibre—a structure which has already been noticed under 'milling,' and which may readily be observed by passing a hair through the fingers in opposite directions. This peculiar structure allows the fibres to glide amongst each other; so that when the mass is agitated, the anterior extremities slide forward in advance of the posterior half, and serve to entangle and contract the whole together. Vegetable fibre being of a smooth linear texture throughout, cannot be felted; and among animal fibres, those are best adapted for the process which are naturally curled or wavy, and have the deepest serratures. Felting is best seen in the making of beaver or stuff hats, to which we shall shortly advert.

The materials commonly used for *hat-making* are the furs of the beaver, seal, hare, and rabbit, and the wool of the sheep. The furs of most animals are mixed with a longer kind of hair, from which they have first to be separated; they are then cut off with a knife, and 'sorted' by a blowing machine, which carries the lightest and finest fibres to the extremity of a hollow trunk or funnel, while the heavier and coarser are left at proportionate distances from the fanners, or source of the current. The materials to be felted are next intimately mixed by the operation of *bowing*, which depends on the vibrations of an elastic string; the rapid alternations of its motion being peculiarly well adapted to remove all irregular knots and adhesions among the fibres, and to dispose them in a very light and uniform arrangement. This texture, when pressed under cloths and leather, readily unites into a mass of some firmness. A piece sufficient to form a hat is next taken up, and dipped in warm water, containing a little sulphuric acid, and moulded into a large conical shape, which is afterwards reduced in its dimensions by working it several hours with the hand, for the purpose of further thickening and fulling it. At this stage any knots are removed, and fresh felt here and there added; the hat is then shaped, water-proofed by a lac varnish, tied upon a block, dyed, stiffened by the application of a solution of glue, steamed, brushed, and ironed. The brim is then trimmed, and it is ready for lining and binding. The material felted as above described generally consists of a variety of furs, as those of the hare, rabbit, and beaver, lambs'-wool, goat and camels' hair, cotton, and silk. Most manufacturers make what they term a foundation of coarser material, to which they apply beaver or other fine furs as a *plate* or finish. What are called *beaver* hats are thus completed with the fur of that animal; while in *stuff* hats this fur is altogether omitted. *Silk* hats have a foundation of felt, chip, straw-plait, whalebone, or pasteboard, upon which silk-plush is afterwards applied. From their cheapness, durability of colour, and lustre, they have lately come much into use, though scarcely so durable, or so soft and elastic for the head, as the old beaver. The best variety of the silk hat is that in which a fine Paris plush is fixed upon a beaver body. *Gossamer* hats, for summer wear, are those in which the foundation or body is of willow-chip or other light material, with a plush of floss-silk.

Felt cloth, manufactured much in the same manner as felt for hats, is a fabric employed for several economical purposes. At one time it excited considerable expectation as a substitute for woven woollen-cloths, and perfect imitations of these were produced, but they were found deficient in firmness and durability. More recently a pneumatic process of felting was introduced, of which better hopes are entertained. The mode is as follows:—Into an air-tight chamber is put a quantity of flocculent particles of wool, which, by a kind of winnowing wheel, are kept floating equally; on one side of the chamber is a network, or gauze of metal, communicating with another chamber, from which the air can be abstracted by an exhausting syringe or air-pump; and on the communications between the chambers being opened, the air rushes with great force to supply the partial vacuum in the exhausted chamber, carrying the flocculent particles against the netting, and so interlacing the fibres, that a cloth of beautiful fabric and close texture is instantaneously made. The only objection to cloth of this kind was its rawness, or liability to shrink after being wetted; and for this reason, we believe, it has never come into anything like use for clothing. Coarse feltings, variously treated, are used for roofing, underlaying copper-sheathing, and other analogous purposes; and for these ends their cheapness renders them specially available; but where elegance and durability are sought to be combined, as in dress and household furnishings, woven fabrics must ever take the precedence.

Straw, plaited, or otherwise worked into a fabric, is in use in almost every country as a material for a light and ornamental head-dress. Many of the tropical grasses are eminently fitted for this species of manufacture, and thus navigators often bring from the Indian Archipelago and South Sea Islands hats, fans, baskets, and other articles, exhibiting a beauty of texture and intricacy of design which the most expert straw-plaiter in Europe could scarcely surpass. It is to straw-plaiting as a branch of civilised industry, however, that we would now direct attention; and for this purpose present the following abridged exposition from the 'Encyclopedia of Domestic Economy:'—*Dunstable* hats are made of whole straw, plaited in long narrow stripes or ribbons, which are afterwards sewed together in the form of a hat or bonnet. The weight and clumsy appearance of these bonnets first suggested the idea of splitting the straw into stripes; but it was a considerable time before a method was invented of performing this in a perfect manner. *Split straw* is an elegant manufacture brought into use about forty years ago, and has now become very general for women's bonnets. The straw of wheat or of rye is cut at the joints; and the outer skin being removed, it is sorted into small bundles, and is next split by means of a very simple instrument, and delivered to be plaited. The plait is sold by the score yards, and about three-score and a half will make an ordinary-sized bonnet. It is sewed by the bonnetmakers, and then blocked, which is a laborious process; and after being pressed, wired, and lined, is ready for sale. There are markets in the plait-districts for the sale of straw, plait, and bonnets; the best market for the latter is St Albans. The various forms of bonnets into which the straw-plait is worked up, varying continually with fashion, baffles all description, and is a subject well understood. Straw is bleached, and straw-hats cleaned, by putting them into a cask into which a few brimstone matches are placed lighted. The fumes of the sulphur have the effect of destroying the colour, or whitening the straw. The same effect may be produced by dipping the straw into the chloride of lime (common bleaching powder), dissolved in water, an article which may now be procured at any large chemist's. Of the straw-hats, the *Leghorn* are the most highly prized, as the finest in the world; these are made in the neighbourhood of Florence, Pisa, the district of Sienna, and the upper part of the vale of the Arno, and are exported from Leghorn. The straw is produced from a small kind of wheat, cultivated on a poor soil, and bleached like flax; it is remarkable for its strength and whiteness; the plait is extremely regular, and the straw is not split. Attempts have been made to grow this kind of wheat in England; but hitherto without success. About twenty years ago a firm established straw-plaiting in the Orkney Isles, and adopted rye-straw as the material. At first there seemed some prospect of success; but it does not appear that the competition of foreign-grown straw could be successfully met. Various other materials besides straw are used for making light hats. *Chip*, which is thin strips of wood made by a plane, is employed; the *willow* is found to answer well, and these strips are woven with a loom into a kind of twill or diamond tissue, and afterwards bleached like straw.

Of straw-plait as a branch of industry, it has been observed that 'there is perhaps no manufacture more deserving of encouragement and sympathy, as it is quite independent of machinery, and is a domestic and healthful employment, affording subsistence to great numbers of families of agricultural labourers, who, without this resource, would be reduced to parish relief. By the estimate of an intelligent individual, intimately acquainted with the manufacture, it is considered that every score of plait consumes a pound of straw, in the state of which it is bought of the farmer; that, on an average, every plaiter makes fifteen yards per day; that in the counties of Hertford, Bedford, and Bucks, there are, at an average, 10,000 scores brought to market every day, to make which 13,000 persons, women and children, must be employed. In Essex and Suffolk it is estimated that 2000 scores are the daily produce; to make which about 3000 persons more must be employed to convert these quantities into bonnets. Including other places where the manufacture is carried on in England, there are perhaps in all about 30,000 persons engaged in it.'

PAPER.

The earliest kind of paper, or material on which writing was performed, of which we have any account, was the *papyrus*, used by the ancient Egyptians, and hence our modern word *paper*. The papyrus was a plant, from which thin fibrous membranes were stript, and being pressed together, they formed a rude species of small sheets. The Chinese are said to have understood the art of making paper from the pulp of rags in very early times; but whether the European mode of making paper was derived from that quarter, is not clearly known. The art was introduced amid the obscurities of the middle ages, and most likely through the ingenuity of the Arabians. In the beginning of the fourteenth century, a paper-mill was established at Nuremberg, in Germany; and in 1588, a mill was erected at Dartmouth, in England. Little progress was made, however, in the manufacture of paper in this country, it being supplied, till within the last seventy years, principally from France and Holland.

The principle on which paper is made is very simple. A portion of linen cloth is ground to pulp; this pulp is shaken in a fine wire sieve, so as to settle in a thin cake, or sheet; the sheet is pressed, in order to squeeze out the liquid; and when dry, we have a sheet of paper. Instead of new linen cloth, rags, for the sake of economy, are always employed; and the more substantial the rag, so is the paper the stronger in texture. The quantity of rags produced in Great Britain and Ireland being altogether insufficient to supply the demand for paper, large importations take place from continental Europe, chiefly Germany. Cotton rags, or the refuse cotton of factories, are also employed in the paper manufacture; but only for inferior sorts, or as an alloy, which is not always justifiable. Any vegetable fibre, indeed, may be used in the fabrication of paper, and attempts (of which we have now a fair specimen before us) have recently been made to manufacture it from the straw of the oat and barley. The processes of preparing the rags, making by hand, and making by machine, may be respectively noticed:—

Preparation of the Rags.

After the rags arrive at the mill, they are picked and sorted into four or five qualities. All substances not suited for paper-making, or which might injure the machinery—such as pins, buttons, pieces of silk and woollen cloth—must be carefully removed. This greatly facilitates the work of the cutters, who have also to see that the rags are sorted into their proper parcels. In cutting, small table frames are used, the upper surfaces of which are composed of wirecloth, containing about nine meshes to the square inch. In the centre of these tables a knife or short scythe is fixed, in a slanting direction. Against this knife the females at the table draw the rags, cutting them into pieces of about four inches square, when they are put into boxes according to the fineness of their texture. During this operation, much dust is beat out of the rags, which falls through the meshes of the wirecloth. It is calculated that a woman will cut a hundredweight of rags by this method in a day. After the rags are cut, they are put into a cylinder of wirecloth, measuring about four feet in diameter and five in length. An axis runs through the centre of the cylinder, which is furnished with spokes about a foot long, attached at right angles to the axis. The machine being set in motion, the spokes beat and toss the rags about, which frees them from any dust that may remain after the cutting. When the rags are very dirty, it has been found advantageous to put them into the duster before being cut, which renders that operation easier and more cleanly for the people engaged at the work.

The next operation is that of boiling the rags in an alkaline lye. Sometimes this is done by simply putting the rags into open vats containing the lye, with a fire underneath. Others, however, use close boilers, into which steam is admitted by means of a pipe from the top. The alkaline lye is composed of from four to ten pounds of the carbonate of soda to the hundredweight of rags, according to their quality, and a third part additional of quicklime, to render it caustic. Some manufacturers use lime alone, and others pot and pearl ashes, for the purpose of bleaching; but soda and quicklime are the substances generally employed. The rags are boiled for about eight hours in this solution, and are then allowed to cool gradually, it having been found that when the cooling takes place too rapidly, any dirt upon the rags is apt to be indelibly fixed.

After being boiled, the rags are carried to the first washing-engine, which consists of a large oblong stone trough, into which a stream of water is allowed to flow and to escape by the other end. This cleans the rags most effectually, the run of water carrying away any impurities that may still adhere to them. On one side of this trough is an engine, which again washes and grinds the rags, and is termed by the workmen the *breaking-in machine*. This powerful apparatus consists of an elliptical-shaped trough, made generally of wood, lined with lead or copper; within it, a grooved roller revolves horizontally over the surface of a sharply-grooved plate, by which the rags are torn to shreds. The grooves on the roller, and those on the plate, act upon the pieces of rags much in the same manner as cutting with a pair of scissors. The trough is half filled with water, which comes in at one end, and escapes through holes at another part. The engineer puts the rags into the engine, spreads them with his hands, and by means of agitators at the bottom of the trough, no piece is allowed to escape the action of the roller. These troughs are about ten feet in length, four and a half in width, and two and a half in depth, being capable of holding from 112 to 120 pounds of rags. The operation of *grinding*, as it is called, occupies about an hour and a half; and when the rags are sufficiently reduced to a pulp, the stuff is passed down from the trough to the draining boxes, by means of a pipe six inches in diameter. This pipe is furnished with a valve at the bottom of the trough, which the engineer opens by means of an iron hook, and through this the pulpy matter flows freely. On reaching the draining boxes, the water is allowed to run off from the pulp previous to the bleaching process.

In the grinding operation a great improvement has lately been effected. It was found that the constant flow of water through the agitated trough of the engine carried off a considerable proportion of the finer particles of the stuff, and thus caused a serious loss. A plan has been invented to lift the waste water by a revolving sieve, which admits the water alone, and excludes the stuff, thereby effecting a most important saving to the manufacturer.

Bleaching is sometimes performed by subjecting the pulp to the action of chlorine, which is manufactured from sulphuric acid, sea salt, and the black oxide of manganese. The chamber in which this is performed must be close, so that the chlorine may not escape. A more common method of bleaching, however, is to steep the pulp in a solution of the chloride of lime, by which the fibres are not so much injured as when chlorine is used. In bleaching, great care should be taken that the solution is not too powerful, or the texture of the paper may be materially injured by the process.

The bleaching-house consists of a long apartment, furnished with stone chests about three feet deep, ranged on each side, and capable of containing about fifty-seven cubic feet. These chests have false bottoms, pierced with small holes, which can be opened at pleasure, to allow the solution to escape. When the water is drained off, the pulp is carried to the bleaching-chests, and about one hundredweight put into each, along with from six to eight pounds of Tennant's saturated chloride of lime, and about twelve gallons of water. The stuff is allowed to steep for twenty-four hours, being frequently stirred in the interval, so that every part may be equally bleached. After bleaching, the pulp is again put into a washing-machine, to free it thoroughly from the bleaching-liquor. This process is similar to that previously described, except that the roller is screwed down closer to the fluted plate, so as to reduce the pulp to a finer consistence. In making what is called machine-paper, the size is now added, the addition or the want of which constitutes the chief difference between paper for the reception of ink and the other sorts. The kinds of size principally used consist of either white soap, starch, glue, or dissolved resin, with the addition of a few pounds of alum. The size is strained through a sieve into the beating-engine, and there mixed with the pulp.

From the second washing, or beating-machine, the pulp is passed down to a large tun or vat, called the *stuff-chest*, which is merely a reservoir to keep the pulp till it is put into the machine which converts it into paper. This vat is furnished with agitators at the bottom, to keep the pulp of an equal thickness, which now bears a strong resemblance to curdled milk. Previous to being put into the vat, however, it is now almost universally the practice to strain the pulp through bars of brass. These are planed perfectly smooth at the edges, and placed so closely together, that the fibrous part of the matter must pass through longitudinally. By this means knots, &c. are kept out, which formerly cost considerable trouble to scrape from the surface of the finished paper.

Making by Hand.

This is the old method of making paper, which is now completely exploded, except for some kinds of writing and coarse packing-papers. The pulp is prepared without size, that being imparted afterwards to the sheets by dipping them in a tub. Properly prepared, the pulp runs into a vat, at one end of which stands the vatman, with two frames or moulds beside him, made of brass wires or wirecloth, fixed upon a wooden frame, of the size of the sheet to be made. The vatman holds in his hand a frame of wood called a *deckle*, which fits exactly all round the edge of the mould, for the purpose of giving a clean edge to the paper. For making what is called wove paper, a wirecloth is required. For laid or corded papers, however, the mould is made of brass wires lying longitudinally, crossed by wooden bars placed underneath, and interlaced by cross wires somewhat thicker than the longitudinal ones.

The vatman, laying the deckle upon the mould, dips it into the vat, and takes up a quantity of the pulp. If he considers there is too much in the mould, he throws off part of it, and then, holding the mould horizontally, he shakes it to and from him, which connects the fibres together, and renders the fabric of an equal thickness throughout. The water flows through between the wires, and as soon as the pulp has attained a degree of consistence, the vatman lifts off the deckle, and hands the mould to the coucher, who stands at the other corner of the vat. The coucher places the mould in an inclined position for a few seconds, so that as much water may flow from the pulp as possible. He then puts a piece of felt or blanketing upon a wooden board, and turning the mould over upon this, the pulp adheres, and the mould is handed back to the vatman. Another felt is placed upon the top of the pulp laid down, and the process is continued until what is termed a *post* is completed. A strong board is then placed upon this, and the whole is put under severe pressure, in order that the water may be thoroughly extracted. When the paper is taken out of this press, it may be handled, and the sheets are taken from between the felts, and placed by themselves. Another pressing is then given, slighter than at first; for if too severe, the sheets are apt to stick so closely together, that they cannot be afterwards parted without injury. After this pressing, the sheets are carefully separated from each other, and again pressed, previous to being sent to the drying loft. In making the finest writing-paper, this separation and pressing are performed twice, which considerably improves the texture of the paper.

The next process is drying, which is done in a loft containing a number of spaces filled with hair-ropes fixed into spars of wood, the ends of which slide up and down upright posts at the corners of each space. Five or six sheets of paper are hung together upon these ropes, and allowed to dry. The air is freely admitted by the sides of the loft, which are sparred with shutters, to close out the air entirely, in case of bad weather; and each loft is provided with pipes, which go round the room, and can be filled with steam, so that the drying process may go on at all times.

When the paper is quite dry, it is sent to the sizing-house, where it is made suitable for receiving ink. The size is made from the parings of skins, &c. which are boiled for about ten hours to reduce them to a gelatine. The gelatine is carefully strained; about a fourth of its weight of alum is then added, and the mixture is allowed to congeal. When used, it is diluted with water, and an additional supply of alum put in. The workman then takes about six quires of paper in his hand, and dips it into the tub containing the size, where it is allowed to remain for a few minutes, so that every sheet may be well soaked. The sheets are carefully lifted out one by one, and put into a press, which is slightly screwed down, that the surplus size may flow out. In order that the sheets may be easily separated, the edges are washed with hot water; and when taken out of the press, each sheet is laid between woollen cloths, in the same manner as when the paper was first taken from the mould. When strongly sized, the sheets are again separated carefully, and kept about forty-eight hours before being hung up to dry. In *blotting*-paper the usual sizing is omitted.

When sized and dried, the paper is taken to the finishing-house, where it undergoes several pressings to smooth the surface. It is then sorted, and put up in reams, consisting of twenty quires of twenty-four sheets each, or 480 sheets. *Hot-pressed* paper is rendered glossy by pressing it between hot plates of polished metal.

Making by Machine.

From the vat or stuff chest, the pulp, prepared as already described, is let out by a sluice into a pipe, which leads it to one end of the *making-machine*. The opening from this corresponds exactly with the breadth of the machine, and the quantity and thickness of the stuff admitted into the latter are regulated according to the kind of paper to be made.

The machine now in general use for the making of paper is the invention of Mr Louis Robert, and was brought to this country about forty years ago by a M. Didot, who, with the assistance of M. M. Fourdrinier, and Mr Dorken the engineer, greatly improved the invention, and obtained a patent for it.

The first part of the machinery upon which the pulp comes is a brass wirecloth, of so fine a texture that there are seventy wires in the inch, and which is woven in the same way as linen. This wirecloth may be described as a sort of belt without any break, which is kept continually revolving, but in such a way that the upper side, upon which the stuff is received, preserves a flat and horizontal surface. The wirecloth moves upon a number of small copper rollers, which have an agitating horizontal motion, and this distributes the stuff equally over the cloth, giving a uniform strength and thickness to the paper. After passing between a pair of rollers, where it delivers the stuff, it is led backwards again under the frame; and so goes on in a continuous revolution. Movable sides are attached to the upper surface of the wire, which regulate the breadth of the sheet to be manufactured.

The first pair of rollers through which the stuff passes are called the couching rollers. The under roller is simply cast-iron, while the upper one is covered with woollen cloth of a peculiar texture, manufactured for the purpose. It is upon this upper one that the stuff is delivered. The pressure from these rollers is slight; and the pulp is next led on to an endless felt, and passes between two cast-iron rollers. The machinery of this felt must be so regulated, that it will go with the same speed as the wirecloth and couching rollers, otherwise confusion would ensue. In passing through the first pair of rollers, only one side of the stuff is rendered smooth; but in the second pair it is reversed, and the rough side is now pressed. These rollers are closer than the first pair, and the pressure being greater, the sheet is now more dry and firm. It often happens that, in passing from these rollers to those that succeed them, the paper breaks, and adheres to the woollen cloth; in the event of which, should the broken parts be carried round on the surface of the roller, they would inevitably injure the part of the sheet which follows. To prevent this casualty, there is affixed lengthwise, along the upper surface of the roller, a large knife, called the *doctor*, the edge of which, being placed in a sloping manner, like the blades of a wright's plane, is brought so close to the roller, as effectually to shave off any substance that may chance to adhere to it.

The sheet next passes through two other pairs of rollers, which press out the water, and render the paper smooth and firm. It is then carried to the drying cylinders, which are hollow, and filled with steam, introduced by pipes placed at both ends of their axes. When these cylinders are too hot, the paper will be observed to shrivel; and by an ingenious contrivance, the extra steam can be let off, so as to reduce the temperature. The water which collects in the cylinder is carried off by means of an instrument shaped like a cork-screw, and which is wrought by the machinery. The paper is again passed through a pair of rollers, to smooth it after being dried, and is then wound upon a reel. As one reel is filled, it is taken off, and another put on in its place; and it is evident that the paper can be made of any length the reel is large enough to hold.

The whole machinery upon which the process we have described is performed, is about fourteen feet in length, and moves at the rate of from twenty-five to forty feet per minute. At one end is seen running in a stream of liquid resembling curdled milk, and at the other comes out a finished fabric, the time required for manufacturing thirty feet of which is little more than a minute. Near the extremity of the machine is usually placed an apparatus for receiving the reels of paper in web, and drawing out and cutting the web into sheets according to the regulated size. The sheets are then sorted and packed up in the usual manner.

By the operations now described, all the printing papers and also letter papers of an ordinary kind are now made, and that to an immense extent. 'Suppose,' says a writer on this subject in the Encyclopædia Britannica, 'that a machine makes ten yards lineal of a web per minute, or 600 in the hour, this is equal to a mile in three hours, or four miles per day of twelve hours. The paper is generally made about fifty-four inches wide. Reckoning that there are 300 machines in Great Britain, and that they work twelve hours a day on an average (many go both by day and night), the length of web would altogether be equal to 1200 miles, and the area of what was made would be about 3,000,000 yards daily.' The annual value of British-made papers is estimated at upwards of two millions.

CAOUTCHOUC—GUTTA PERCHA.

These two remarkable substances, to which we have briefly adverted in previous numbers, are now so largely used in connection with textile fabrics, that a more extended notice of their properties and applications may not be uninstructive to the reader.

Caoutchouc was first seen in Europe about the middle of the eighteenth century. It was then brought from Guiana, and other provinces on the eastern coast of South America, and, from its valuable power of cleaning paper, was called *India-rubber*. The striking elasticity and insolubility of caoutchouc, which we believe to be the aboriginal name for the juice, caused it speedily to become an object of attention to chemists and others, who imagined, not incorrectly, that the secret of dissolving it might be turned to some account. As the use of it increased in the civilised world, the substance became naturally an object of research to voyagers also, and varieties of it were found in many tropical climes, particularly in some parts of China, on the coast of Guinea, in Sumatra, and other East Indian isles and provinces. It was thus discovered to be the produce of several tropical trees, particularly *Ficus elastica*, *Jatropha elastica*, and *Urceola elastica*. It may also be obtained from the juices of others belonging to the same natural order; but our commercial supplies, which now amount to several hundred tons yearly, are mainly derived from the *Ficus elastica* in the old world, and from the *Jatropha* in the new. The mode of obtaining it is simple:—In the cooler seasons of the year, incisions are made around the tree, completely through the bark, and the milky juice which exudes is either immediately applied to moulds of unburnt clay, or collected in vessels. If applied to moulds, it is dried, layer by layer, over a wood fire, till of the desired thickness; if otherwise, it is allowed to coagulate and harden at leisure. In the former case, when the coating is judged to be sufficiently thick and dry, the clay mould, which, in the West Indies and South America, has usually the form of a pear, is broken, and the fragments are withdrawn through the neck; the caoutchouc thus comes to have the form of a flask, in which state it is exported. Besides bottles, shoes, tablets, toys, and the like, are formed on the spot by the native collectors. From the East Indies caoutchouc is exported in large junks and balls, lighter in colour than that brought from South America, these lumps being obtained by simple exposure of the juice to the sun. The juice itself, which is of a pale yellow colour, and about the consistence of cream, has of late years been imported into Europe in small quantities in closely-stoppered vessels; and if kept cool, and carefully excluded from the air, it may be preserved in this state for a considerable time. Caoutchouc in the solid state is highly elastic, is insoluble in any of the ordinary solvents, melts at 248° Fahrenheit, and remains viscid for a considerable time, is highly inflammable, burns with a white flame and much smoke, emitting at the same time a peculiar and offensive odour. When solid, it may be cut into threads and sheets of great tenuity and thinness; when melted, it may be used as a lute or cement; and when dissolved in naphtha, which is the most common solvent, it may be employed as a varnish, and applied to the surface of any textile fabric, rendering it quite impervious to air or moisture.

The applications of caoutchouc have of late years been very numerous. In the form of tapes and threads covered with silk, cotton, linen, &c. it is largely employed in the formation of elastic tissues. In solution, it has been applied for coating cordage and cables, to protect them from the destructive influence of salt water. An early application of the same liquid was in the preparation of waterproof cloth; of this a new variety has made its appearance within the last few months. Those valuable little articles known by the name of India-rubber *corks*, are formed of small stoppers of cotton, coated externally with a thin caoutchouc membrane. In the laboratory, sheet caoutchouc is quite indispensable; it supplies the place of a mass of expensive and easily-deranged mechanism of brass-joints and unions; it is easily made into a flexible tube, by taking a narrow ribbon of the membrane, slightly moistening the edges with turpentine, and laying them together over a glass tube; they immediately adhere with surprising tenacity, and in a few minutes the elastic tube is completed. Caoutchouc, in fact, may be said to have contributed in no small degree to the perfection of the experimental chemistry of the day. In mechanical surgery, caoutchouc is equally serviceable, forming elastic bandages, impermeable plasters, flexible tubes, and the recent elegant substitute for a poultice—a kind of half-sponge, with an India-rubber back to it; besides forming instruments of many kinds of great value but small cost. It has also been applied to bookbinding, which it effects without sewing or stitching. Among the most important applications of caoutchouc, is its use in the formation of marine glue, noticed in the preceding number.

Very recently, caoutchouc has been made to acquire new properties, by what has been termed *vulcanisation*. The process is thus described:—The caoutchouc is immersed in a bath of fused sulphur, heated to a proper temperature, until, by absorbing a portion of the sulphur, it assumes a carbonised appearance, and eventually acquires the consistency of horn. The same condition can, however, be produced by either kneading the India-rubber with sulphur, and then exposing it to a temperature of 190 degrees Fahrenheit, or by dissolving it in any of the common solvents, as turpentine, holding sulphur in solution or suspension. The *rationale* of this operation appears to be, that the India-rubber forms an actual chemical compound with the sulphur; becomes, in short, a sulphuret of caoutchouc, the properties of which are thus enumerated:—The new compound remains elastic at all temperatures, while ordinary caoutchouc becomes inelastic and rigid at a few degrees above the freezing-point: vulcanised caoutchouc is not reducible by the ordinary solvents, neither is it affected by heat within a considerable range of temperature. Finally, it acquires extraordinary powers of resisting compression, with a great increase of strength and elasticity. Most readers must be familiar with the construction of the powerful spiral spring in use for the 'buffers' of railway carriages, to moderate the effects of concussion; their ordinary strength is such as to demand a pressure equivalent to three tons and upwards, to compress the spiral close together. Mr Fuller has invented a spring, in which vulcanised caoutchouc takes the place of the steel, and the surprising result is, that the India-rubber springs are more than *three times* the strength of the metallic; that is, they resist, at the height of their tension, a pressure equal to from *five to ten tons*.

Gifted with these new powers, vulcanised caoutchouc has already been called into extensive employment for the most various and opposite purposes. It forms, in hydraulic engines of all kinds, one of the most valuable materials for 'washers,' applying itself so accurately to the surfaces between which it is placed, as to prevent the slightest leakage, other things being equal.

In this capacity, and from its power of resisting heat, it has also been proposed for the use of steam-pipe joints. It makes an admirable spring, more docile, and more equal in power, than those of steel: it has been for this purpose applied to locks and window-blinds. It is manufactured also into the most elaborate ornaments, being superior to leather in the sharp outline and bold relief of their detail. It is formed into a tubing of great strength and flexibility, well adapted, the consideration of expense excepted, for fire-hose, and for any apparatus required in conveying steam, water, or gas. This tube promises to become invaluable in the construction of life-boats, superseding those made of canvas, which were slowly destroyed by the influence of sea-water. A curious use to which it has been put is as a substitute for the iron tire or hoop of the carriage-wheel: the advantages it is said to afford are a much lighter draught, and an absence of noise. Its most important application is in its use in railways, and, as has been mentioned, in railway carriages. It is laid between the rail and the sleeper, and thus prevents the rails from indicating any traces of pressure. The useful little articles 'elastic bands' are made of this substance. Besides all these applications, it is proposed to apply it as a coating to protect the wires of the submarine telegraph from the influence of the sea water: it forms impervious bottles for ether, inkstands, trouser-straps, gloves, boots, surgical bandages, and a number of other articles, for which its nature almost seems to have been expressly designed.

Gutta percha is of recent introduction into England, having been first brought under the notice of the Society of Arts by Dr Montgomerie in 1843. The tree from which it is procured is said to belong to the natural order *Sapotaceæ*, and is found abundantly in Singapore, the Malayan Peninsula, Borneo, and in all probability throughout the entire Indian Archipelago. The tree is one of the largest in the forests, frequently attaining to the diameter of three, four, or even six feet. The timber is valueless for building purposes, on account of the loose and open character of its tissue; but the tree bears a fruit which yields a concrete oil, used for food by the natives. Gutta percha is contained in the sap, and is thus procured:—A magnificent tree of fifty, or perhaps one hundred years' growth, is felled; the bark is stripped off, and a milky juice, which exudes from the lacerated surfaces, is collected, and poured into a trough, formed by the hollow stem of the plantain leaf. On exposure to the air, the juice quickly coagulates. From twenty to thirty pounds is the average produce of one tree. This wasteful, sinful procedure, which might, and ought to be superseded by simply tapping or incising the bark, is adopted to a very large extent, as may be conceived from the amount of the gutta now imported reaching many hundreds of tons annually.

Gutta percha comes to us in two forms: in thin slips or scraps, or in rolls, which are formed by rolling the thin layers together in a soft state. When pure, the slips are transparent, and somewhat elastic, varying in colour from a whitish-yellow to a pink. In the mass it is seldom free from some impurities—such as saw-dust, pieces of leaves, &c. It is purified by a process called 'devilling,' or kneading, which is done in hot water: the water soon dissolves some of the foreign matters, and washes out others, until after a short time the gutta percha is left in a mass, ductile, soft, and plastic, of a whitish-gray colour. Thus prepared, gutta percha possesses very curious properties. Below the temperature of 50 degrees, it is as hard as wood, but it will receive an indentation from the finger nail. It is excessively tough, and only flexible in the condition of thin slips: in the mass, it has a good deal the appearance, and something of the feel, of horn; its texture is somewhat fibrous; and from the resistance it offers to anything rubbed across it, it appears that it was first used as a substitute for horn for the handles of knives and choppers. By an increase of heat, it is made more flexible, until, at a temperature considerably below the boiling-point of water, it becomes like so much softened bees'-wax. It is now easily cut and divided in any manner by a knife, and may be moulded into all varieties of form with the greatest ease; or may be cut, and united again so perfectly, as scarcely to exhibit even the appearance of a joint, and possessing all the strength of an undivided mass. Whatever be the shape into which the gutta percha is now formed, it will retain precisely the same form as it cools, hardening again to its previous state of rigidity. It is in a great measure devoid of elasticity, offering a striking contrast to caoutchouc, but its tenacity is little less than wonderful: a thin slip, an eighth of an inch substance, sustained a weight of forty-two pounds, and only broke with the pressure of fifty-six pounds. When in its hard state, it is cut with incredible difficulty by the knife or saw. Like caoutchouc, it burns brightly when lighted, disengaging the peculiar odour accompanying the combustion of that substance; like it also, it is soluble with difficulty in ether and other caoutchouc solvents, but very readily in oil of turpentine.

In solution, gutta percha appears to be as well adapted as that of India-rubber for the manufacture of waterproof cloth, and for the other purposes to which that liquid is now applied. In the solid state, it is in use among the Malays, as above-mentioned; and they prefer it to wood and horn, even where the latter is attainable. There are a number of cases also in which it appears likely to become an admirable substitute for leather, possessing, as it does, some properties in common with, and some vastly superior to, those of that material. Its value has been readily recognised by our inventors, as shown by the numerous patents taken out in reference to its applications. In these it is proposed to employ it as an ingredient in mastics and cements; for the manufacture of a thread which is used to form piece goods, ribbons, paper, and other articles; as a substitute for caoutchouc in binding books; for waterproofing boots, shoes, and other articles of apparel; for the manufacture of flexible hose, tubes, bottles, &c. But the most comprehensive is the patent of Mr Hancock, who has instituted a series of curious experiments upon this remarkable substance. He unites the gutta percha with caoutchouc, and another substance called *jintawan*, by which an elastic material results, which is impervious to, and insoluble in, water. The hardness or elasticity of the compound is easily determined by the alteration of the amount of gutta percha; the latter is added in larger quantity if firmness is requisite, and *vice versâ* if flexibility and elasticity are necessary. From this mixture a very curious substance, light, porous, and spongy, is prepared, suitable for stuffing or forming the seats of chairs, cushions, mattresses, &c.; it also forms springs for clocks, clasps, belts, garters, and string. By an alteration of the process, much hardness is acquired, and moulds and balls of the material are capable of being turned in a lathe, and otherwise treated like ivory. In this state it offers itself for a thousand other offices: thus it may be formed into excellent picture-frames, incredibly tough walking-sticks, door-handles, chess-men, sword and knife-handles, buttons, combs, and flutes. It has been proposed as a material for embossed alphabets and maps for the blind, on account of the clear sharp impression it is capable of receiving and retaining. It is also an excellent matrix for receiving the impression of medals and coins, and is valuable on account of its subsequent non-liability to break. By mixing a proper portion of sulphuric acid with it, or adding a portion of wax or tallow, it may be reduced to any degree of solubility, and furnishes a good varnish, quite impermeable to water. Mr Hancock proposes such a fluid as valuable for amalgamating with colours in printing: it appears probable that this will form an extensive application of the discovery, and that colours so printed will prove as lasting as the fabrics on which they are impressed. Time alone, however, can determine the extent to which gutta percha and its congener caoutchouc will be applied in the useful and ornamental arts.

MINING—MINERALS.

The term *Mineral* is somewhat varied and indefinite in its application. In the widest sense, it is made to embrace the whole of inorganic nature; and thus we speak of the mineral in contradistinction to the vegetable and animal kingdoms. Occasionally, it is restricted to those native products which appear in a crystallised or definite form; but more generally and properly it is extended to all the earths, rocks, salts, and ores which are obtained from the crust of the earth. Employing it in the latter signification, we intend, in the present sheet, to treat of the nature, origin, and uses of such substances as coal, limestone, sandstone, rock-salt, sulphur, gems—reserving consideration of the metallic ores and metals for a subsequent number. It is almost superfluous to observe, that the mining, digging, transport, and preparation of these materials for application to the purposes of civilised life, constitute departments of human industry of high scientific, as well as economic importance.

For the more accurate comprehension of the subject, it may be necessary to premise that we speak of the *crust* of the earth—meaning thereby that superficial rind or portion accessible to human investigation—in contradistinction to the interior masses, concerning the nature of which we can only form conjectures. In this crust the rocky substances are variously arranged: some are found in layers or strata—hence said to be *stratified;* others appear in vast irregular masses, presenting no trace of bed or layer, and are accordingly termed *unstratified*. The matter of the stratified has evidently been deposited from water, and from this view of their origin, they are generally known as *aqueous* or *sedimentary* rocks; while the unstratified, presenting no appearance of deposit, but everywhere an irregular configuration, and, moreover, often breaking through and contorting the stratified, are considered of *igneous* or *volcanic* origin. Both sedimentary and igneous rocks present various mineralogical and chemical characters: thus, of the former, we have roofing-slate, sandstone, coal, limestone, &c.; of the latter, granite, basalt, and lava—all very distinct in composition and appearance. Besides differences in mineral composition, the sedimentary rocks contain different kinds of fossils—that is, the petrified remains of animals and plants; and such distinctions have rendered it necessary to arrange the rocks constituting the crust of our globe into various *formations*—meaning by a formation any suite of rocks possessing some peculiar mineral or fossil character. Thus we speak of the 'coal formation,' meaning thereby not merely the beds or layers of coal, but the sandstones, shales, ironstones, and the like, which alternate with and accompany that mineral—seeing that the whole have been evidently deposited under similar conditions, and that similar organisms are found fossil within them. Further, both the stratified and unstratified rocks are frequently traversed by rents and fissures, some of which are entirely void, others partially filled or lined with crystallised products differing from the adjacent rocks, and many again wholly filled up with crystallised substances, metallic ores, and other ingredients, constituting what are termed *lodes* and *veins*. (See Geology.) Deviating in some degree from the usual technical arrangements, we shall describe the principal economic minerals under such heads as appear best calculated to aid the comprehension of the ordinary inquirer.

BITUMINOUS SUBSTANCES.

Bitumen—from a Greek word signifying the pitch-tree—may be regarded as embracing all those inflammable minerals which, like pitch, burn with flame and smoke in the open air. Naphtha, petroleum, and asphalte are familiar examples; but all substances impregnated with these bitumens are said to be *bituminous*. Hence under this head may be included coal in all its varieties, as well as bituminous slate, slaggy mineral pitch, and the asphaltes of commerce.

Coal.

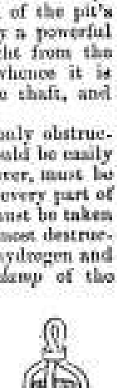
Coal, of which there are several distinct varieties, is one of the most important minerals with which man has yet become acquainted. By it he fuses the metals, produces steam which sets machinery in motion, prepares gas for light, heats his apartments, cooks his food, and, in short, renders all the resources of nature fit for civilised use. It is uncertain when coal first began to be used in Britain as fuel, but in all probability it was not earlier than the beginning of the twelfth century. In 1281, Newcastle is noticed as having some trade in that article; and a little later, we find it mentioned in the Chartulary of the Abbey of Dunfermline. In the reign of Edward I., its use in London was prohibited, in consequence of the supposed injurious influences of the smoke; and this prohibition we find renewed at several subsequent periods, but all to no purpose. The increasing scarcity of wood as fuel rendered some other substitute necessary; and, from its compact form and powerful heat, no known substance could for one moment be brought into competition with coal. The smoke nuisance was therefore submitted to; and despite of every obstacle, the 'obnoxious' mineral was soon in the ascendant. At the beginning of the sixteenth century, it seems to have been getting into use in the Lowlands of Scotland, where we find Bœthius taking notice of a 'black stone' found in Fife and the Lothians, the heat of which was sufficiently intense to fuse the most refractory metals. Since the time of Charles I. it has become almost the only description of fuel used in London, and in most other towns and districts throughout the kingdom—peat or turf being but occasionally employed, and that solely in remote localities. It is within the current century, however, that the great demand has been made upon our coal-fields; since the application of the steam-engine to the purposes of the mine, the factory, the railway, and river; since the introduction of gas, the extension of our foundries, and the general advancement of those economical processes which distinguish the present from every other period of our country's history. According to the most recent estimates, not less than thirty millions of tons of coal are raised from the different mines in the British islands, of which between three and four millions are exported to other countries.

The coal worked in Britain may be said to be exclusively obtained from the great coal-formation, where it alternates with strata of sandstone, bituminous shale, bands of ironstone, fire-clay, and impure limestone—the whole suite being usually termed the *coal-measures*. Attempts have been made to work the thin beds found in more recent formations, as the oolite and tertiary, but in every case without success. The principal districts, or 'fields,' as they are called, are those of Northumberland and Durham, Lancashire, Stafford, South Wales, and the Lowlands of Scotland—the latter extending from Fife to Ayrshire at an average breadth of about thirty miles. In these fields there may be as many as ten, twenty, or even forty seams or strata of coal, varying from a foot to thirty feet in thickness; but of these, in general, not more than five or six can be worked with profit. The mineral so obtained is of different varieties and qualities; so pure, as to leave after combustion the smallest per centage of ash; or so foul, as to be burned with difficulty. The principal varieties are—*caking* coal, a highly bituminous sort, like that of Newcastle, which emits much smoke and gas, and cakes together during combustion; *cubic*, which is also bituminous, but breaks into larger cubical masses, and does not cake while burning; *splint*, a hard slaty variety, which is still less bituminous, and does not cake, but burns with great heat, and leaves little ash; *cannel*, a compact shining variety, also bituminous, burns with a clear flame, does not cake, and leaves a whitish ash, principally used, where it can be obtained, for the manufacture of gas. All these varieties are less or more bituminous; but there is another variety, known by the name of *anthracite*, or 'blind coal,' which is non-bituminous. This anthracite has a glistening and semi-metallic aspect, does not soil the fingers when rubbed, and burns without smoke. It is, in fact, a natural coke, or charcoal, the original coal having been deprived of its bituminous products by heat or other causes. It is found in small patches in several coal-fields in contact with the igneous rocks, which have evidently produced the change, but abundantly in South Wales, where it occupies a considerable area. It is used exclusively in the reduction of the metallic ores, for which it has been employed only since the introduction of the hot-blast process. Several fields, both of bituminous and anthracite coal, occur in Ireland; but comparatively little is raised, and almost all the coal used in Dublin, Belfast, and other large towns is imported from England.

Besides the supply obtained in Britain, there are coal-fields, less or more extensive, in France, Spain, Belgium, and Germany; in India, China, the East India islands, Australia, and New Zealand; in Nova Scotia, and the states of North America; in the Isthmus of Panama, Chili, and Peru; and even in some of the islands of the Pacific and Arctic Oceans. Of these fields, the North American are by far the most extensive and important, presenting areas of bituminous and anthracite coal greater than the whole extent of our own island. That of Pennsylvania, Virginia, and Ohio, for example, extends continuously from north-east to south-west for a distance of 720 miles, its greatest breadth being 180 miles; its area thus amounting to 129,600 square miles. That situated in Illinois, Indiana, and Kentucky, embraces an area of 14,000 square miles; while several, many times larger than the largest coal-field in Britain, are found in Michigan, and other parts of the Union. Many of the coal-fields in the world are yet untouched; it being only after the wood of a new country has been used up, and civilisation made some progress, that man betakes himself to the difficult and often dangerous task of extracting mineral fuel. All the coal-fields now mentioned belong to the same great formation; but there are other patches of a more recent date which are occasionally worked, as the lignite, or brown coal of Germany, and of Bovey Hayfield, near Exeter. This, however, is a very different material in comparison, and is only had recourse to where the lower formation is absent, or at such a depth, as to preclude its easy working. Taking, therefore, an estimate of the whole amount of coal known to exist, there need be no dread of the supply being exhausted for thousands of years to come; for though the fields of one country should be exhausted, the fields of another lie patent to the same commercial influence which imports tea from China, cutlery and cloth from Britain, and cotton from America.

Coal being, in every instance, a true stratified rock, the modes of obtaining it are much the same in the different countries where it is sought after. In early times, our ancestors could avail themselves of little more than the mere outcrop—that is, that portion of a seam which approaches the surface; and this was excavated just as a stratum of limestone or sandstone is quarried at the present day. By and by they sank to greater depths, but still entering in a slanting direction, after the dip or inclination of the strata, and not descending by shafts or perpendicular pits, as is now the practice. To rid their workings of water, they hewed long tunnels or subterranean drains from some low level, and carrying this forward to the seam of coal, effected a drainage to that depth. Where the coal seams lay on high ground, and where there was any deep glen or ravine in the neighbourhood, such drainage often allowed them to work at a considerable depth; but these *day-levels* (so called from their discharging their contents to the open day, in contradistinction to other levels within the mine) were, upon the whole, but imperfect and expensive affairs. In some instances, where pits were sunk, windmills were erected for the purpose of pumping the water; but no certain effect could be calculated upon from an agency so unstable as the wind. The invention of the steam-engine soon set aside these rude and imperfect appliances; shafts, instead of slanting adits, are now everywhere sunk, and the water brought to the surface at once, no matter whether the depth be 20 or 300 fathoms. Of course the fittings of a coal mine depend, as do all other commercial speculations, upon the value of the material sought to be obtained. In some districts the shafts are of no great depth, the pumping engines small and rude, and the mineral brought to the surface simply by animal power; while in other localities the shafts are of enormous depth and finely executed, the engines of great magnitude and superior finish, and no animal power employed unless in the hewing of the coal. In Britain, a Newcastle colliery may be taken as the most perfect of its kind. Here the shafts, which are often sunk at vast expense, vary from 150 to 300 fathoms in depth, are lined with casings of stone, wood, or iron, and are divided into various compartments for the accommodation of the pumping gear, and the ascending and descending corves which contain the coal—these compartments also subserving an important end in the ventilation of the mine. Having reached the stratum of coal, which generally lies at a considerable inclination, main *drifts* or excavations are made in different directions for drainage, transit, and ventilation; and then the minor workings branch off from these, care being taken to leave pillars or masses of the stratum for the support of the superincumbent material. The water that oozes from the workings finds its way to the lower level, or *sump*, of the pit's bottom, from whence it is pumped up by a powerful engine; and the coal hewn out is brought from the various workings to the main drifts, whence it is dragged by ponies to the bottom of the shaft, and raised in corves, or baskets, to the surface.

Were the accumulation of water the only obstruction to the mining of coal, the difficulty could be easily surmounted. A supply of fresh air, however, must be regularly and unceasingly maintained in every part of the workings; and not only so, but care must be taken to prevent the accumulation of two gases most destructive to human life; namely, carburetted hydrogen and carbonic gas—the *fire-damp* and *choke-damp* of the miners. For this purpose the various underground workings are so arranged and boarded off, that while one set receives the descending current, another carries it forward again to the pit bottom, where, by means of rarefaction, produced by a huge fire, it is carried up the shaft to the atmosphere. By these means not only is fresh air supplied to the miners, but the deleterious gases are carried off, and the whole subterranean recesses rendered safe and healthy. The most ingenious of human inventions are, however, imperfect; and choke-damp and fire-damp will exude from the coal seam, and lurk in recesses, there either to suffocate the first comer, or to explode the instant that a lamp is brought in contact. To prevent these casualties as much as possible, various air-tight trap-doors and boardings are employed, and the miner is furnished with safety-lamps of various constructions,



which, while they afford sufficient light, prevent the carburetted hydrogen from coming in contact with the flame within (see fig.).* These remarks apply in particular to the Newcastle coal-field, where, in consequence of such difficulties, coal-mining is conducted with greater care and skill than in any other district; but it must be remembered that there are many fields where fire-damp is unknown, and where the most ordinary ventilation is sufficient to prevent the accumulation of carbonic acid or any obnoxious effluvia. Indeed we know of an excellent coal-field which returns its thousands annually, and where no precaution either as to lamps or ventilation is necessary—all that is requisite being occasional wooden props, to prevent falls of loose material from the roof of the compartment in which the miner may be working. In some of the largest Pennsylvanian mines even this precaution is unnecessary, the anthracite being of great thickness, and so exposed and level, that it is hewn out either in open quarry or in huge drifts, precisely after the fashion of our railway tunnels.

Important and varied as are the uses, and vast as must be the consumption, of this mineral in Britain, yet so abundant is it, that in many localities the best household coal never exceeds 7s. a ton, while in Edinburgh it averages about 12s.; and in London, to which it is all sea-borne, it ranges between 15s. and 23s. 'Notwithstanding the cheapness of the produce of this kind,' says Mr Ansted, 'the value of the coal actually brought to the surface in Britain amounts annually to nearly ten millions of pounds sterling, and almost the whole of this is derived, although in unequal proportions, from the Newcastle, the South Welsh, the Staffordshire, and Scotch coal-fields. With regard to the first of these—the Newcastle coal-field—it is said that upwards of six millions of tons are there annually raised up out of the bowels of the earth; that 60,000 persons are employed in the mining operations; that 1400 vessels are constantly engaged in conveying the coal (amounting to three millions of tons) required for the consumption of the Metropolis alone; and that the capital employed in simply conducting this trade amounts to several millions sterling.' From this single instance, some idea may be formed of the magnitude of the trade in coal, which is doubtless one of the most important props of our country's commerce, as it is of her manufacturing and mechanical superiority.

As to the origin of coal, no matter what the variety, there can be no doubt that it is essentially vegetable. Not only are fossil trunks, branches, leaves, and fruits found in the mass, but scarcely a portion of it, when submitted to the microscope, but shows the ducts and fibres of a true vegetable structure. We know, moreover, that vegetable matter, when subjected to moisture and pressure, and excluded from the action of the air, will in a short period pass into a bituminous or carbonaceous mass, which time and greater pressure and heat would by and by convert into true mineral coal. Peat, were it excluded from atmospheric influence, would soon pass into a species of coal: brown coal and lignite, in which the trunks and branches of the trees are still perceptible, are only varieties less perfect than the true coal; and even in the old coal formation itself, various beds present various degrees of perfection, according as the vegetable mass seems to have been more quickly and perfectly removed from the action of the atmosphere. How the masses of vegetable matter were accumulated, is still a subject of speculation with geologists—some contending that the trees, grasses, ferns, &c. which compose it, must have grown and accumulated just as peat-mosses do at the present day, and that the land was then submerged, and the mass covered over by layers of sand and mud, which, hardening, formed strata of stone and shale; others reject this theory as untenable, and consider the whole strata (sandstone, shale, &c.) of the coal-measures to have been deposited in estuaries liable to periodic inundations, like those of the Niger and Ganges, but only on a more gigantic scale. According to this notion, which is more in accordance with the phenomena presented, coal is partly composed of vegetables which grew *in situ* in the form of jungle, and partly of masses drifted down from the interior by the waters of the river.

* Very few persons are unacquainted with the nature of the safety-lamp, invented by Sir Humphry Davy, and introduced to the miners in 1816. As shown in the text, it consists of an oil-lamp enclosed in a wire-gauze cylinder, of which the apertures are extremely minute—a square inch of the surface containing 625 openings. Through apertures so small, flame will not pass, and the lamp may therefore be carried into the most explosive atmospheres without risk. When the fire-damp is to the air in the proportion of 1 to 5, 6, or 7, the cylinder is filled with the flame; but even though the wire-gauze should become red hot, the exterior air is not kindled. It is perhaps possible, by certain chemical arrangements, to force the flame through the gauze, if a strong current be employed, but no instance of such an event ever having occurred naturally in a mine is, we believe, recorded; and therefore the Davy-lamp in its original form is esteemed perfectly safe, notwithstanding the numerous *improvements* proposed on it. If the miners would always employ this safeguard instead of candles, there can be little doubt that fewer explosions would occur; but the feeble light which it affords renders it unacceptable, and men will actually, and without dispute, frequently risk their lives for the sake of a little more light and the avoidance of a little trouble. Many mines have been conducted since the introduction of this lamp, which, without it, must have been closed; and some have been re-opened that could not be worked in safety with the old *steel-mill*—a machine of revolving steel and flint, employed before the Davy lamp in dangerous pits. This is especially the case in what are termed the 'pillar-workings' of the pit, where the ventilation becomes more difficult; and in almost all pillar-workings the *Davy*, as the pitmen call it, is in requisition. In many pits a *locked* Davy is delivered to the pitmen, who return it to the overseers before leaving the pit.

Jet—Amber.

Though the chief use of coal be doubtless that of producing heat and light, there are certain minor purposes to which some of the varieties are applied. Thus we have occasionally seen very pretty vases, and other ornaments, made from cannel coal when it is sufficiently compact and lustrous. It is easily turned on the lathe, and takes a polish which is not readily tarnished; the only objection to its use being brittleness, and liability to be injured by fire.

Jet, of which necklaces, ear-rings, and other ornaments are made, is but a variety of coal, as common in its origin and nature as that which we pile on our fires. It is occasionally found in the lignite beds of England, but principally in Germany and Prussia, where it occurs associated with amber, which is regarded as a fossil gum, while jet seems to be the trunk and branches of trees more completely bituminised, and freer from earthy impurities than cannel or other coals. It is easily turned on the lathe, or cut with the chisel, and is susceptible of a fine polish. Imitations of jet are extensively manufactured by the glass-maker; but these may be readily detected by their greater hardness and weight.

Amber, a well-known yellow resin-like substance, is believed, as stated, to be a fossil gum or resin; and its connection with deposits of lignite seems to confirm that opinion. It is solid, brittle, commonly transparent, and when rubbed, becomes electrical. It is found in various countries, more particularly on the Adriatic and Sicilian shores; on the Baltic, between Memel and Dantzic, where there are regular mines of it; and in Japan, Madagascar, and the Philippine Islands. It is used chiefly in the manufacture of beads, necklaces, trinkets, and various ornaments, for which purpose it is easily cut, and takes a beautiful polish. Dissolved by drying linseed oil, it forms amber-varnish. The largest known specimen of amber was found near the surface of the ground in Lithuania, about twelve miles from the Baltic: it weighs 18 lbs., and is in the royal cabinet at Berlin. Other curious specimens have been detected enclosing insects, and even drops of water—

these apparently having been enclosed when the gum was exuding in a fluid state from the living tree.

Naphtha—Petroleum—Asphalte.

Naphtha, petroleum, mineral pitch, and asphalte, may in a great measure be regarded as one and the same substance in different degrees of concentration and purity. Thus naphtha, on exposure to the air, soon loses its limpid appearance, and passes into petroleum; and petroleum, under similar treatment, dries and shrinks into a viscous sluggy state, undistinguishable from native mineral pitch.

Natural naphtha is a limpid, or but slightly-coloured bitumen, highly inflammable, and of a strong bituminous, but not disagreeable odour. It is found at Baku on the Caspian, at Hit on the Euphrates, and at other places in Mesopotamia; it occurs abundantly in the lower districts of the Birman empire; exists at various places in the north of Italy, as Piacenza, Modena, &c.; and in some districts of North America. It generally exudes from fissures in the rocky strata, or is collected in shallow wells, dug in the clays and shales where it occurs. A similar liquid can be obtained by distilling petroleum, coal-tar, and other bitumens; but the artificial product has a more penetrating and unpleasant odour. Naphtha has the property of dissolving most of the essential oils and resins, and is at present largely used as a solvent of caoutchouc. It is also used for lamps; and the cities of Parma and Genoa are said to be lighted with the produce of the wells in the duchies of Modena and Parma. A very fine black pigment may be prepared from the soot of naphtha lamps.

Petroleum, or rock-oil, is another liquid bitumen, of a brownish colour and variable consistency, and yielding a strong disagreeable odour. It is found exuding from various secondary strata, but chiefly in coal districts, where it is evidently a product of that formation. It occurs in small quantities in various localities of Britain, but abundantly in other countries of Europe, in Persia, the Birman empire, in Texas, and in the islands of Trinidad and Barbadoes. On exposure to the air, petroleum thickens, and assumes a darker hue, in which state it is generally known by the name of mineral pitch, or Barbadoes tar. On further exposure, and especially when mingled with earthy impurities, it passes into a solid state, then becoming the common asphalte or bitumen of commerce. In its ordinary liquid state it is burned for light; worked into balls with earth and gravel, it is used in eastern countries as fuel; and mingled with grease, it is occasionally employed as a substitute for tar in coating vessels.

Asphalte, so called from its adhesive nature, differs from mineral pitch in being solid and brittle at the ordinary state of the atmosphere. It melts easily, and is highly inflammable, leaving, when pure, little or no ash after combustion. It is found in most of the localities where petroleum springs occur, being nothing more than their accumulated produce. The chief supplies are obtained from the shores of the Dead Sea, from Barbadoes, from Trinidad, where it occupies a basin or lake about three miles in circumference, and from Clermont, Seyssel, and Bourg in France, where it occurs in limestone and calcareous shales. Asphalte was employed by the ancients in some of their cements, and also in the process of embalming. It is now extensively used in the formation of pavement, roofing, and other economical purposes. Melted and mingled with properly-sifted gravel, or iron slag, it forms a very durable and unexpensive pavement—being liable to be softened, however, during intense heats. See p. 336.

CALCAREOUS SUBSTANCES.

Under this head we include such economic minerals as contain a notable proportion of *calx* or lime in their composition. Common limestone, magnesian and lithographic limestones, marble, chalk, marl, gypsum, and alabaster, are familiar examples. Some of these have evidently been deposited from calcareous waters; others are as evidently the production of animalcules, like the coral polype; and some are almost wholly composed of the shells of molluscs, and of other calcareous exuviæ. Whatever may have been their several origins, they have all undergone certain chemical and structural changes since their formation—thus rendering them less or more compact and crystalline, producing a dull massive rock or a brilliant marble, an opaque gypsum or a translucent alabaster. Chemically, they have one common basis; namely, *calcium*—a substance obtained with difficulty in the laboratory, and never found as a natural product. It is one of the metallic elements discovered by Davy, and so extremely oxidable, that on exposure to the air it is almost instantaneously converted into lime (oxide of calcium); and this lime, if further exposed, becomes a limestone or carbonate of lime, by absorption of moisture and carbonic acid.

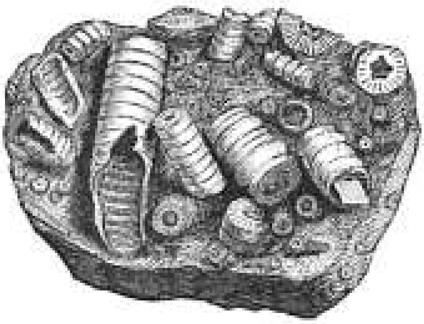
Common Limestone.

Limestones fit for building and agricultural purposes are found in every formation, from the oldest to those of the most recent origin—being crystalline and concretionary in the primitive and transition series, but gradually losing this structure, and becoming more earthy in the secondary and tertiary strata. In all of them there is a certain amount of impurities, consisting for the most part of clay and sand, with traces of iron and other ingredients. The economic value of any limestone, as well as its fitness for any particular purpose, must depend therefore upon its actual composition, and not upon its absolute purity as a carbonate. The rock is generally dug from open quarries, but occasionally, when it dips rapidly, and is worth the expense, it is followed downward by mining—the greater part of the stratum being excavated, and only portions left at intervals to support the superincumbent material. It is then broken into fragments of moderate size, and conveyed to a kiln, where, being placed in alternate layers with coal or turf, it is roasted, thereby expelling its water and carbonic acid. In the best-contrived kilns the process is carried on continuously; broken limestone and fuel being constantly thrown in at the top, and the burned lime raked out at intervals from beneath. In this state it is known as *shell*, or unslaked lime, and requires to be moistened with water to convert it into powdery quicklime. Occasionally, when the limestones contain a considerable per centage of silica (sand), and the heat been very high, the lime refuses to slake, and is said to be *over-burned*; in other words, a portion of silicate has been formed. Quicklime is a soft bulky powder soluble in water; and what is remarkable, the colder the water the larger quantity of lime is taken up. Thus a pint of water at 60 degrees will dissolve eleven grains; while at 212 degrees, or the boiling point, only seven grains are retained in solution. As stated under 'Fictile Manufactures,' and 'Applied Chemistry,' quicklime is largely employed in the formation of mortar and cements, in glassmaking, leather-dressing, dyeing and bleaching; and, as will hereafter be seen, its uses are not less important in agriculture, in the purification of gas, in medicine, and other industrial processes. Applied to land, it promotes the decay of vegetable fibre, neutralises the effects of certain hurtful compounds of iron, and probably serves to liberate potash from the insoluble silicates of that base contained in the soil. Lime-water for chemical and pharmaceutical purposes, is always prepared by agitating cold water with excess of quicklime in a closely-stoppered vessel, and then after subsidence pouring off the clear liquid. Besides the above applications, a large quantity of limestone is used as a flux in metallurgy, such strata being sought for this purpose as contain but a small per centage of impurities.

Limestone is one of the most abundant of rocks, there being no district of any extent in which it does not appear as a member of one or other of the geological formations. In Great Britain and Ireland the supply is inexhaustible; it is worked in beds from a few feet to one hundred in thickness; the mountain or carboniferous limestone, which underlies the coal-formation, often exceeding that thickness, and ranging unbroken for many miles in extent.

Marble.

Marble is but a technical term for any species of limestone sufficiently pure and compact to be susceptible of a fine polished surface. No matter what the colour, whether white or black, whether studded with the strange forms of fossils or streaked with the most fantastic veinings, marble is but a carbonate of lime, containing only a few subordinate impurities, which do no more than affect its colours and markings. The best varieties are obtained from the primary and transition formations, in which they occur granular, crystalline, and not unfrequently replete with party-coloured veinings. Pretty enough marbles for slabs and other architectural purposes are sometimes obtained from the secondary formations, these being, in general, curiously marked with the shells, encrinites, and other corals



Fragment of Encrinital Marble.

which are imbedded in the mass. None of these, however, are susceptible of the same degree of polish as the primary marbles, some of which, like that of Carrara, seem almost translucent. Most countries of any extent have varieties of native marbles, which, though inferior to those of Italy and the Archipelago, might still be more extensively used than they are, were it not for the expense in cutting and polishing, and, above all, for the rapidity with which many of them become weathered and tarnished.

Sculptors and architects generally arrange the marbles of a country into some such divisions as the following: — *Uni-coloured*, as the black and white; *variegated*, when marked with irregular spots and veins; *madrepore*, when studded with encrinal or coral markings; *shell*, when only a few shells are interspersed through the mass; *lumachelli*, entirely composed of shells; *cipolin*, containing veins of greenish talc; *breccia*, marbles formed of angular fragments of different composition and colour; and *puddingstone*, when the fragments are round instead of angular. The celebrated marbles of Greece and Rome, such as the Parian, the Pentelic, the Carrara, &c. were of one uniform colour, and only occasionally marked with grayish or greenish veins. Besides these, which were chiefly employed in sculpture, and in the decoration of their public edifices, the ancients indulged in a variety of fancy marbles for minor ornamental purposes—such as black, red, green, yellow, spotted, and veined. The localities of some of these ancient marbles are lost, but inexhaustible supplies of first-rate statuary and architectural marbles can still be obtained from the Archipelago, from Carrara, Genoa, Corsica, Sicily, and other parts of Italy. At Carrara alone, about 1200 men are employed at the different quarries, and at the mills for sawing the marble. The annual rental is calculated at about £28,000, and the value of the yearly exportations of the raw material is not less than half a million. So accessible are these quarries, and so free from flaws is the rock in some portions, that blocks of more than 200 cubic feet can be detached by means rude and primitive compared with quarrying in Britain. The value of the material differs according to the quality and size of the block; large blocks ranging from £2 to £3 per cubic foot.

Many marbles of excellent quality are found in France; in England they are abundant in the counties of Derby, Devon, and Anglesea, the last being of a green colour; in Scotland, at Assynt, Ballachulish, and in the islands of Tyree, Skye, and Jura; and in Ireland, at Kilkenny and other places. The Kilkenny marble is black, and encloses shells of a whitish colour, which, when cut across and polished, present various circular markings, which add to the beauty of the slab. The United States also furnishes some excellent architectural marbles, principally of primary formation. One range, which passes unbroken through several of the states, is perhaps one of the most extensive and valuable primary limestones in the world. It is of a pure white colour, and of a highly crystalline texture, affording blocks of more than fifty feet long and eight feet thick. It is employed in several of the states' public buildings—as, for example, the City Hall of New York, and Girard College, Philadelphia.

The applications of marble are so numerous and common, that we need here merely indicate its use in building, statuary, and monumental erections; in internal decoration, as mosaic-work, mantel-pieces, vases, table-slabs, and other articles of furniture. Party-coloured stones susceptible of a high polish, as porphyries, serpentines, and the like, are commonly but erroneously termed and classed with 'marble'—a term which is applicable alone to rocks essentially composed of carbonate of lime, and susceptible of polish as above described. As limestones, all marbles are consequently corroded and acted upon by acids; while porphyries and serpentines being essentially siliceous, are not so affected. Even alabaster, though having a calcareous base, is not in the above sense a marble; but is, as will shortly be seen, a sulphate of lime incorrodible by acids. The preparation of marble as an ornamental material is simple but laborious. The blocks are generally detached from the quarry by sets of iron wedges—blasting by gunpowder being apt to produce rents and flaws where least wanted. They are next reduced by hammer and pick, and finally chiselled into the desired form. Slabs are obtained by cutting the blocks asunder with a thin plate of soft iron, under which sand or grit, liberally supplied with water, acts as the cutting agent. Pieces of moderate size are generally cut by hand; but where the blocks are large, machines of various constructions are employed. Marble cutting, indeed, is the subject of several patents, in which machinery, moved by steam or water, effects not only plain cutting and polishing, but even mouldings and ornaments of an intricate kind. In polishing, sharp sand, emery, tripoli, and tin-putty are the substances employed—the workman graduating his material with the increasing smoothness of the surface. The body with which the sand is rubbed upon the marble is usually a plate of iron; but for the subsequent process a plate of lead is used, with fine sand and emery. The polishing rubbers are coarse linen cloths, wedged tight into an iron planing-tool. Throughout the whole operation, a constant supply of water is indispensable.

Magnesian Limestone—Magnesia.

Magnesian limestone, which appears extensively in England, Germany, and other continental countries, occurs often in beds of great thickness, immediately above the coal-measures, just as the mountain or carboniferous limestone lies immediately beneath. It is usually of a cream-yellow colour, and of very variable consistency, some layers being soft and powdery, others irregularly crystalline and concretionary, and some compact and homogeneous. The compact granular variety is generally known by the name of *dolomite*, after Dolomieu, a French geologist. Magnesian limestone is, for the most part, used as the ordinary carbonates of lime—that is, for agricultural and building purposes—some of the English quarries furnishing an exceedingly durable material. The new houses of parliament, for example, are built of a magnesian limestone; that of Bolsover Moor in Derbyshire having been selected after the most rigid scientific tests of a commission of inquiry. Besides these uses, some of the more compact and homogeneous schists are employed for lithographic blocks, the chief supply for that purpose being derived from Germany, though lithographic schists are also obtained from the white lias limestone in England. (See LITHOGRAPHY.)

Magnesian limestone is so called from its containing a notable per centage of magnesia—a well-known medicinal earth, commonly obtained by burning the carbonate of magnesia. Magnesium is the metallic basis of magnesia, just as calcium is the base of lime; it is strictly a product of the laboratory, and does not occur in nature. The *calcined magnesia* of the druggist is procured either from this source, or from the bittern of sea-salt, or from the waters of certain springs impregnated with the sulphate of magnesia. The hydrated carbonate of magnesia, the *magnesia alba* of the shops, is also obtained by a chemical process from the sulphate. Natural carbonate of magnesia is found in Piedmont, in Moravia, in the United States, and in the East Indies. It exists as a component part of many mineral substances, making them feel soft and soapy to the touch. *Sulphate of magnesia* (Epsom salts) is obtained by a simple process from bittern, by treating magnesian limestone with dilute sulphuric acid, or from certain mineral springs, as, for example, those of Epsom in Surrey, which give to the salt its most familiar name. This salt, which consists of 20 parts magnesia, 40 sulphuric acid, and 63 of water, is one of the most common and useful in medicine, and is, moreover, the chief source of the other forms in which magnesia is administered.

Meerschaum (German, *foam of the sea*), a substance in great repute among tobacco-pipe fanciers, is an earthy carbonate of magnesia, extremely light, and of a yellowish-brown colour. It is found in various parts of southern Europe, particularly in Greece and Turkey, where, besides being fashioned into pipe-bowls, it serves also the purposes of a fulling-earth. Germany, however, is the great seat of the meerschaum pipe manufacture, whence France and England obtain their supplies. The substance is first soaked in tallow, then in wax, fashioned into the desired form, and finally polished with shave grass. The rage for this species of pipe has led to clever imitations, which the most practised connoisseur cannot detect till he has used the article for some time; the spurious material assuming a dry and calcined appearance, or cracking and splintering, while the genuine meerschaum becomes of a beautiful brown, and remains quite uninjured by fire.

Chalk.

Chalk, another well-known mineral, is a carbonate of lime of a white or whitish-gray colour, having a soft meagre feel and earthy fracture. It is the last or youngest of the secondary rocks, and constitutes an important geological feature of England—the chalk-hills which form the white cliffs of our southern shores having conferred the ancient name of *Albion* (*alba*, white) upon our island. Calcined like common lime, it is used for manure and cement, in polishing metals and glass, as a marking material, in painting and whitewashing, and in various other processes. For the last purpose it is purified by trituration and elutriation, and sold under the name of *whiting*, or *Spanish white*. The chalk-formation yields also the flint of commerce; but this more properly falls to be considered under the class *siliceous substances*. What are called *Drawing chalks* have no relation to this substance. *Red* chalk, for example, is a clay, coloured with peroxide of iron, found in several localities; and the *French* chalk used by artists is a soft magnesian mineral, allied to steatite. *Crayons* are usually made of fine pipe-clay coloured with metallic pigments.

Marl—Calc Sand.

Marl is one of the most recent calcareous deposits, being in many places still in the course of formation. Though essentially a mixture of carbonate of lime and clay, it occurs in various states of purity, from a marly clay, which will scarcely effervesce under acids, to shell-marl, containing from 80 to 90 per cent. of lime. *Marl-clay*, for instance, occurs as a whitish friable clay, with an admixture of lime, and sometimes also of magnesian earth; the term *clay-marl* is used when the calcareous matter prevails over the clay. *Shell-marl* is almost wholly composed of lime and fresh-water shells, with a trace of clay and other earthy matter, and where solidified by chemical aggregation, is known as *rock-marl*. Marl uniformly occurs in valleys formerly the sites of lakes, or in existing lakes, and seems to be partly derived from the waters of calcareous springs which enter such lakes, and partly from the shells and secretions of the fresh-water molluscs which inhabit them. It is dug from open excavations, and applied to certain soils as a manure, or as a top-dressing for pasture.

Calcareous sand, which consists almost entirely of comminuted shells, is another recent product occasionally employed as a fertiliser. It is found in layers in ancient or raised beaches, and in masses by the sea-shore, where, thrown up by the waves, it often consolidates into beds of considerable thickness. As an instance of its value, Sir H. de la Beche mentions that between five and six millions of cubic feet are annually conveyed from the Cornish coasts, to be spread over the land in the interior as a mineral manure. As shells consist almost wholly of carbonate of lime, with a little animal matter, it would be more advantageous in most cases to reduce them to quicklime, which must be much more energetic in its action as a fertiliser.

Gypsum—Alabaster.

Gypsum, also known as sulphate of lime and plaster of Paris, is found in England, and in many other countries. It occurs in various states of crystallisation and purity: thus the ordinary gypsum of commerce is soft, and imperfectly crystalline; *selenite* is a transparent, highly crystalline mass; *satin gypsum* is fibrous and crystalline; and *alabaster* is pure white, and translucent. Gypsum occurs both in old and new formations, but principally in the new red sandstone, and in the tertiary beds, or those above the chalk. It is mined in various localities in England, and extensively quarried at Montmartre near Paris, whence it has derived its ordinary name of plaster of Paris. Calcined, pulverised, and mixed with water, it is run into moulds, forming stucco images, mouldings, and ornamental fronts for buildings. It is also used for stereotype and pottery moulds, and for medals and casts of various kinds. Mingled with a certain per centage of quicklime, it makes an excellent mortar; its virtues as a fertiliser have been also greatly extolled.

Some of the English gypseous alabasters, such as those of Derbyshire and Staffordshire, stand the turning-lathe well, and are accordingly formed into jars, vases, and other mantel-piece ornaments. The finest specimens, however, are found near Volterra in Tuscany. These are of a pure white colour, and granular texture, and when cut and polished, outrival the finest Carrara marble, from which they are, however, readily distinguished by their softness and liability to tarnish. A large trade in alabaster work is carried on in Florence, Leghorn, and Milan, where the material is fashioned, partly by the chisel, and partly by the turning-lathe, into statues, vases, lamps, boxes, stands for time-pieces, and other ornamental objects. All sculptures of alabaster should invariably be kept under a glass-shade, as a few months' exposure destroys at once their purity of colour and marble translucency.

Coral.

Coral, or coral-stone, is another calcareous material of commerce, which deserves to be noticed. Being entirely the secretion of certain marine animalcules, it is pretty nearly a pure carbonate of lime, and occurs in the warmer latitudes of the Pacific in vast barriers and reefs, often from fifty to one hundred feet in thickness, and from a few miles to hundreds of leagues in linear extent. Selecting for their residence some submarine ledge of rock, the animalcules begin to ply their vocation, increase, and spread, ever adding to their calcareous secretions, which by and by come to the surface, when they stop and carry on their operations laterally—thus in time elaborating masses which may well compete with any of the ancient rock formations. [See Zoology]. There are numerous varieties of the coral animalcule, each variety forming a coral of different shape, but still of the same substance; and ultimately, when indurated by ages, of the same solid and rocky-like consistence. Coral-rock is occasionally employed in the settlements of the South Sea islands as a building stone, volcanic forces having thrown beds of it several hundred feet above the present sea-level.

The recent branching corals are solely in request for ornamental purposes—their value depending upon the size, solidity, and colour of the specimen. Black and red varieties are the most highly prized—portions of Sicilian coral having been known to bring as much as eight or ten guineas per ounce. The price, however, is extremely variable, other portions of the same mass selling for less than a shilling a pound. Regular coral fisheries are established in the Straits of Messina, on the shores of Majorca and Ivica, the coast of Provence, and in other parts of the Mediterranean. Abundant supplies are also obtained from the Red Sea, the Persian Gulf, the coast of Sumatra, &c. The mode of fishing coral, as practised in the Mediterranean, is extremely primitive, but curious:—Seven or eight men go in a boat commanded by the proprietor; the caster throws the net or dredge used to tear up the coral from the bottom of the sea, the rest of the hands work the boat and help to draw the net. This is composed of two beams of wood tied crosswise, with leads fastened to them to sink them: to these beams is fastened a quantity of hemp twisted loosely round, and intermingled with some loose netting. In this condition the machine is let down into the sea, and when the coral is pretty strongly entwined in the hemp and nets, they draw it up with a rope, which they unwind according to the depth, and which it sometimes requires half-a-dozen boats to draw. Coral is worked up like precious stones, and must be kept from the action of acids.

ARGILLACEOUS SUBSTANCES.

Under this section we include all those substances in which clay (*argilla*) is a prevailing ingredient—as the common clay of the brick and tile-maker, the prepared clay of the potter, fullers' earth, and the slate now so generally used for roofing. Argillaceous compounds occur in every formation, from the lowest slate, through the shales and fire-clays of the coal-measures, up to the plastic clays of the tertiary and superficial deposits. In the earlier formations they are compact, slaty, and somewhat crystalline; as we ascend, they become dull and merely laminated; while in the more recent deposits lamination disappears, and we are presented with mere tenacious masses, void of anything like structural arrangement. As discovered by Davy, *aluminium* is the metallic basis of pure clay or alumina (oxide of aluminium); but neither the metal nor its oxide is ever found in nature in a state of absolute purity. Sand, lime, magnesia, metallic oxides, and other ingredients, are less or more incorporated with all natural clays; and according to the characters so derived, do they acquire their peculiar values.

Clay.

The common superficial clay, which is so liberally spread over our island, must be familiar to every one. It is of various colours—yellow, red, or bluish; more or less mixed up with sand and fragments of rock; and when softened with water, becomes plastic and tenacious. It is this variety that is ordinarily used for the manufacture of bricks, roofing and drain-tiles, chimney-tops, water-tubes, and the coarser sorts of earthenware. For these purposes it is broken down, partly by exposure to the weather, and partly by the pug-mill, kneaded with water, and freed from the grosser impurities, after which it is beat up into the desired consistency, passed through moulds, dried so far in the atmosphere, and then burned in clamps or in kilns. For bricks, slabs, crucibles, &c. which have to resist the action of fire, some of the coal-measure clays are generally had recourse to; these, from their greater purity, and a certain per centage of silica, being susceptible of a more thorough burning. In this case the raw material requires to be mixed, but generally in connection with the working of coal or ironstone. In England, the Windsor, Stourbridge, and Welsh fire-clays are esteemed the best—the latter yielding those large square slabs employed in the construction of drying-kilns, brewers' coppers, sugar-boilers, furnaces, &c. In the preparation of fire-clays, greater labour and care are necessary—the crude material being generally ground under heavy stone or cast-iron wheels, and in most instances requiring artificial admixture.

Pipe-clay, potters'-clay, and porcelain-clay, are but technical names for pure varieties of well-prepared specimens of the same substance. We have seen that common brown ware can be made from ordinary clay; but when the finer varieties of white ware or china are attempted, not only finer clays must be sought, but even these must be mixed with a certain proportion of calcined flint or silex. One of the finest varieties of aluminous earth is the China-clay of Devon and Cornwall, or the *kaolin* of the Chinese. This is a decomposed felspar—one of the constituent minerals of granite—which has accumulated in vast quantities in certain localities, having been no doubt washed down by rains from the weathered and exposed surface of granitic rocks. At one time the use of this substance was unknown in England, but now about 38,000 tons, worth about £50,000, are annually exported from the south of England for the Staffordshire potteries, and for the manufacture of mosaic tesseræ, buttons, artificial gems, and the like. The best pipe-clay is obtained from Poole in Dorsetshire, and the isle of Purbeck; it is employed in the manufacture of tobacco-pipes and fine pottery, and also sometimes used for the fulling or scouring of woollens.

Fullers' Earth.

Fullers' earth is a soft, dull, unctuous kind of clay, usually of a greenish-brown colour. It is dug in various parts of England, particularly in Buckingham, Surrey, Hampshire, and Bedfordshire, the lighter-coloured beds being the most esteemed. It is used in the fulling of cloth, from its property—a property common to all soft aluminous minerals—of absorbing oil and grease. At one time it was deemed of so much importance to the national trade in woollen, that its exportation was prohibited; but now soap is chiefly used instead, and fullers' clay has fallen in importance. What the present consumption may be, it is impossible to say; but about forty years ago not less than 7000 tons were annually made use of. Although denominated a clay, it is essentially composed of siliceous earth, only about a fourth part being pure alumina; and if the proportion of clay were much greater, it would become too tenacious to be worked by the fuller. Every clay that is of an unctuous or saponaceous quality, will answer in some degree the purposes of fulling; but not so well as proper fullers' earth, which is distinguished from common clay by its falling to pieces in water with a slight crackling noise, instead of making a paste with it as clay does.

Ochre.

This is a painter's term for a native earthy mixture of alumina, silica, and oxide of iron. It is found of various hues, but chiefly of a yellow or reddish-brown, and is employed as an ingredient in painters' colours, and in the polishing of metal articles. It is obtained from various places, particularly from Shotover Hill, near Oxford; from the coal-measures of the east of Fife; and from Italy. The quantity raised in Britain is unknown, but about 5000 hundredweights are said to be annually imported. In general, ochre is obtained by a rude sort of mining; and requires to be prepared for use by trituration and elutriation.

Clay-Slate.

Clay-slate, of which roofing and writing-slate are the most familiar examples, is very extensively diffused, and as extensively made use of, in the British islands. It belongs to one of the lowest or oldest formations, is essentially composed of alumina and silex, has a peculiarly fissile structure, and is usually of a dark lustrous blue, bluish-green, or purplish colour. Like all mixed rocks, the chemical composition of clay-slate varies considerably. The following is given as the analysis of a common Scotch variety:—Silex, 50; alumina, 27; oxide and sulphate of iron, 11; potash, 4; magnesia, 1; carbon, a trace; and water, 7. The principal quarries are in Wales, where they give employment to nearly five thousand hands; in the north of England and west of Scotland; the most extensive being in Caernarthen near Bangor, in Borrowdale in Cumberland, and at Easdale and Ballachulish in Argyleshire. The beds of clay-slate are often of great thickness, but only certain portions are sufficiently compact to be of commercial importance. The chief consumer of this material is the slater, though considerable quantities are also used as pavement in cellars and warehouses, for shelves in dairies, for the construction of cisterns, and the like. The finer-grained varieties are polished for school-slates and slate-pencil; and those of attractive colours are now manufactured into flower-pots, vases, fancy-tables, and other ornamental objects.

Clay-slate is invariably quarried; and here it must be observed that the splitting of the rock does not take place in the direction of the bed, but at a considerable angle to the plane of stratification. This peculiar structure is known as *cleavage* (see GEOLOGY), and seems to have been superinduced long after the deposition of the strata. It is totally different from *lamination*, which allows certain sandstones and shales to be split into thin slaty bands, and which is a natural structure of deposition, always parallel to the plane of stratification. A piece of slate being split to the desired thickness, it is next squared by a knife or cutting edge of steel, the slate being held over a similar cutting edge or anvil. Polishing is performed by sand, emery-powder, and water; and some varieties of slate stand to be sawn, planed, and turned by tools differing little from those of the joiner. The following is generally given as a test of the fitness of slates for roofing and other external purposes:—Lay one in an oven till perfectly dry; weigh it, and then immerse it in water for some time. When taken out, wipe it carefully with a dry cloth, and weigh it again. Those slates which have acquired the least additional weight, and consequently have absorbed least water from being the least porous, are the fittest for roofing. Good slates should be thin, dense, and of a smooth surface. Balance one on the finger, and strike it with a hammer; if the sound is clear, the slate may be considered as firm; if dull, the slate is less dense, and should be rejected. *Whet, polishing*, and other varieties of slate, are treated under the following section.

SILICEOUS SUBSTANCES.

Silex or silica is one of the most important and most generally diffused of the mineral ingredients that enter into the composition of the rocky crust of the globe. Rock-crystal, quartz, chalcedony, and flint, may be regarded as nearly pure silica; and all the varieties of sandstone, quartz-rock, and granite, are in a great measure composed of it—many sandstones, for example, being pure granular quartz or silica, with a slight argillaceous cement. As in the case of the alkaline earths, it has been shown that silica is an oxide, the basis of which is *silicium* or *silicon*—a substance more closely allied to boron than any other substance, but probably not metallic.

Quartz—Rock-Crystal.

Quartz and quartz-rock, though of importance as forming the bases of other rocks, are of themselves of no great commercial value. Pounded quartz, as stated under 'Fictile Manufactures,' enters largely into the composition of Chinese porcelain, performing the same part as calcined flint in the wares of England. The purer varieties of rock-crystal are occasionally cut as ornamental stones; and of late the transparent and colourless varieties have been pretty generally adopted by opticians as spectacle lenses. Their extreme hardness renders them more durable than glass, and less liable to be scratched, while they are altogether cooler and more agreeable. The so-called Brazilian pebble, used for this purpose, is of pure silica, and is sometimes found in crystals as large as a cocoa-nut. Quartz, in its distinctly crystalline forms, constitutes several of the 'Precious Stones,' or gems, and will be further treated under that head.

Flint.

The common nodular flints found in the chalk-formation are nearly pure silica, exhibiting but a trace of alumina, oxide of iron, and lime. The formation of flint within a mass so different in composition as chalk, is still, in some respects, an unsolved problem in geology. It occurs in nodular masses of very irregular forms and of variable magnitude, some of these not exceeding an inch, others more than a yard in circumference. Although thickly distributed in horizontal layers, they are never in contact with each other, each nodule being completely enveloped by the chalk. Externally, they are composed of a white cherty crust; internally, they are of gray or black silex, and often contain cavities lined with chalcedony and crystallised quartz. When taken from the quarry, they are brittle, and full of moisture, but soon dry, and assume their well-known hard and refractory qualities. Flints, almost without exception, enclose remains of sponges, alcyonia, echinida, and other marine organisms, the structures of which are often preserved in the most delicate and beautiful manner. From these facts, it would seem that flints are simply aggregations of silex around some organic nucleus, the same as iron-stone nodules or *septaria* are aggregations of clay and carbonate of iron.

The uses of flint are various: calcined and ground to a powder, it is used in the manufacture of the finer sorts of pottery and porcelain; it also enters into the composition of flint-glass; is employed in the preparation of certain kinds of soap; and before the invention of the percussion-cap, gun-flints were in universal use. Flints also form excellent building materials, because they give a firm hold to the mortar by their irregularly rough surfaces, and resist, by their hardness, every vicissitude of weather. The counties of Kent, Essex, Suffolk, and Norfolk, according to Dr Ure, contain many substantial specimens of this sort of masonry. The reduction of flint to economical uses is extremely simple. We have stated how it is prepared for the potter and glass-blower (p. 321); the formation of gun-flints is a process strictly mechanical, and depends wholly on dexterous manipulation. Having made choice of a good nodule, weighing from 2 lbs. to 20 lbs.—that is, one of a fine uniform grain, compact, and possessed of a certain translucency—the workman, furnished with an assortment of iron mallets, proceeds, first, to break the block in moderate-sized fragments; secondly, to cleave these fragments into chips, which scale off with a conchoidal fracture; thirdly, to fashion them into gun-flints; and lastly, to trim the edge which is intended to strike against the lock. A clever workman will cleave and fashion about 2000 gun-flints a-week without any assistance, if the balls be of good quality.

Sandstones.

Sandstone, or freestone, as it is sometimes called, occurs in innumerable varieties, differing in colour, in composition, fineness of grain, and compactness. Thus we have some red, from the presence of iron oxide; some silvery and glistening, from the presence of minute scales of mica; others white, yellow, and mottled; and some almost jet-black, from the presence of bituminous or carbonaceous matter. As to mineral composition, there is no other class of rocks so varied; for though quartz grains give to them their family character, clay, lime, mica, carbon, iron, and the like, mingle with them so capriciously, that it is impossible to find any two strata of sandstone exactly of the same composition. Again, their texture is equally if not still more varied; in some the grains being as large as peas, in others quite impalpable; some being so soft and friable as to be rubbed down by the hand, and others so hard and compact that nothing but the chisel of the stone-cutter can touch them. The principal use of sandstone is in building, and for this purpose good durable strata are found in almost every formation, from the greywacke up to the recent tertiaries.

In England, where bricks form the more available material for the construction of houses, there are comparatively few freestone quarries of much importance. Those of Portland Isle, which have furnished the stone for St Paul's and other public buildings in London, those of Bath, and of Gateshead Fell, near Newcastle, are the most extensive and valuable. In Scotland, freestone of excellent quality is to be found in most localities, and consequently it is the prevailing architectural material. The best strata are those underlying the coal-formation—such as are quarried in the neighbourhood of Glasgow, near Linlithgow, in the neighbourhood of Edinburgh, and in several parts of Fifeshire. The blocks from the quarries of Craigleith, Granton, Cullelo, &c. which all belong to the same suite of strata, almost rival marble in their whiteness, compactness, and durability, and even surpass it in fitness for certain kinds of architectural sculpture. The principal buildings of the New Town of Edinburgh are constructed of this material, and certainly no city in the world can boast of similar erections. Good building sandstone is also obtained from the old red formation, such as is quarried at Kingoodie, and other places near Dundee, the rock being at once exceedingly durable, and producing blocks of any dimensions.

Many sandstones are likewise used as pavement, those being sought for that purpose which are at once compact and thin—bedded or schistose. By far the most valuable of this kind are the Forfarshire gray micaceous flagstones, now so generally employed as foot-pavement in all our large towns. A very extensive trade in these is carried on at Arbroath and Montrose, the flagstones being now dressed and hewn by machinery at the quarries. Another excellent material, still more durable, but exceedingly hard and refractory, is also obtained from Caithness, which, when well laid down, appears to the unpractised eye more like plates of cast-iron than slabs of stone. Pavement of average quality is likewise obtained from the coal-measures; but being of a softer and more absorbent texture, is not so well adapted for out-door purposes. All these beds are highly fissile or schistose, occurring in laminæ or layers of from one to fourteen inches in thickness; and thus accounts for the fact, that at one time the thinner sorts were used for roofing, under the name of *tile-stones* or gray-slate.

Besides building and paving, several sorts of sandstone are employed for grindstones, millstones, whetstones, and the like. Thus the quarries of Gateshead Fell, situated on the *millstone grit*, or quartzose sandstones of the lower coal-measures, furnish the grindstones known in all parts of the world as 'Newcastle grindstones.' Good millstone and whetstone beds are found in various other places, as are also varieties fit for the wheels of glass-cutters and cutlers. The stones chiefly used in Sheffield are procured at Wickersley in Yorkshire. The celebrated *burr* millstones of France are obtained from the upper fresh-water siliceous limestones of the Paris basin, and are not strictly sandstones, in the usual acceptation of that term. A close grit, containing a certain amount of talc, is quarried at Coxgreen, in the neighbourhood of Newcastle, and highly prized as a firestone in the erection of glass-furnaces.

Sand.

On narrowly inspecting the immense masses of sand borne down by our rivers, piled up along our shores, or scattered in dunes and strata over the surface of the country, it will be found that the great bulk of it is composed of siliceous particles, evidently derived from decomposed quartz-rock, granite, sandstone, and the like. As might be expected, most sands are mingled with clay, lime, and other earthy impurities; and it is according to their siliceous character, and degree of purity from earthy ingredients, that they become of value in the arts. Thus sharp, well-sifted sand is an indispensable ingredient in well-prepared mortar, without which the builder, the plasterer, and fresco-painter could not proceed a single step: the commoner sorts are widely used in paving, in the construction of ovens, kilns, annealing furnaces, and the like, where heat is wished to be retained; and some peculiar varieties are much used in the preparation of moulds for the casting of iron, brass, and other metals. Good siliceous sand is an indispensable ingredient in all sorts of glass, now one of the most important manufactures in the civilised world. The most valuable sands for this purpose are those of Aumont, near Senlis, in France, and those of the Isle of Wight, and of Lynn in Norfolk, in England; though of course each glassmaking country possesses sands more or less fitted for the same uses, if properly washed and sifted.

Granitic Rocks.

This term may be considered as embracing not only the true igneous granite, but the gneissose and mica-slate rocks, which, though stratified, partake of the same mineral character, and are usually associated with it. In all of them, silica is a predominant ingredient, imparting those hard and durable qualities which render them of economical importance. Ordinary granite is a crystalline compound of quartz, felspar, and mica; but other minerals, such as hornblende, hyperstheme, &c. occasionally mingle with it, thus producing a number of varieties. The small-grained grayish granite of Aberdeen is essentially a compound of quartz, felspar, and mica; that of Peterhead is the same compound, rendered red by the oxide of iron contained in the felspar crystals. Granitic compounds are very widely distributed, forming the fundamental rock of our principal mountain chains. The Grampians in Scotland, the Cumberland and Cornish hills in England, the Wicklow mountains in Ireland, the Pyrenees in Spain, the Dovrefelds in Norway, the Ural in Russia, the Abyssinian and other African ranges, and the Andes in South America, are all less or more composed of rocks partaking of a granitic character.

The economical uses to which granitic rocks are applied are by no means unimportant. Compact granite, from its extreme hardness, is largely employed in the construction of docks, piers, lighthouse foundations, bridges, and other structures where durability is the main object in view. Waterloo Bridge in London, the Liverpool and other English docks, are built of granite. It is the ordinary building stone in Aberdeen, and is largely used in the metropolis for paving. The Pyramids, though internally constructed of limestone, are externally coated with granite. Pompey's Pillar, and other ancient Egyptian structures, are composed of it; the column of Alexander, and the pedestal of the colossal statue of Peter the Great, in the Russian capital, as well as several monumental monoliths in other countries, are also of granite. Within these few years, the granite of Aberdeenshire has been brought into use as an ornamental stone; and machinery has been erected, we believe, both at Aberdeen and Peterhead for the purpose of polishing it like marble, to which many prefer it, for chimney slabs, vases, pedestals, pillars, &c. When uniform and compact in grain, it is susceptible of a very high polish; and has this advantage over marble, that it is not easily stained or scratched, nor at all acted upon by acids.

Serpentine, or the magnesian rock generally so called, is one of very varied composition and quality. The noble serpentine of the mineralogist is a green translucent rock, rather soft, but susceptible of a good polish; and if found in sufficiently large blocks, would make not a bad substitute for marble. We have before us a specimen of a beautiful leek-green variety from New Zealand, where it is said to occur eight or ten feet thick, and capable of being raised in blocks of any size. Should this be the case, the houses of our brethren who have made these islands their adopted home, need be in no lack of interior decorations. Potstone, the *lapis ollaris* of the ancients, is another granitic product, easily worked into form, and formerly used for culinary vessels; whence its common designation. *Jade*, sometimes called *nephrite*, from its supposed medicinal virtues, is another dark leek-green mineral of the same family. It contains a larger amount of silica than the true serpentine, which it greatly resembles. In New Zealand and the Indian Archipelago, it is fashioned into hatchets, edge-tools, and other implements.

Mica—Talc—Asbestos.

Mica, talc, asbestos, and other kindred minerals which are the products of the granitic and primary rocks, may be appropriately considered in this place. The silvery-looking, scaly substance which occurs in ordinary granite is mica, so called from its glistening aspect. It is sometimes found in crystals more than a foot square; and when of this size, is split into thin plates, and from its transparency, used in certain cases as a substitute for glass. It stands a higher degree of heat, without splintering, than glass, and is well adapted for ship-lights, not being liable to fracture during the firing of cannon. The large sheets exposed for sale by the mineral dealers are generally brought from Siberia; hence the term, *Siberian glass*.

Talc, when crystallised, has much the same appearance, but on trial, will be found to be less transparent, softer, and non-elastic. The larger crystals are sometimes applied to the same purposes as mica, but the principal use of the mineral is in porcelain paste, and in polishing alabaster figures. It is also said to be an ingredient in rouge for the toilet, having the property of communicating softness to the skin. Talc-slate, the other form in which this mineral occurs, is a massive mineral, breaking up in tabular fragments; it has a white streak, and greasy or soapy feel. It is employed in the porcelain and crayon manufactures, and is used as a marking material by carpenters, tailors, and others. Talc occurs in the primary and transition districts of Scotland, in various parts of the continent, and largely in India and Ceylon.

Asbestos, or amianthus, is a soft mineral, occurring in separate filaments of a silky lustre, and consisting essentially of silica, magnesia, and lime. When steeped in oil, it may be woven into cloth, which is incombustible, and may therefore be purified by fire; hence the terms amianthus (*amianthus*, undefiled) and asbestos (*asbestos*, unconsumable). Cloth of this kind was used by the ancients to wrap the bodies of the dead about to be burned, to prevent their ashes being mixed with those of the funeral pile. In the United States of America, asbestos is sometimes used as a lamp-wick.

Whetslate, or whetstone, also with some degree of scientific pedantry termed novaculite, from *novacula*, a razor, is an allied substance, essentially composed of silica in impalpable grains, with a small per centage of magnesian earth. Very fine varieties are brought from Turkey, under the name of *hones*, and largely used for sharpening steel instruments.

Basaltic Rock.

Under this head we include all the basalts, greenstones, whinstones, and traps, which make up the sum of the igneous rocks of the secondary formations. They are essentially siliceous—quartz, hornblende, hypersthene, augite, and so forth, entering largely into their composition. Some of the basalts and greenstones dress well under the hammer, and though of a dingy colour, make an excellent building stone, their durability being equal to that of granite itself. Ordinary greenstone, or whinstone, is a very valuable rock in many districts of Scotland, where it furnishes material at once for houses, fences, drains, and roads. Indeed no rock is better adapted, or more extensively used, for causewaying, and for macadamised roads it is unrivalled. Large quantities are, or at least used to be, shipped from the Firth of Forth for the kerbstones and causeways of the streets of London. We have seen some ornamental pedestals in basalt which took on a pretty fair polish; and an elaborately-carved Bhuddist idol, of considerable size, now in the museum at St Andrews, is of the same material. Some of the trap-rocks stand fire to perfection, and this has suggested their use as oven-soles, where such varieties can be procured. An attempt has also been made to employ certain varieties of trap in the manufacture of a coarse bottle-glass.

Volcanic Products.

The mineral products ejected from volcanoes are chiefly lava, obsidian, pumice, scoriæ, and a light impalpable dust, in all of which silica and alumina are the main ingredients. Some of the compacter sorts of *lava* are hardly to be distinguished from the trap-rocks of the secondary formations, and may consequently be employed for the same economical purposes. *Obsidian*—so named, according to Pliny, from one Obsidius, who first brought it from Ethiopia—is a true volcanic glass, of various colours, but usually black, and nearly opaque. In Mexico and Peru, it is occasionally fashioned into adzes, hatchets, and other cutting instruments, or into ring-stones. So closely does it resemble the slag of our glass furnaces, that in hand specimens it is almost impossible to distinguish the natural from the artificial product. It consists chemically of silica and alumina, with a little potash and oxide of iron. *Pumice*, a well-known volcanic product, is extremely light and porous, and of a fibrous texture; it is harsh to the touch, is usually of a grayish colour, and has a shining pearly lustre. Like obsidian, it is principally composed of silica and alumina, with traces of potash, soda, and oxide of iron. Pumice is quarried and exported in large quantities from the Lipari and Ponza islands, off the coast of Sicily. It is used for polishing metals, glass, marble, wood, ivory, and also in the smoothing of parchment and vellum. *Pozzolana*, already described under 'Fictile Manufactures,' is another volcanic product, which has been long and largely used in the preparation of hydraulic cements.

Tripoli, &c.

We include under this head several siliceous earths and slates extensively employed in the polishing of metallic surfaces. The most familiar of these are tripoli (so called from Tripoli in Barbary, where it was originally procured), polishing-slate, semi-opal, and some of the porcelain earths. The uses of these substances are well known: it is their peculiar origin that confers on them an especial scientific value and interest. It has been established by Ehrenberg that these and several other rocky masses are not the results of ordinary deposition, but an aggregation of the siliceous shells of the minutest animalcules. This is a curious fact: the remains of creatures individually invisible to the naked eye, forming rocks which, in the course of time, were to figure in the economical applications of the human race!

On analysis, a hundred parts of tripoli are found to contain upwards of eighty of silica, the remainder consisting of alumina, oxide of iron, and water. The *polirschiefer*, or polishing-slate of the Germans, found at Billin in Bohemia; and the *berg-mehl*, or mountain-meal of the Swedes, said to be mixed with bread in times of scarcity, are substances of similar origin and use. Another species of infusorial earth is said to be occasionally eaten by the North American Indians; it is probably the same as the European mountain-meal. The well-known *rotten-stone* of Derbyshire and other localities is more argillaceous than siliceous; it is largely used for giving the final polish to metals, glass, marble, and precious stones.

SALINE SUBSTANCES.

Under this section we comprehend such products as rock-salt, alum, saltpetre, borax, and the like, which are found either as native salts, or are procured by artificial processes from certain mineral substances with which they are combined in nature. Some of these salts are of vast economical importance, and appear to be as indispensable to the progress of civilised life as either coal or iron.

Rock-Salt.

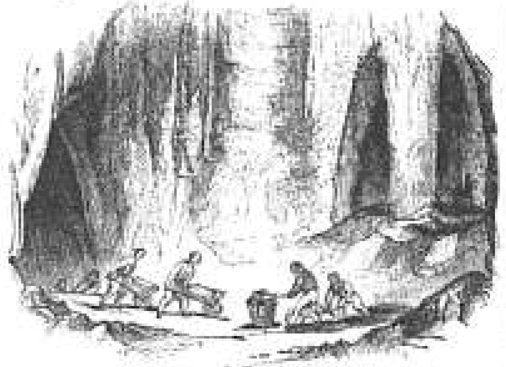
The common culinary salt of every-day use is chemically a muriate of soda, or, more strictly, a chloride of sodium, every hundred parts of which are composed of sixty chlorine and forty soda. It exists abundantly in sea-water, constituting more than a thirtieth part of its weight; it is discharged by salt or brine-springs—which arise from different geological formations, and are situated in different countries—to the extent of from 20 to 30 per cent.; and it is found in various degrees of purity in beds and irregular masses, from 20 or 30 to more than 120 feet in thickness. Native chloride of sodium is never found in a state of absolute purity, but is always less or more combined with certain salts of lime, magnesia, soda, iron, and alumina; to free it from these impurities, and render it fit for culinary purposes, is the duty of the salt-boiler and refiner.

At one time salt was largely, and is still to some extent, derived by evaporation from sea-water, by the following simple process:—A reservoir is erected near the sea, into which, at high water, supplies are taken by means of a pipe extending a good way down the beach. The pipe is generally placed near the low-water mark, in order to get the water from a point as far from the surface as possible, so that it may be the more impregnated with salt, and require less boiling. The pans are built on a range on both sides of the reservoir, from which the water is pumped into them after the impurities have settled. The pans are shallow vessels, made of sheet iron, about twenty feet long, and twelve broad, with a furnace below. These are contained in a small low-roofed house, the covering of which is of deals, with an opening at the meeting of the roof and the wall, to allow the vapour to escape. When the water is boiling, a little bullock's blood is put into the pan, which brings the impurities to the surface, and allows of their being skimmed off. As the water boils down, more is pumped in; and this process is repeated before the salt is finally drawn. From a pan of 1300 gallons, fifteen or twenty bushels, of fifty-six pounds each, are obtained in this manner, the process requiring about twenty-four hours. The salt is at first very light and floury in proportion to its bulk, and in this state is most appreciated. A still finer article resolving into large crystals—bay-salt—is made with a low fire, and when a longer time is allowed in the evaporation. For use at table, the salt is refined, and usually run into large lumps.

The water which remains after the salt is crystallised, called the *mother-water*, contains a considerable quantity of the chloride of magnesium or bitterns, chloride of sodium, and sulphate of magnesia. If the mother-water is exposed in tanks during winter, it will afford three successive crystalline deposits, the last of which is sulphate of soda nearly in a pure state. The chloride of magnesium deteriorates the salt very much, but may be removed by the following simple expedient, mentioned by Dr Ure:—'Let quicklime be introduced in equivalent quantity to the magnesia present, and it will precipitate this earth, and form chloride of calcium, which will immediately react upon the sulphate of soda in the mother-water, producing sulphate of lime and chloride of sodium. The former being nearly insoluble, is easily separated. Lime, moreover, decomposes directly the chloride of magnesium, but with the effect of merely substituting chloride of calcium in its stead. But in general there is abundance of sulphate of soda in brine-springs to decompose the chloride of calcium. A still better mode of proceeding with sea-water would be to add to it in the settling tank the quantity of lime equivalent to the magnesia, whereby an available deposit of this earth would be obtained. Brine thus purified may at once be safely crystallised by rapid evaporation.'

The process of procuring salt from sea-water is now all but abandoned in Britain, and is only had recourse to in some southern and tropical countries, where the arts of life are still in a rude and primitive condition. The supply is mainly obtained from brine-springs, such as those of Droitwich in Worcestershire; and from the mineral rock-salt, which abounds in the new red sandstone and upper secondary formations. This important mineral product occurs in Cheshire and Worcester in England, at Altemonte in Calabria, Halle in the Tyrol, Cardona in the Pyrenees, Wieliczka in Poland, and in several districts of North America. As brine-springs always issue from saliferous deposits, and are doubtlessly derived from the solution of the solid masses by subterranean waters, we shall restrict our description to the solid rock-salt, taking the mines of Cheshire as a sufficiently illustrative example. These mines, together with the brine-pits of Worcester, not only supply sufficient salt for the consumption of almost the whole of Britain, but furnish an article of export to the extent perhaps of half a million tons annually.

It has been stated that the chief deposits of English rock-salt are confined to the new red sandstone formation, where it alternates with its argillaceous and gypseous marls. 'In Cheshire,' says Professor Ansted, 'the rock occurs in large quantities in the condition of an impure muriate of soda, and associated with a peculiar marl; it is sometimes massive, and sometimes existing in large cubical crystals; and the beds containing it usually alternate with considerable quantities of gypsum, although this latter mineral is not worked to profit. The appearance of the rock-salt is by no means of that brilliant character, nor has it the delicate transparency and bright reflecting surface which the reader may perhaps suppose characteristic of it. It is usually of a dull red tint, and associated with red and palish-green marl; but it is still not without many features of great interest; and when lighted up with numerous candles, the vast subterranean halls that have been excavated present an appearance richly repaying any trouble that may have been incurred in visiting them. At Nantwich, and the other places in Cheshire where the salt is worked, the beds containing it are reached at a depth of from fifty to a hundred and fifty yards below the surface. The number of saliferous beds in the district is five; the thinnest of them being only six inches, but the thickest nearly forty feet; and a considerable quantity of salt is also mixed with the marls associated with the purer beds. The method of working the thick beds is not much unlike that of mining the thicker seams of coal. The roof, however, being more tough, and not so liable to fall, and the noxious gases—with the exception of carbonic acid gas—totally absent, the works are more simple, and are far more pleasant to visit. Large pillars of various dimensions are left to support the roof at irregular intervals, but these bear only a small ratio to the portion of the bed excavated, and rather add to the picturesque effect in relieving the deep shadows, and giving the eye an object on which to rest. The intervening portions are loosened from the rock by blasting; and it may be readily understood that the effect of the explosions heard from time to time, and re-echoing through the wide spaces, and from the distant walls of rock, give a grandeur and impressiveness to the scene not often surpassed. The great charm, indeed, on the occasion of a visit to these mines, even when they are illuminated by thousands of lights, is chiefly owing to the gloomy and cavernous appearance, the dim endless perspective, broken by the numerous pillars, and the lights, half-disclosing and half-concealing the deep recesses which are formed and terminated by these monstrous and solid projections.



The descent to the mines is by a shaft, used for the general purposes of drainage, ventilation, and lifting the miners and produce of the mine. The shafts are of large size in the more important works, and the excavations very considerable, the part of the bed excavated being in some cases as much as several acres. Over this great space, the roof, which is twenty feet above the floor, is supported by pillars, which are not less than fifteen feet thick. The Wilton mine, one of the largest of them, is worked 330 feet below the surface; and from it, and one or two of the adjacent mines, upwards of 60,000 tons of rock-salt are annually obtained, two-thirds of which are immediately exported, and the rest is dissolved in water, and afterwards reduced to a crystalline state by evaporating the solution.' The modes of working rock-salt are much the same in all countries; while the fineness and purity of the manufactured material depend upon the rapidity with which the brine is evaporated, and the nature of the clarifying agents employed. The uses of salt, whether obtained from sea-water or from mineral products, are so numerous and so well known, that it would be almost superfluous to attempt their enumeration. From its use as a simple condiment, through all its applications in the arts, up to the manufacture of soda from its substance, salt is one of the most important of natural products.

The formation of rock-salt is a subject which has much engaged the attention of speculative geologists. The sandstones and marls with which it is associated are evidently derived from deposition in water; but the irregularity of the salt beds, the fact of their occurring in masses of vast thickness, and the soluble nature of the compound, all point to a somewhat different origin. At present, salt lakes and superficial accumulations of salt occur in various parts of the world, and these have furnished data for reasoning as to the saliferous deposits of earlier eras. Salt lakes are chiefly derived from salt springs; and being subjected to the vapourising influence of the sun, which carries off only fresh vapour, their waters become in time saturated with saline matter. But water can hold only a fixed amount of salt in solution; and so soon as this amount is attained, the salt begins to fall to the bottom by its own gravity. In the course of ages these layers will form a thick bed, interstratified, it may be, with mud, or other earthy sediment; and should the lake be ultimately dried up, the salt will constitute a deposit something analogous to the rock-salt of the new red sandstone. Such is the process which some geologists have advanced to account for the formation of rock-salt—supposing that portions of the seas of deposit were occasionally cut off by igneous disturbances from connection with the main ocean, and subjected to a rapid evaporating power, without receiving fresh accessions of water.

Alum.

This is a well-known earthy salt, found native only in small quantities, but very largely manufactured from certain argillaceous strata, generally distinguished as alum-clays and shales. It is composed of alumina, sulphuric acid, potash, and has a sweet and astringent taste, and is a powerful styptic. It is much used in dyeing and in calico-printing, in consequence of the attraction its base has for colouring matter; it is also used in lake colours, in leather-dressing, in the preparation of paper pastes, in clarifying liquors, and by candlemakers to harden and whiten the tallow.

Native alum being too scanty a product to be used for any of these purposes, it has become the duty of the chemist to prepare it artificially—either from mineral substances which contain the elements of alum, or by mixing these elements together, so as to lead to their chemical combination. Thus at Hurlett and Campsie, near Glasgow, it is manufactured from certain of the coal shales, and at Whitby in Yorkshire from strata of alum-slate belonging to the lias formation; while at Newcastle and in France it is artificially prepared by mixing clay, sulphuric acid, and potash—soda or ammonia being sometimes substituted for potash. In the former case, if the crude ore is hard and slaty, it requires to be calcined, and exposed to the air, in order to facilitate its solution in water; if soft, crumbling, and efflorescent, calcination is dispensed with. This being effected, it is next steeped till the ore is spent; the liquid is then pumped off, boiled, and ultimately crystallised by adding the potash, without which, or some other alkali, sulphate of alumina does not crystallise. When alum-shale contains sulphate of iron (copperas or green vitriol), which is the case at Campsie, this salt is removed from the concentrated solution before adding the potash to obtain the alum. In the second or chemical mode of manufacture, calcined Cornish clay and sulphuric acid are combined to form the sulphate of alumina, to a solution of which the sulphate of potash is added to induce crystallisation. These different ingredients are allowed to remain at rest in circular vessels, where the alum gradually crystallises round the sides, shooting forth large crystals towards the centre, where the mother-liquor (or uncrystallisable portion) remains. The alum thus produced requires to be further fined or *roched*; that is, dissolved by the action of steam, and again crystallised for the market.

In both of the methods above described, an alkali is used to induce crystallisation; but as the sulphate of alumina is the sole efficient agent in the arts, a process has been invented to produce a 'patent alum' having all the properties of common alum, but without containing potash. 'In making this alum,' says Mr Dodd, 'sulphuric acid and Cornish clay are used as in the other case; but the clay is used in greater proportion, so as to form a thick paste. This paste is placed in a heated trough, where the moisture is so far evaporated as to convert the mass to the form of a dry earth. From the trough it is removed to tanks, where water is employed to dissolve it; and while in the liquid state, the composition is acted upon by an agent intended to remove any iron that may be in the clay—this being the only contained ingredient which is injurious to the alum. The agent employed combines with the iron existing in the clay, and forms with it Prussian blue. This pigment is allowed to subside, and the remaining liquor, being a solution of sulphate of alumina, is boiled till all the water is driven off. The solid residue is formed into cakes an inch or two in thickness, and in this form it comes into the market. Instead of being a crystal, it is an opaque earthy solid, differing from common alum in containing no potash, but possessing in common with it the properties which render it valuable in the arts. As the Prussian blue is procured in far too large a quantity to be allowed to remain in that state, it is restored again, by chemical means, to the form which it before presented, ready to be again used in making more alum.

Of the alums manufactured in other countries, the *roch* (so called from Roccha in Syria) is imported from Smyrna, and the *Rowan* prepared at La Tolfa, near Rome—either of which brings fully double the price of the British manufacture, the annual value of which is estimated at £22,000. Alum is also largely prepared in China, whence India obtains her main supply.

Nitrate of Potash.

This is the *saltpetre* of ordinary language—a salt composed of nitric acid and potash. It is of very varied utility, being used in the manufacture of gunpowder, signal-lights, nitric and sulphuric acids, and in dyeing, metallurgy, curing of meat, and in medicine. The sal-prunella of the shops is the ordinary saltpetre purified and moulded into cakes and little balls. Our main supply of saltpetre is derived from Bengal, where it exists in the soil, and from which the rough nitre or crude saltpetre of commerce is obtained by washing, evaporation, and crystallisation. From 10,000 to 15,000 tons of this salt are annually imported into Britain. In France, Germany, and other continental countries, the salt is produced artificially on what are called *nitriaries*, or nitre-beds.

Nitrate of Soda.

This salt, sometimes known by the name of cubic nitre, possesses properties similar to those of saltpetre, differing chiefly in being more pungent in taste, more soluble in cold water, and more inclined to attract moisture from the atmosphere. It differs also in the form of its crystals—these being of a rhomboid form, while those of saltpetre are six-sided prisms. It is obtained almost wholly from South America, where it occurs in immense deposits in the high districts of Atacama and Tarapaca in Peru. Indeed, according to Darwin, a great proportion of the surface of the southern regions of South America consists of *salinas*, or salt plains, from which common salt, and the sulphates and nitrates of soda, might be procured in any quantities—these occurring sometimes as an efflorescence, sometimes in crystallised strata, but oftener mingled with clay, sand, and other earthy impurities. One deposit which he visited in 1835, was full 3300 feet above the Pacific, and consisted of a hard stratum, between two and three feet thick, of the nitrate mingled with the sulphate of soda, and a good deal of common salt. It lay close beneath the surface, and followed, for a length of 150 miles, the margin of a grand basin or plain, which, from its outline, must once have been a lake, or more probably an inland arm of the sea, as iodic salts were abundant in the stratum. This salt was first imported from Iquique in 1830, and so rapidly has its commercial value increased, that, ten years after, about 150,000 hundredweights were shipped for Great Britain alone. In 1835, Mr Darwin found the selling price at Iquique 14s. per 100 pounds—the main part of the expense being its transport from the mountains on mules and asses. It is principally used as a manure, and as a top-dressing for pasture, its advantages being very perceptible on all but wet plashy soils; it is also used in the preparation of nitric acid, and for many of the purposes to which saltpetre is applied; but, owing to its deliquescent properties, it is not adapted for the manufacture of gunpowder.

Natron.

Natron is a native sesquicarbonate of soda, found as an efflorescence or as deposit in sandy soils in Egypt, Mexico, Hungary, and other countries; hence sometimes called *mineral soda*. At the lakes of Sukena in Africa, this salt is said to form a striated crystalline stratum just below the surface. From these lakes several hundred tons are collected annually in the dry season, chiefly for consumption in Africa, but sometimes exported to Europe under the name of *trona*. Natron has many of the properties of the two preceding salts, and according to Herodotus, was employed by the Egyptians in the process of embalming.

Borax.

This compound salt is found native as an efflorescence on the soil, or dissolved in the waters of certain lakes, in Persia and Thibet, in China, Ceylon, and South America. It occurs also in combination with several minerals, and, as might be expected, is given off in solution by hot and thermal springs. It is a compound of soda with a peculiar acid, first isolated by Homberg about the beginning of last century. The acid is now known to be an oxide of an elementary substance, to which the name of *boron* is given (see CHEMISTRY); the acid itself is known by the term *boracic acid*. 'Until the recent discovery of a more advantageous mode of obtaining borax, it was brought to Europe,' says Parnell, 'in considerable quantities from the East Indies. It was imported in small dirty crystalline masses called *tincal*, which contain scarcely more than half their weight of pure borax—the remainder consisting chiefly of a peculiar saponaceous combination of soda with a fatty acid. The salt was never termed borax till purified by some such process as the following:—The crude salt, being placed in proper pans, is covered with cold water to a height of two or three inches above its surface, and allowed to stand for some hours. Recently-slaked lime is then added to the amount of one part to four hundred parts of tincal; the mixture is thoroughly stirred, allowed to stand for twelve hours, again strongly agitated, and the troubled supernatant liquid decanted. The liquor is not thrown away, but preserved to wash the impure borax; the solid matters held in suspension being first separated by subsidence and decantation. The washing is continued with the same liquid, clarified by subsidence as often as applied, until it is no longer rendered turbid. In this way a great portion of the fatty matter may be washed away as an insoluble soap of lime. The salt thus purified is dissolved in two and a half parts of boiling water, and mixed with a solution of chloride of calcium, containing two parts of that salt to one hundred parts of tincal. A precipitate is thereby produced, consisting chiefly of the insoluble soap of lime; the liquor is separated from the precipitate by filtration, and evaporated down to a density of 1·14 or 1·16. It is then run off into crystallising vessels, and cooled very gradually to obtain large crystals.' Such, with some slight variations, was the mode of preparing borax from tincal.

Tincal, however, is now no longer the European source of the salt, which is largely and economically obtained from the boracic lagoons of Tuscany. These lagoons may be ranked among the wonders of the age, and are unique in Europe, if not in the world. They are situated on the sides of hills, and are supplied with water by the condensation in them of volcanic vapours or soffioni, highly charged with free boracic acid, together with borate and sulphate of ammonia, and other saline substances. The soil surrounding these beds of hot water is covered with a saline efflorescence, consisting chiefly of boracic acid, but likewise containing in smaller proportion salts of ammonia, borate, and sulphate of alumina, and persulphate of iron. The presence of free boracic acid in these and other volcanic vapours was ascertained towards the end of last century; but it was not till 1816 that an effectual mode of procuring the crystallised product was discovered. The lagoons are now artificially constructed over the soffioni, the continuous discharge from which more largely impregnates the water with boracic acid, and this solution is still further concentrated by ingeniously applying the superabundant heat of the soffioni to evaporate the water. Passing in this manner from reservoir to reservoir, and from evaporating pan to pan, the solution is ultimately allowed to crystallise; and the acid so obtained packed in barrels for exportation. For the conversion of this crude acid into borax there are several processes in use, the chief objects of which are to get rid of the ammonia and other natural impurities, and ultimately to obtain the pure salt in large and hard crystals.

The applications of borax in the industrial arts are already numerous, and constantly on the increase: about 800 tons boracic acid, at an average of £45 per ton, being annually imported into Britain, besides perhaps 200 or 250 tons of tincal, at £2 or thereby per ton. After refinement, a large proportion, perhaps one-half, is re-exported. Borax is largely employed by braziers, silversmiths, and other workers in metals, as a flux; by potters in the formation of a glaze for earthenware and porcelain; by chemists as a reagent in blowpipe analyses; in the preparation of certain kinds of glass, and generally if its price permitted; in the fabrication of artificial gems; in medicine; and in other minor arts.

Baryta—Strontia.

These are two alkaline earths (see CHEMISTRY) very similar to each other, and indeed, till recently, considered identical. The former is an oxide of barium, the latter of strontium; neither the metalloids nor their oxides are found in nature. The only two abundant natural compounds of baryta are the sulphate, which occurs crystalline, and the carbonate. Sulphate of baryta, or *heavy spar*, is found in various districts, particularly in Cumberland and Westmoreland; a variety from Derbyshire is provincially called *cawk*. Heavy spar, according to Dr Ure, is used to adulterate white lead by the English dealers to a shameful extent; sulphuret of barium is employed as a chemical reagent; and all the salts of baryta, with the exception of the sulphate, are highly poisonous. The native forms of strontia are the carbonate and sulphate, both found in a crystalline state. The former occurs abundantly in the lead mines at Strontian, in Argyleshire; hence the name; the latter is found near Bristol, and associated with native sulphur in Sicily. The only preparation of strontia used in the arts, is the nitrate employed in combination with chlorate of potash and charcoal, to produce the brilliant red colour in fireworks and theatrical conflagrations.

Sulphur.

Though sulphur or brimstone be an elementary substance, *sui generis*, and, strictly speaking, does not come under the head of saline substances, yet it may, without much impropriety, be considered in this place, as often occurring in efflorescent salts or crystals. It is a yellow brittle mineral product, found in most parts of the world, but most abundantly in volcanic regions, and in the immediate neighbourhood of burning mountains, such as Ætna, Hecla, &c. It occurs either as an efflorescence on the surface, or in masses mingled with clay, ashes, and other volcanic products. Our chief supply is obtained from Sicily, where it occurs in beds of a blue-clay formation; and whence it is imported, as dug from the mines, in square masses or blocks, called rough brimstone. Sulphur is also obtained artificially from the sulphurets of copper, iron, and other metals; but the facility with which native material can be secured, prevents its artificial production from being followed to any great extent.

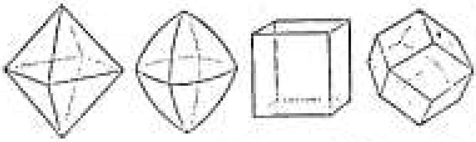
Unlike most other materials of commerce, the formation of sulphur is still going forward wherever volcanic agency is in a state of activity. It appears to be sublimed by the subterranean heat through the crevices and fumeroles of the mountains; and this collects either as a slight efflorescent crust on the surface, or in crystals and in masses throughout the material of the ejected clays, ashes, &c. Speaking of the sulphur mountains of Iceland, Sir George Mackenzie says—'At the foot of an elevation, in a hollow formed by a bank of clay and sulphur, steam rushed with great force and noise from among the loose fragments of rock. Ascending still higher, we came to a ridge composed entirely of sulphur and clay, joining two summits of the mountain. Here we found a much greater quantity of sulphur than on any other part of the surface we had gone over. It formed a smooth crust, from a quarter of an inch to several inches in thickness: the crust was beautifully crystallised. Immediately beneath it we found a quantity of loose granular sulphur, which appeared to be collecting and crystallising as it was sublimed along with the steam. Sometimes we met with clay of different colours—white, red, and blue—under the crust; but we could not examine this place to any depth, as the moment the crust was removed, steam came forth, and proved extremely annoying. We found several pieces of wood, which were probably the remains of planks that had been formerly used in collecting the sulphur, small crystals of which partially covered them. There appears to be a constant sublimation of this substance, and were artificial chambers constructed for the reception and condensation of the vapours, much of it might probably be collected. As it is, there is a large quantity on the surface, and by digging, there is little doubt that great stores may be found.' Such is the usual origin of native sulphur—a substance of greater commercial value to a country like Britain than the most of our readers may imagine. It is employed for making gunpowder, sulphuric acid—which is indispensable to so many manufacturing processes—cinnabar, and for a variety of other purposes in the arts, as well as being used medicinally—requiring altogether an annual supply little short of 20,000 tons. For a further account of the nature and properties of sulphur, and of the manufacture of sulphuric acid, see 'Chemistry,' pp. 298-9. Orpiment and realgar, the one a yellow, and the other a red sulphuret of arsenic, though found in a mineral state, and as such used in the arts, will be more systematically treated under 'Metals and Metallurgy.'

PRECIOUS STONES.

All our so-called 'precious stones'—the diamond, ruby, emerald, amethyst, &c.—are but compounds of carbon, alumina, silica, lime, &c. and might therefore, so far as their mineralogical character is concerned, have been considered under the sections already presented. As none of them, however, occur in rocky masses, but rather as crystals, geodes, and concretions within other rocks, and as fashion has generally set a price upon them wholly disproportioned to their utility, it may be as well to treat them as an independent class. Our limits will only permit us to mention a few of the more esteemed; seeing that lapidaries, jewellers, and others, have vastly increased the nomenclature of precious stones by giving individual names to specimens which are, in reality, but varieties of the same substance. For an account of *pastes*, or *artificial gems*, see 'Fictile Manufactures,' p. 333; and for *pearls*, native and artificial, which are often erroneously classed with gems, see 'Zoology,' p. 183, and 'Fisheries,' pp. 703-4.

Diamond.

The most highly-prized of precious stones is the diamond, a crystalline mineral of unsurpassed lustre and hardness. It is the hardest known substance, and can be polished or cut only by its own dust or powder; hence the common saying of 'diamond cut diamond.' When perfectly pure, it is as transparent as a drop of the purest water, in which state it is known as a diamond of the first water; and in proportion as it falls short of this perfection, it is said to be of the second, third, or fourth water, till it becomes a coloured one. Coloured diamonds are generally yellow, blue, green, or red, and the higher the colour, the more valuable they are, though still inferior to those absolutely transparent. Diamond, as has been demonstrated by numerous experiments, consists solely of carbon, being, in fact, a crystallised charcoal, generally appearing in one or other of the subjoined forms:—



Diamonds were originally discovered in Bengal, but they have since been found in other parts of India, in the East India islands, in the Brazils, and recently in the Ural mountains. They occur chiefly in alluvial deposits of gravel and sand, lying in detached octohedral crystals, sometimes with plain, but more frequently with rounded surfaces. The finest are cut for ornamental purposes into *brilliants*, having curvilineal faces both at top and bottom; or into *rose diamonds*—that is, those having their tops or upper surfaces cut into a number of triangular facets, but quite flat beneath. The black, dirty, and flawy ones, and those unfit for being cut (technically called *boats*), are pulverised for the purpose of polishing others, besides being applied to various uses in the arts. Fractured portions, with good cutting edges, are usually set for glaziers' cutting pencils, in which state they are worth from twelve to twenty shillings; and also as *drills* for piercing other precious stones. It is the ornamental diamonds that bring the exorbitant prices so frequently mentioned in modern history, their value depending upon shape, colour, and purity, and being fixed at so much per carat of 3⅕ troy grains. 'The largest diamond ever known was brought to the king of Portugal from Brazil. It is uncut, weighs 1680 grains, and its value is often quoted at £5,644,800. Similar extravagant valuations are applied to the famous Russian one weighing 195 carats; to that in the possession of the Great Mogul, weighing, cut, 280 carats; and to others; but it does not appear that any sum exceeding £150,000 has ever been given. The last great sale of jewels was in London in 1837, for the distribution of the Deccan booty, obtained by the army under the Marquis of Hastings. On that occasion, the magnificent Nassau diamond, weighing 357⅛ grains, of the purest water, brought only £7200.' The Russian diamond, says another authority, is of the size of a pigeon's egg, and was purloined from a Brahminical idol by a French soldier; it passed through several hands, and was ultimately purchased by the Empress Catharine for the sum of £90,000, an annuity of £4000, and a title of nobility. Perhaps the most perfect and beautiful diamond hitherto found is a brilliant brought from Malacca by a gentleman of the name of Pitt, who, after getting it cut in London, sold it to the Regent, Duke of Orleans, for the sum of £100,000; its weight 136¾ carats. It is now, or rather we should say was lately, in the crown jewels of France; its further history is a problem yet to be solved.

The art of cutting diamonds—which is distinct from that of the lapidary or polisher of inferior gems—is thus described by Webster:—The gem may be split by a steel tool if a blow be applied; but to effect this it is necessary to have a perfect knowledge of its crystallised structure; and the workman cannot form facets at pleasure by splitting. To produce the faces which are required for exhibiting the gem in all its beauty, the process called *cutting* is resorted to, but which is, in fact, abrasion rather than cutting. For this purpose the diamond is fixed on the end of a stick or handle, in a small ball of cement; that part which is to be reduced being left to project. Another diamond is also fixed in a similar manner, and the two stones are rubbed against each other with considerable force, until they are ground away as much as is necessary to produce a facet. Other facets are formed in a similar way by shifting the position of the diamonds in the cement. When the faces are thus completed, they are next to receive an exquisite polish. For this purpose the stones are imbedded in soft solder, contained in a small copper cup, the faces to be polished being left to protrude. A flat circular plate of cast-iron is then charged with diamond-powder, and the stone is held against this plate, while it is made to revolve till the polish is complete.

Sapphire—Ruby—Topaz—Garnet, &c.

These may be conveniently grouped together as consisting essentially of crystallised alumina—traces of magnesia, silica, fluoric acid, chromic acid, &c. constituting the specific distinctions. The sapphire is of various colours—the *blue* being generally known among jewellers and lapidaries as the sapphire; the *red*, the Oriental ruby, and, next to the diamond, the most valuable of gems; and the *yellow*, the Oriental topaz. Sapphires are sometimes substituted for diamonds, by exposing them to a strong heat, which destroys their colour, but improves their hardness and transparency; and this kind of fraud would be difficult to detect by any one who was not a good judge of those gems.

Corundum, or adamantine spar, is nearly allied to the sapphire, and, with the exception of the diamond, is the hardest substance known. It is almost a pure crystallised alumina, consisting of more than ninety per cent. of that substance, with a little silica and iron. It is found in India, China, and some parts of Europe; and is used in the East for the same purposes to which diamond powder is applied in England. Emery, so called from Cape *Emeri*, in the island of Naxos, is but a variety of corundum, with an admixture of iron, which gives to it a bluish-gray colour. From its extreme hardness, its powder is largely employed in the polishing of glass and metals, and in the cutting of gems and other minerals—all of which are abraded by it, with the exception of the diamond. Emery-powder is prepared by grinding the mineral in steel mills; it is afterwards assorted into parcels of different degrees of fineness, by agitating it with water, and separating the particles which deposit themselves at different stages—the finest being the last which subside. Emery paper and emery cloth are prepared like common sand paper—namely, by coating the fabrics with a strong size of glue, gum, flour, and alum, upon which the powder is sifted while the size is sufficiently soft to retain it.

The ruby, found chiefly in the sand of rivers in Ceylon, Pegu, and Mysore, is also of various colours—the scarlet-coloured being distinguished as *spinelle ruby*; the pale or rose-red, *balass ruby*; and the yellowish-red, *rubicelle*. Rubies from two to six carats are rare, and when of this size, and of the fine deep cochineal red so much prized, fall little short of the diamond in value. The topaz likewise presents various shades between yellow and wine-colour; but, from its large per centage of silica, is harder than either of the preceding. The best varieties are known as the Brazilian, the Saxon, Siberian, and Scotch.

The garnet, another well-known mineral, belongs to the same section, the varieties being essentially of alumina, with silica, magnesia, iron, &c. The most valuable is the *precious garnet*, almandine, or carbuncle, which is commonly a transparent, red, and beautiful mineral, either crystallised, or in roundish grains. It is found in Ceylon, Pegu, and Greenland. The *pyrope*, a blood-red variety, found in Germany and Ceylon, is perfectly transparent, and, in roundish or angular grains, is perhaps next in value. The common garnet is not transparent like the preceding, and is most frequently of a dull-red or blackish-brown. It is found plentifully in Scotland, Sweden, and other countries, where the primitive rocks abound; but comparatively few specimens are fit for the jeweller. The black garnet, or, more properly, *melanite*, is a mineral found in volcanic rocks, and worked into necklaces at Naples.

Emerald—Beryl—Amethyst—Carnelian, &c.

In these the predominant ingredient is silica; they may be called siliceous gems, just as the ruby and sapphire might be styled aluminous, or the diamond carbonaceous. The emerald is one of the most esteemed, being of a beautiful green colour, and occurring in prismatic crystals. It consists essentially of silica, with a small per centage of alumina and glucina, the colouring matter being oxide of chromium. The finest emeralds are brought from Peru and Brazil; the mines from which the ancients obtained their supply are said to have been in Upper Egypt. Fine emeralds are extremely rare; and one of four carats, of approved hue, and well cut, is worth about £160. Beryl differs little from emerald except in colour—the latter name embracing the green varieties, the former all those that are tinged less or more with yellow or blue, or are altogether colourless. Beryls are found in Siberia, France, the United States, and in Brazil, the latter country furnishing the brilliant variety known as the precious beryl, or aqua-marine. Heliotrope, or *bloodstone*, is another common deep-green siliceous mineral, somewhat translucent, and often variegated with blood-red spots—whence its common appellation. It is found in Siberia, in Iceland, and the Hebrides, but chiefly in India, which furnishes the finest specimens. It is in request among the Chinese as an ornament to their girdle-clasps.

Amethyst is a pure rock-crystal, of a purplish-violet colour, and of great brilliancy. It is found in India, in Germany, Sweden, and Spain, but chiefly in Brazil, and is in great request for cutting into seals, bracelets, and brooches. 'Some of the ancient vases and cups,' says Brande, 'are composed of this mineral, and it was an opinion among the Persians that wine drunk out of such cups would not intoxicate; hence its name from the Greek *amethystos*.' The cairngorm of the lapidary is another crystallised quartz, of various hues, and nearly transparent. It derives its name from the mountain Cairngorm in Inverness-shire, and is much used as an ornamental stone in this country.

Agate, chalcedony, opal, carnelian, sardonyx, jasper, and some kindred substances, may be, without much impropriety, regarded as merely varieties of the same mineral, having different colours and degrees of transparency. They are found in most countries, and are used for seals, brooches, cameos,* and other ornamental purposes—the larger geodes or mass being often fashioned into cups and vases. Carnelians and opals are perhaps the most valuable, some specimens of the Oriental opal being worth double the price of a sapphire of the same size. This variety is sometimes known as the Nonnius opal, from the senator Nonnius, the possessor of the famous opal of Rome, worth 20,000 sesterces, who preferred banishment to parting with it to Antony. The *cat's-eye* opal, so called from its presenting an effulgent pearly light, like the changeable reflections of the eye of a cat, is another siliceous mineral or quartz, interspersed with filaments of asbestos. It is found chiefly in Ceylon and the Indian peninsula, and is held in great estimation among gem fanciers. When the late king of Candy's jewels were brought to the hammer in London, in 1820, a specimen, which measured about two inches in diameter, brought upwards of £400. *Mocha-stone*, also in some repute, is a semi-transparent chalcedony, enclosing various ramified forms produced by oxide of iron, or other metallic substances, but sometimes also by the presence of vegetable bodies, such as mosses. The finest are found in Guzerat, but receive their name from being brought from Mocha. The *onyx*, so much admired by the ancients, is a species of agate, in which the siliceous particles are arranged in alternating horizontal layers of opaque white and translucent blue, gray, or brown. It is employed for cameos, the figure being cut out of the opaque white, and the dark part forming the ground, or *vice versâ*. It is most valuable when the colours are in strong contrast, and when the layer is thick enough to give a high relief to the object engraved.

The district of Cambay in India, yields agates, chalcedonies, carnelians, and jaspers of every variety, and of enormous size; and these, now so common in the market, are known by the general name of *Cambay Stones*. Great numbers of people find constant employment in quarrying these. When first taken from the rock, their colours are faint and tracings imperfect. They are first exposed for some time to the air, and afterwards heated nearly to redness by a slow fire of wood or cow-dung. Under this process the colours come out in the greatest brilliancy. They are now cut up by the common lapidaries' wheel, and polished in the usual way with emery or ground corundum. Cutting is but rarely resorted to: in general the stones are chipped as nearly to the required form as possible, and then ground with emery and polished. They form a considerable article of sale in the Bombay market, and are imported in immense quantities by the London lapidaries, who improve their polish, and alter their forms into such as may be considered most saleable. The Bombay brooch and necklace pieces, paper-folders, finger-rings, shirt-buttons, earring-drops, &c. are those most frequently found on sale.

Lapis-lazuli, or azure-stone, at one time held in the highest estimation, is another precious mineral, whose chief constituents are silica and alumina. Its principal localities are China, Persia, and Siberia, where it occurs in massive, but rarely in regular crystals. The finer specimens are prized by the lapidary; but by far the most important application of the substance is to the production of ultramarine—a pigment which, till of late, was more precious than gold. Within these few years, however, the chemist has succeeded in producing an artificial ultramarine, possessing all the properties of the native pigment, and at such a rate that several pounds weight can be procured for what, a dozen years ago, would scarcely have purchased a single ounce.

Calcareous Spars.

Several of the calcareous spars are of great beauty and transparency, but in general their softness and frangibility prevent them from being employed for ornamental purposes. *Iceland spar*, so called from the largest and most transparent specimens being found there, is a rhomboidal carbonate of lime, much used for experiments on the double refraction and polarisation of light. *Fluor spar* is a common mineral product, found in many places, but in great beauty and abundance in Derbyshire. It is a fluoride of calcium, occurring in crystals and in nodules of various colours, and often very prettily banded. The nodular specimens are occasionally worked into beads, brooches, and other ornamental purposes; but chiefly manufactured into vases, toilet-boxes, jars, and such-like articles. The acid of fluor spar, when disengaged, is used in etching on glass (p. 331); and the spar itself is occasionally employed, under the blowpipe, as a flux for promoting the fusion of other minerals.

* *Cameo* (a word of Oriental origin) is the term applied to gems of various colours sculptured in relief. 'The art of engraving on gems,' says Brande, 'boasts of high antiquity, having been practised with various degrees of success by the Egyptians, Greeks, and Romans. It was again revived in Italy in the fifteenth century, and is even at the present day cultivated with great avidity and considerable success. The cameos of the ancients were usually confined to the agate, onyx, and sard, which, on account of the variety of their strata, were better accommodated to a display of the artist's talents; but they are also occasionally found executed on opal, beryl, or emerald, and even on a sort of factitious stone, the *Vitrum obsidianum* of Pliny, distinguished by the moderns as the antique paste. One of the most famous cameos is the onyx at present in Paris, called the *apotheosis of Augustus*. It is one foot in height and ten inches in width.' To this we may add, that a cheap kind of cameo has recently been prepared from large shells found on the coasts of Africa and Brazil. These shells have two layers, the ground being either of a pale coffee colour, or of a reddish orange, and the figure of a nacreous white. Cheap imitation cameos are also extensively manufactured in glass enamel.

The peculiar lustre of the metals, arising out of their opacity and reflective power with regard to light, their conduction of heat and electricity, their density, fusibility, ductility, malleability, and the like, are features which, though differing in each, yet readily distinguish them as a class from all other substances. It is this density and hardness in some, this ductility and malleability in others, and the facility with which many of them can be amalgamated, that have rendered them such valuable aids to human progress, and made them available for almost every purpose of utility or ornament. Without them, indeed, any high degree of civilisation were impossible; they are essential to every process in agriculture, architecture, machinery, navigation—to every art, in fine, which marks the advancement of mankind from the lowest stages of barbarism. As elementary substances, their scientific distinctions have been detailed under CHEMISTRY; we would now direct attention to their history, the localities where found, the modes of obtaining and preparing them, the purposes to which they are applied, their relative values, and other particulars of economic importance.

GEOLOGICAL CONDITIONS.

The metals, as found in nature, are seldom or never in a state of purity. It is true that the miner occasionally detects a fragment of native gold, native silver, and the like; that is, specimens of gold and silver, pure and ductile as from the crucible of the chemist; but such fragments are rare, and bear no appreciable proportion to the quantity which occurs in the crude state of ores. These ores are sulphurets, carbonates, oxides, &c. mingled with earthy impurities, generally situated in veins, sometimes disseminated through rocky masses, rarely in beds or strata, and distributed through the formations of all eras, but more especially through those of the primary and transition series. Thus iron, the most familiar and useful of all the metals, occurs in more than twenty different mineral states, being combined with carbon, oxygen, sulphur, phosphorus, &c.; is found in veins traversing different formations; is disseminated through various rocks, so as to give to them a ferruginous aspect; and, as clay-ironstone, is interstratified with the clays and shales of the coal-measures. To arrange and classify the ores is the study of the mineralogist; to determine their value, or the amount of metal they contain, is the art of the chemist; to raise them from their various positions, is the labour of the miner; to separate the metal from the earthy impurities with which it is associated, is the work of the metallurgist; and to fashion it into implements, utensils, and machines, is the calling of the founder, blacksmith, machinist, cutler, and others. As with the ores of iron, so with those of the other metals, only that few of them can be said to occur stratified like the clay or carbonaceous ironstone. It must not be supposed, however, that the respective metals always lie in separate veins—that copper, for example, is always the only metal found in a copper vein; or lead in a so-called vein of lead. The fact is, that though some one metal generally predominates, three, four, or even more metals, may be strangely combined and intermixed with the same veinstone. In our own island, the vein which contains lead as the principal metal, often embodies silver, zinc, and cobalt: platina is generally associated with gold; manganese not unfrequently with iron.

Respecting the origin of the metals, geology and chemistry afford us no certain knowledge. We cannot tell why, or in what manner, the Creator has formed gold, or silver, or iron, any more than we can tell why he has created oxygen, hydrogen, or any other so-called *elementary* substance. Investigation has, no doubt, collected a vast amount of accurate data as to the nature of veins, and the ores which fill them; and we can speculate with some degree of certainty as to the causes which have contributed to these results. We see that subterraneous and igneous forces have at various epochs upheaved and rent asunder the stony crust of the globe; that the fissures so produced have been subsequently filled with mineral matter, differing widely in kind from the rock in which it is enclosed; and that, incorporated with this mineral *matrix* or veinstone, occur various metallic ores in films, strings, crystals, or amorphous masses. But whether this veinstone, with its associated metals, has been the result of infiltration from above when that portion of the globe was under water, of sublimation from igneous sources beneath, or of long-continued chemical and electrical agencies, science has not been, nor may ever be, able to determine; and even if it could determine, still the question would remain—Whence the substances we designate metallic? Are they further developments of previously existing bodies? Are any or all of them transmutable one into another under the operation of certain natural agencies? Or are they, in reality, elementary substances, each after its own kind? These are questions which have engaged the attention of the scientific in all ages; years and lives have been spent in attempting a solution; and yet, except in the acquirement of more correct data whereupon to pursue the inquiry, man is no nearer to a satisfactory answer. It would be a strange revelation indeed, if we could detect nature elaborating substances having so many different aspects and properties from the same source; and more wonderful still, if the chemist, imitating her processes, could accomplish the like results. Laying aside, however, these high aspirations, we observe in the present day many waters containing iron, copper, lead, and the like, in solution, which waters, gathering these ores from existing sources, transport them to new localities, where they combine with other substances, and form new deposits, as bog-iron ore, cupriferous marls, or auriferous sand. In time these sands, marls, and bog-silts become true rocky strata, either to present phenomena analogous to the clay-ironstone of the coal-measures, or if subjected to igneous and other forces, to contribute, it may be, to the formation of new metallic veins. The operations of nature are ever in progress; each stage presenting new phases, which gradually merge into those that follow, and never exhibiting any appearance which can suggest to the mind the idea of an ultimate completion.

Beds—Veins.

It has already been mentioned that the chief forms in which the metalliferous ores occur are *veins*, *beds*, or *fragmentary deposits*. In the last of these the ore is associated with sand, gravel, and other superficial debris, which has evidently been transported by alluvial agency from mountain metalliferous districts. In this case there is no geological complexity; the matrix in which the ore originally lay has been disintegrated by atmospheric forces, and its fragments borne down by rains and streams to the valleys in which they now occur. The origin of metalliferous beds or strata, whether in the older or more recent formations, is almost as apparent. The stratum, for the most part composed of earthy matter, is a true sedimentary rock, and has evidently been deposited in waters holding in solution a notable amount of the metal in question, which, uniting with the earthy matter, determined the quality of the matrix. Every stratified rock, indeed, is less or more impregnated with one or other of the metals, but it is only those in which the metallic ingredient is peculiarly abundant that demand the attention of the miner. Veins, however, are the principal forms in which metallic ores are distributed throughout the crust of the globe. A description of those of Cornwall will almost suffice for those of every other country, as the differences are comparatively unimportant to the general observer.

A vein may be said to resemble a deep cleft or rent in a clayey field, which has been subjected for some time to the desiccating influences of the sun. This cleft, whatever may be its depth, must of course have a direction under ground, either slanting or perpendicular; and if we suppose it filled with metallic ore, we form the idea of a vein, or, as it is termed in Cornwall, a *lode*; if we suppose the cleft filled with any other stony substance, we can imagine what is called a non-metalliferous vein, of which there are many, sometimes pursuing their own exclusive courses, and at others intersecting the metalliferous veins. The direction of the lodes is by no means accidental, but nearly determinate. They usually *strike* east and west, and *dip* or underlie either towards the north or south; while the non-metalliferous veins, which run north and south, dip either towards the east or west. The cases in which metalliferous veins assume a north and south direction are few, and chiefly foreign. It frequently happens that the metalliferous lodes, as we have said, cross each other; and, as a leading fact, the intersection of two lodes at a small angle is productive of good ore. Should, however, a copper lode pass through a tin lode, the copper lode invariably divides the tin one, and generally heaves it out of its course, to the frequent perplexity and loss of the miner. All mining experience of a general character is, nevertheless, sometimes set at defiance; for, in the small space of one little hill, instances may be found in which veins of almost every description dip or underlie in numerous directions, traversing each other in such a manner as completely to baffle the miners; but it is an ascertained fact, that there are seldom or never, *in the same district*, two *series* of metalliferous veins running at right angles to each other. On an average, the direction of the Cornish lodes are about 4 degrees south of true west, and their dip or inclination about 60 or 70 degrees from the horizon.

The length of no one lode has as yet been satisfactorily traced, though some of them have been followed for two or three, or even four or five miles; nor has the miner ever yet seen the bottom of one, although there are several mines in Cornwall upwards of 1000 feet in depth from the surface, and two or three about 1300 feet deep. The lodes differ exceedingly in respect of width, in which, indeed, they vary from a mere line to forty or fifty feet. On the average, they may be assumed to be three and a-half feet wide. Lodes of from one to three feet in width are usually less intermixed with foreign and troublesome substances than those which are wider. A vein of tin in a mine called Whealan Coates was only three inches wide, and yet proved so rich as to be worth working. Some of the veins containing copper in Herland mine did not exceed six inches in width; and after continuing this thickness for a few fathoms, eventually passed away east and west in mere strings; but they yielded ore of a very rich character. In the next hill there was also a very productive vein from twelve to twenty-four feet in width.

The compositions of the lodes or veins are as variable as the nature of the rocks through which they pass. By far the greater number consist of matter similar to that of the contiguous or intersected rock; but many also contain large intermixtures of quartz. These ingredients occasionally occur in separate streaks or striæ, but for the most part they are mingled without regularity or order, and throughout them are dispersed the metallic ores. Sometimes these are aggregated very thickly, and very generally occur in large irregular lumps or patches, called *bunches*, connected with each other by small films or *threads* of ore. At other times the ore is very sparingly sprinkled through the whole of the earthy matter of the vein, and in some rare instances it forms the larger part of its contents. The sides of metalliferous veins are usually very determinate, being covered by a hard dark-coloured crust, called by the miner the *walls* of the vein.

We have noticed that there is a second series of veins, called non-metalliferous veins, which run north and south; that is, nearly at right angles to the metalliferous lodes. When these veins are chiefly composed of quartz, they are locally denominated *cross-courses*; and when consisting mostly of clay, they are named *flucans*. Their general direction, when accurately traced, is about south-east and north-west. Their dimensions are variable, being perhaps on an average about two feet; their dip, too, fluctuates, but, as a general rule, it is greater from the horizon than that of the lodes. The clay with which the flucans are filled invariably partakes of the same character as the contiguous rock. Tin and copper ores are occasionally found in small quantities in the cross veins, and in two or three instances silver and its ores have also occurred to some amount. The chief metallic produce, however, of this class of veins is lead ore; but this they seldom yield in the neighbourhood of lodes which have been productive of other metals. Indeed it is, as has been stated above, a general law in Cornwall, that two series of productive metalliferous veins, at right angles to each other, are very seldom or never found in the same district. Both the lodes and the cross veins ramify and divide; and whilst the part which in one place is large will sometimes, within a short distance, dwindle and die away, the portion which is small, where the other is rich, will often, within a small space, enlarge and become productive.

As these two series of veins—the lodes and the cross veins—run at right angles to each other, they of course frequently meet and intersect. In a few instances the lodes traverse the cross veins, but in far the greater number of cases the cross veins cut through the lodes. Occasionally, the cross vein simply intersects the lode; but more generally displacements, provincially termed *heaves*, attend their contact. If, for example, a cross vein, in its north or south course, meets with a lode containing copper or tin, the last seems to have been split, as it were, into numerous little branches by the first, which generally pursues its uninterrupted course straight forwards. Another effect, too, of a much more extraordinary kind, is produced by this intrusive cross vein. In searching for the tin or copper lode on the other side of this north and south vein, a lengthened period frequently elapses before the fugitive can be discovered. Notwithstanding the experience of the miners, forty years have sometimes passed over before the search, though carried on with vigour and great expense and labour, has proved successful. It is by no means a simple task for the mining engineer to lay down a law for the recovery of the lode. Instances have been known in which it has been again found 120 or even 450 feet north or south of its original course. The cross vein will not perhaps generally intersect the lode exactly at right angles, but its inclination to the course of the lode will usually be such as to produce at the intersection an obtuse angle at one side of the lode and an acute at the other side; and it is thought, by the most experienced observers, as well in Saxony as in Cornwall, that the second portion of the lode will more frequently be discovered on the side of the obtuse angle, formed by it with the cross course, than on the side of the acute angle. In other words, on whichever portion of the lode we approach the cross vein, the other portion will be found towards the same hand—namely, to the right. There are other kinds of interruption to which metalliferous veins are subject, though far less extensive in their agency than the cross veins. These are denominated *slides*, and generally consist of clay or argillaceous matter. (See GEOLOGY.) Their direction is nearly parallel to that of the contiguous lodes; but their dip or underlie being either greater than, or opposed to, that of the latter, they intersect them either in a horizontal, or more or less inclined direction.

It is a well-known but remarkable fact, that some of the metallic ores lie much nearer to the surface than others. Gold, in the small veins of it which are sparingly distributed through some of the rocks in Brazil and elsewhere, is worked by open cuttings from the surface. Silver is found in some foreign mines at a depth of from two to three hundred feet, while the silver mines of Mexico are of a much more considerable depth. Tin is also found at shallow depths, of which the great lode of the Charleston mines in Cornwall furnishes a good example. Lead is usually met with at a trifling depth, and slightly spotted veins of it are sometimes to be observed in the sides of brooks, and in the rocky channels of rivers. Copper, on the contrary, generally lies deep, and the enormous deposits of this metal found in Cornwall are generally situated two or three hundred feet below the surface. Where tin and copper are found together in the same vein, the tin commonly occupies the upper part, and disappears at the depth at which the copper is discovered. Sometimes, however, the ores of both metals occupy the vein together to a great depth, as at the Poldice mine near Redruth. On referring to the *known* depths to which different metals extend, it will be found that those which commonly lie near the surface, as lead, zinc, gold, and occasionally tin, do not generally penetrate to any great depth; while those which lie deeper, as copper and silver, are worked in the bottoms of our deepest mines. This coincidence may be the result of a natural law, or it may be apparent, and consequent only upon the limit of our experience and knowledge.

MINING OPERATIONS.

When the mineral contents of a district are entirely unknown, the operations instituted for the discovery of lodes must be founded upon the general presumptions furnished by geological science in connection with mining experience, as metallic veins usually present no precise traces of their existence at the surface. The first objects of pursuit, in such circumstances, to the Cornish miner, for example, are what he denominates *shode* or *shoad-stones*. These stones are partially rounded and apparently water-worn, and are found on the surface, or at very small depths below it. Their mineralogical characters nearly resemble those of the contents of the lodes in the vicinity, of which they are presumed to be portions removed by alluvial action. As, however, the shoad-stones contain tin ore, a careful search for them has been constantly kept up, and their increasing scarcity will probably render this mode of discovery impracticable. When they were uncollected, the examiner might commence marking their presence at any given spot, and then trace them to where they appeared in the greatest abundance, which situation was probably the nearest position of the lode itself. Upon arriving at this place, he would cut trenches, or dig small shafts, or trial-pits, to ascertain how far his suspicions were well founded.

Should the precise situation of the vein, whose existence has been ascertained by tracing the shoad-stones, or by any other mode, be unobservable, it may be ascertained by opening trenches in the alluvial soil, deep enough to expose the solid rock; their direction being at right angles to that in which analogy, or the position of other veins in the neighbourhood, would render it probable that those in question should lie. Supposing the direction or strike of the vein, and its dip or underlie, to be ascertained either by the shoding, and by sinking a few shallow pits upon it, or by previous experience in some adjoining mine, the further exploration may be continued, either by sinking upon its course from the surface, or by forming a horizontal passage to intersect it, which is commenced from a valley, or the lowest point in the neighbourhood, and is called an *adit*. This last plan, however, being both tedious and costly, is seldom adopted, unless there is a tolerable certainty of its results being highly favourable.

The lode and its directions being discovered by the means above detailed, the next point is to determine the site of the shaft, upon some convenient spot of ground. If the shaft is to be sunk in an inclined direction upon the course of the vein, which is frequently desirable, the site is not so circumscribed as when it is to be sunk perpendicularly upon it. In the latter case, the shaft is necessarily commenced on that side towards which the vein inclines or underlies, and at such a distance from its appearance at the surface (or outcrop) as to cut the vein at a premeditated depth, which may be from ten to thirty fathoms, in accordance with the means of the adventurers, and with their knowledge of the quality and conditions of the lode, the upper portions of which are seldom productive.

The vein being cut, the shaft may be continued either perpendicularly, and through the vein, or obliquely, and in the course of the vein. Should the lode be expected to turn out profitably, the former plan will be adopted, as it will be ultimately the most advantageous, and will enable a large mine to be carried out. But if the lode is questionable, and the means of the miner the same, the latter course will be proceeded upon, as it is far the cheaper one, as well as the speedier.

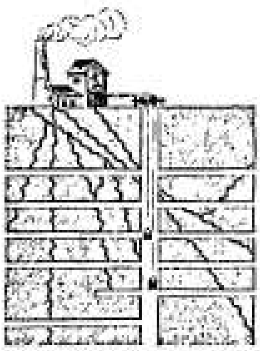
In driving the second and the succeeding levels, it is clear that the further we proceed from the shaft in each direction, the greater will be the closeness of the air, and the more essential will ventilation become. It is then that small shafts, called *winzes*, are sunk. Thus a communication is opened between all the levels, each one of them possessing winzes opening upwards from itself to the next superior level, and also others opening downwards from itself to the next inferior level, by which means a double communication with the atmosphere and every level is effected, and an ascending and descending current of air produced. In other respects, the system of ventilation very closely resembles that adopted in coal-mines. (See MINING AND MINERALS.)

In addition to their utility for the purposes of ventilation, winzes are equally necessary to the working out of the ore from the lode, and, indeed, are advantageous in trying its value. Unless little or no ore has been discovered upon the opening of the first level, winzes will be commenced at a very early stage of the mining operations; and when the ore is found to be tolerably good, they will be opened at intervals of twenty or thirty fathoms in each level. Their position will be especially determined, so as to prove the richest and most promising parts of the vein, and to avoid those hard and unproductive portions which may be supposed to be unworthy of exploration. As far, too, as it can be effected in accordance with these views, the position of the winzes will be such as that each of them may come about midway between the nearest two above it. The system of works, therefore, by which the lode is explored and the mine established, is not unlike a system of masonry, if the horizontal beddings of the stonework be supposed to represent the levels, and the vertical joints the winzes.

When, by these arrangements, the lode has become divided into a number of solid rectangular masses, as just described, the mine will have been brought into an effective state of working, and parties of men will be set to raise ores from all the most productive points. Where the vein is not very hard and stubborn, the ore may be broken down with the pick and wedge only; but it is generally necessary to blast the rock with gunpowder or gun-cotton, by which mode large quantities of ore are detached at every 'shot.' In working the ores either by the pick or the blast, the men usually work upwards, from the upper part of one level towards the bottom of the one above it; and the excavations are so arranged that the ore may readily fall down to the level below them, whence it is carried in tram-wagons to the nearest point of the shaft, and is thence raised to the surface, either by a horse *whim* or by a steam-engine.

Simultaneously with the working of the ore, provision must be made for carrying off the water which issues from the rocky sides and bottom of the mines. This is generally effected by pumping apparatus, moved either by water or steam-power. In the early periods of mining industry wooden pumps alone were employed; but they have been for many years entirely superseded by iron pumps, which admit of the *lifts* or columns being carried to a great height without the danger of leaking or bursting. None of the pumps used in mines act at all by atmospheric pressure, as in the case of the common household pump; for they are invariably arranged in lifts of considerable height, such as from twenty to thirty fathoms, and the water itself is discharged into cisterns placed at the foot of each lift, whence it is raised again by mechanical means. The whole column of pumps is usually worked by a single pump-rod, which traverses the middle of it, and communicates with each column by a rod attached to its side. The efficiency of a steam-engine for mining purposes is estimated by a standard which is termed *duty*, and which conveniently and accurately defines the work performed, with reference to the consumption of a given quantity of coal. By the duty of an engine is meant the number of pounds (always expressed in millions) of water which have been raised through the height of one foot by the consumption of a bushel of coal; the data for this calculation being the quantity of water discharged from the pumps in a given time, and the quantity of coal consumed by the engine in the same time. In 1813, a system for the registration of the duty, and other peculiarities of the performances of the engines working in Cornwall, was organised, and the results, ascertained monthly, have since been published in the shape of monthly reports. In considering that some of the most powerful engines in Cornwall consume from three to four thousand bushels of coal per month, that some mines employ several such engines, and that the mere expense of drainage is not unfrequently £12,000 or £13,000 per annum, the immense importance of the improvements, the results of which are just noticed, will be at once understood. The Messrs Lean estimate the saving to the county effected since 1813, upon the whole number of engines reported, to amount to a hundred thousand tons of coal in the year, equivalent in value to £80,000 sterling per annum.

A mine in a complete working condition exhibits a most extensive series of operations, in connection with the shaft, the lifting and descending by ropes and pulleys, the drainage, the excavation, the ventilation, &c. At the bottom of the shaft, and in the various stages in which the excavations are going on by the miners, in their attempts to follow the lodes, the operations are on a scale which seldom fails to surprise the stranger. When the levels have been carried to a considerable distance from the shaft, the ventilation will again be found defective, notwithstanding the frequent communications by winzes; for the greater the distance the current of air is carried, the more feeble it plainly becomes. This deficiency is still further augmented by the increasing number of the men now employed in the works, the presence of a great number of candles, and the smoke resulting from the larger employment of gunpowder in the process of blasting. The expense, too, of the transport of ore and masses of rubbish or *deads* to the shaft, is, on account of its greater distance, much more considerable. To add to these, we have the greater expenditure necessary for the drainage of the water from the mine, and for the support of its passages and roofs by timber, or by rude masonry. In addition to the circumstances just named, the irregular distribution of the metalliferous portions of the lode will cause inequality in the workings, and will, with the other matters, render the sinking of one or more shafts indispensable. Again, when the depth becomes very considerable, many of the first shafts are rendered in a great measure useless, either from their being inclined, and thus inconveniently circumstanced for machinery, or from having cut the lode at a shallow depth, and thus requiring cross-cuts progressively, longer in proportion to the increase of the depth and inclination or distance of the lode from the shaft. Hence, in very deep mines, a double line of shafts will often be found to range along the course of the principal veins; and sometimes even three shafts will be found placed opposite each other, and intersecting the same lode successively at increased depths. In such cases, while the most recent shafts are used for drainage and the extraction of the ore and masses of rock, the older and more shallow shafts are often fitted up as footways, and serve for the partial ascent and descent of the miners. In some of the large Cornish mines, it is customary to sink two new shafts within a few fathoms of each other—one being of large dimensions, and intended as a drainage or *engine-shaft*; and the other being smaller, and adapted to the drawing only of ore and *stuff*. Both shafts are united at convenient distances by cross-cuts.



When circumstances permit, mines are entered, as has been stated, by an adit in a hill-side, instead of by shafts. Of this character are the openings into the lead-mines of the north of England, of Derbyshire, and of North Wales, all of which are situated in the carboniferous limestone, and the grits and shales resting upon it. In some valley, where the edges of the strata are exposed to view, a spot is selected from which it may be practicable to drive a level upon the vein itself, and in one of the beds known to be favourable to its productiveness. The progress of such a level explores the vein most efficiently, and opens a convenient passage for the extraction of the ore. In the case of fragmentary deposits, all that is necessary is to turn the debris over with pick and shovel, and make selection of the more promising fragments. The mining of stratified ores, as the clay or carbonaceous ironstone, is conducted precisely in the same manner as coal; but being in thinner layers, the workings are not upon such a costly and extensive scale.

METALLURGY.

Metallurgy—from the Greek *metallon*, and *ergon*, a work—is the art of separating metals from their ores; and as this separation is undertaken only with a view to some economic purpose, the term may be regarded as embracing the whole art of working in metals, from the reduction of the ore, to the ultimate application of the metallic product. With respect to the primary reduction, though heat be the grand agent, yet so different is the treatment of the different ores as to dressing, roasting, smelting with fluxes, the application of amalgams, and the use of even more complicated chemical processes, that what is peculiar in each, will be best adverted to under our notices of the respective metals, which are here tabulated in the order of their specific gravities, taken at 60° Fahrenheit:—

Name.	*Specific Grav.*	*Melting Point.*	*Discoverer.*	*Date.*
Platinum,	20·98	ox. bl.*	Wood,	1741
Gold,	19·26	2016°	Known to the Ancients.	
Tungsten,	17·60	ox. bl.	D'Elhuiart,	1781
Mercury,	13·57	−39°	Known to the Ancients.	
Palladium,	11·35	...	Wollaston,	1803
Lead,	11·35	612°	Known to the Ancients.	
Silver,	10·47	1873°	Known to the Ancients.	
Bismuth,	9·82	497°	Agricola,	1530
Uranium,	9·10	ox. bl.	Klaproth,	1789
Copper,	8·89	1996°	Known to the Ancients.	
Cadmium,	8·60	442°	Stromeyer,	1818
Cobalt,	8·54	2810°	Brandt,	1733
Nickel,	8·98	2810°	Cronstedt,	1751
Iron,	7·79	3480°	Known to the Ancients.	
Molybdenum,	7·40	ox. bl.	Hielm,	1782

* Ox. bl.—Fusible only by the oxy-hydrogen blowpipe.

Tin,	7·29	442°	Known to the Ancients.	
Zinc,	7·92	773°	Paracelsus,	1520
Manganese,	8·05	2960°	Gahn and Scheele,	1774
Antimony,	6·70	...	Basil Valentine,	1490
Tellurium,	6·11	620°	Müller,	1782
Arsenic,	5·88	...	Brandt,	1733
Titanium,	5·28	ex. bl.	Gregor,	1791
Aluminium,	2·60	...	Wöhler,	1828
Magnesium,	1·70	...	Bussy,	1829
Sodium,	·97	190°	Davy,	1807
Potassium,	·86	136°	Davy,	1807
Chromium,	Undetermined.	ex. bl.	Vauquelin,	1797
Columbium,		ex. bl.	Hatchett,	1802
Rhodium,		ex. bl.	Wollaston,	1803
Iridium,		ex. bl.	Tennant,	1803
Osmium,		ex. bl.	Tennant,	1803
Cerium,		...	Hisinger,	1804
Barium,		...	Davy,	1807
Strontium,		...	Davy,	1807
Calcium,		...	Davy,	1807
Lithium,		...	Arfwedson,	1818
Zirconium,		...	Berzelius,	1824
Glucinium,		...	Wöhler,	1828
Yttrium,		...	Wöhler,	1828
Thorium,		...	Berzelius,	1829
Vanadium,		...	Sefström,	1830
Lantanium,		...	Mosander,	1839
Didymium,		...	Mosander,	1840
Erbium,		...	Mosander,	1840
Terbium,		...	Mosander,	1840
Ruthenium,		...	Klaus,	1844
Niobium,		...	H. Rose,	1845
Pelopium,		...	H. Rose,	1846

Gold.

As the most valuable and longest known of the metals, gold deserves to rank first in our catalogue. When pure, it is of a deep and peculiar-yellow colour, rather soft, and extremely heavy, having a specific gravity of 19·3; that is, nineteen times heavier, bulk for bulk, than pure water. It exceeds all the other metals in ductility and malleability; it may be beaten into leaves 1-282,000th of an inch in thickness, and a single grain may be drawn out into 500 feet of wire. Though soft, its fusing-point is as high as 2016° of Fahrenheit; it is unchanged by fire with access of air—the hottest furnace producing no other effect upon it than to keep it in fusion, when it appears of a brilliant greenish colour. It expands during fusion, and contracts in cooling, more than any other metal. It is not acted upon by any of the common acids; but chlorine and nitro-muriatic acid (*aqua regia*) corrode and dissolve it, forming a chloride of gold, which is soluble in water. The metal occurs in greater or less abundance in almost every quarter of the globe, and is obtained either in the native state, from alluvial sands and gravels, or in mineral veins in combination with silver, and often mixed with metallic sulphurets and arseniurets. In the native state it occurs in small crystals, in threads or granular fragments, which, when of a certain magnitude, are called by the name of *pepitas*. The largest known pepita is said to have been found in Peru, its weight being about 20¼ lbs. avoirdupois; but masses have been reported from the province of Quito weighing 50 and 60 lbs.!

The geological formations in which gold occurs are the crystalline primitive rocks, the compact transition strata, the trachytic and trap rocks, and alluvial grounds of the current era. In the three former sources, the ores of the metal are *in situ*; in the latter, it is a travelled or transported product, being carried thither, from the rocks in which it was originally formed, by streams and rivers. In the former case, it is obtained by the difficult and dangerous process of mining; in the latter, the soil or gravel is merely turned over, and the metallic portions (the *gold-dust* of commerce) separated by hand-picking, washings, and siftings. It is thus obtained from *mines* in Brazil, Peru, Mexico, Carolina, Hungary, Transylvania, and the Uralian Mountains; and from *sands* from the Peruvian, Mexican, and Brazilian rivers, the coast of California, several of the rivers of Africa, from the Rhine, Rhone, and Danube, in continental Europe, and in small quantities from Wicklow in Ireland, from Cornwall, and from the Leadhill district in Scotland. With the exception of iron, perhaps there is no metal more generally disseminated than gold; but in comparatively few localities is it sufficiently abundant to repay the cost of mining and collecting. The deposits, for example, in our own country are quite insignificant; that of Wicklow, to be sure, yielded some years ago a few thousand ounces, but is now, we believe, abandoned like all the other localities. It is the new world which yields the great commercial supplies of the precious metals, and which, under more skilful modes of procedure, could readily supply double the amount, and that at little more than the present cost. Of late years, several English companies have attempted improved modes; but the systems of mining, the apparatus, the methods of reduction, are still exceedingly rude and wasteful.

Mr Gardner, who recently travelled in Brazil, describes the gold field of that region, whether in veins or in alluvial deposits, as inexhaustible, but extremely irregular in the amount of production; a vein which, for weeks, had yielded only a few ounces, all on a sudden producing more than 100 lbs. in a single day. The following is the treatment of the ore as practised at one of the most extensive mines he visited. 'The ore is first removed from its bed by blasting, and is afterwards broken by female slaves into small pieces, about the size of the stones put upon macadamised roads, after which it is conveyed to the stamping machine, to be reduced to powder. This machine consists of a number of perpendicular shafts placed in a row, and heavily loaded below with large blocks of iron; these, being alternately lifted up to a certain height by a toothed cylinder, turned by a large water-wheel, fall down upon and crush the stones to powder. A small stream of water, constantly made to run through them, carries away the pulverised matter to what is called the strakes, a wooden platform, slightly inclined, and divided into a number of very shallow compartments, of 14 inches in width, the length being about 26 feet. The floor of each of these compartments is covered with pieces of tanned hide, about 3 feet long and 16 inches wide, which have the hair on; the particles of gold are deposited among the hairs, while the earthy matter, being lighter, is washed away. The greater part of the gold dust is collected on the three upper skins, which are changed every four hours, while the lower skins are changed every six or eight hours, according to the richness of the ore. The sand which is washed from the head skins is collected and amalgamated with quicksilver in barrels, while that from the lower skins is conveyed to the washing-house, and concentrated over strakes of similar construction to those of the stamping mill, till it be rich enough to be amalgamated with that from the head skins. The barrels into which this rich sand is put together with the quicksilver are turned by water, and the process of amalgamation is generally completed in the course of forty-eight hours. When taken out, the amalgam is separated from the earthy sand by washing; it is then pressed in chamois skins, and the quicksilver is separated from the gold by sublimation. In the whole process, the loss of mercury amounts to about 35 lbs. a-month; but up to two months before my visit, it was nearly double that quantity. For a long time the gold dust was extracted from the sand by hand-washing in Bateias, after the Brazilian manner; but the process of amalgamation is found to be superior, requiring less labour, and extracting a larger proportion of gold. The *sillerthal*, or running amalgamation process, similar to that used in the Tyrol, has also been tried here, but was not found to answer, owing to the great loss of quicksilver. The roasting process has also been attempted; but although by this means the ore yields a much larger per centage of gold, the fumes arising from the arsenic were found to be so injurious to the health of the workmen, that it was abandoned.' In different countries different metallurgic processes are adopted; but on the whole, that of stamping and amalgamating seems to be the readiest and most successful. The metallic grains found in the sands of rivers do not require to be subjected to any metallurgic process, in the strict acceptation of that term.

The applications of gold are numerous and important; but in most cases it is used in an alloyed, and not in a pure state. This arises from its softness, and consequent liability to be worn down; the common alloys of copper or silver conferring the necessary hardness, without impairing in any appreciable degree the beauty and lustre of the more precious metal. In this condition it is employed for coin, plate, and a variety of articles of luxury and ornament, for which purposes it has ever been in the highest repute. It is also extensively used in the arts for gilding, conferring on materials often the most worthless the semblance of its own unrivalled beauty. The gold coin of the realm, commonly called *standard gold*, consists of 11 parts pure gold and 1 of copper; it is extremely ductile and malleable, but harder than pure gold, and therefore better calculated to resist the wear and tear of circulation. The colour of this alloy is deeper yellow than that of pure gold, and verges upon orange; 20 lbs. troy of it are coined into 934½ sovereigns; 1 lb. troy, therefore, produces 46 29/40 sovereigns. It sometimes happens that a part of the alloy of gold coin is silver; hence the pale colour of some sovereigns as compared with others. The gold employed by jewellers, &c. is all less or more alloyed; and from the great skill now attained in putting rich surfaces on such alloys, it requires very considerable skill on the part of the purchaser to prevent deception. The art of *gilding* consists in covering other substances with a thin coat of gold, which may be done either by mechanical or chemical means. The mechanical mode is the application of gold-leaf or gold-powder, which is made to adhere by size or varnish; the chemical, by plunging the substances in solutions of gold, or by the electrotype process. The production of *gold-leaf* and *gold-wire* of such extreme fineness as we have mentioned, requires considerable ingenuity; and is all the more readily accomplished the finer the standard of the metal. The former is made by rolling out plates of pure gold as thin as possible, and then beating them between folds of fine vellum (gold-beaters' skin) by a heavy hammer, until the requisite degree of tenuity has been reached; the latter is formed by drawing a cylindrical rod of the pure metal through a series of gradually-decreasing holes punched in a steel plate.

The probable supply and consumption of gold are generally estimated in conjunction with those of silver, the two conjointly forming the 'precious metals' of the economist and statistician. (See p. 375.)

Silver.

This is another of the metals which have been longest known and esteemed, having been extensively employed from the earliest times in the fabrication of articles both of utility and ornament. Every one must be familiar with its peculiar white colour and great lustre; the epithet *silvery* conveying an idea not to be confounded with any other. In malleability and ductility it ranks next to gold, being frequently hammered into leaves 1-10,000th part of an inch in thickness, and drawn into wires finer than the human hair. Its specific gravity is only 10·5, and its fusing point 1873° of Fahrenheit. Silver is a widely-disseminated product of nature, occurring in the metallic or native state in fine threads or strings in various rocks, but chiefly in veins in primitive and secondary mountains. It is found also in combination with other metallic ores, as those of lead, and as a native sulphuret.

Silver, we have said, is very generally distributed; but the great sources of supply are Mexico and Peru in the new world. A considerable supply is also obtained from other parts of South America, from the Uralian Mountains, Austria, and Norway. In Britain it is found in small quantities, associated with lead—as in Derbyshire, at Alston Moor, Leadhills, &c.; and also in veins in the island of Anglesey. Most of the silver mines are situated in high, bleak, desolate tracts, which would never be inhabited by man, unless for the sake of the treasures in the rocks beneath. Those of Peru, for example, are found at an elevation of from 12,000 to 14,000 feet above the sea, in a wild barren region, to which every necessary of life has to be brought from a toilsome and expensive distance; and yet towns like Cerro de Pasco, of 18,000 inhabitants, have there risen into life and activity. The silver veins of Pasco are extremely rich. 'One of them,' says a recent traveller, 'runs nearly in a straight line from north to south, and has already been traced to the length of 9600 feet, and the breadth of 412 feet; another, which takes a direction from east-south-east to west-north-west, and which intersects the former, is known to the extent of 6400 feet long, and 390 feet in breadth. From these large veins numberless smaller ones branch off in various directions, so that a network of silver may be supposed to spread beneath the surface of the earth. Some thousand openings, or *mouths*, are the entrances to these mines. Most of these entrances are within the city itself, in small houses; and some are in the dwellings of the mine owners. Many of them are exceedingly shallow, and not more than five hundred deserve the name of shafts. All are worked in a very disorderly and careless way, the grand object of their owners being to avoid expense. The dangerous parts in the shafts are never walled up, and the excavations proceed without the adoption of any measures of security. The consequence is, that accidents, caused by the falling in of the galleries, are of frequent occurrence; and every year the lives of numbers of the Indian miners are sacrificed.' All the other operations, it would appear, are as rude as the mining: the raising of the ore, the breaking and stamping, the separating of the silver from the dross, are all executed in a very clumsy, imperfect, and at the same time a very expensive manner. 'The amalgamation of the quicksilver with the metal is effected by the tramping of horses! The animals employed in this way are a small ill-looking race, brought from Ayacucho and Cuzco, where they are found in numerous herds. The quicksilver speedily has a fatal effect on their hoofs, and after a few years the animals become unfit for work. The separation of the metals is managed with as little judgment as the amalgamation, and the waste of quicksilver is enormous. It is computed that on each mark of silver half a pound of quicksilver is expended. The quicksilver, with the exception of some little brought from Idria and Huancavelica, comes from Spain in iron jars, each containing about 75 lbs. weight of metal. In Lima, the price of these jars is from 60 to 100 dollars each, but they are occasionally sold as high as 135 or 140 dollars. Considering the vast losses which the Peruvian mine owners sustain by the waste of quicksilver, and the defective mode of refining, it may fairly be inferred that their profits are about one-third less than they would be under a better system of management.' Within the last few years, however, a number of English companies have been drawn to South America, and, in consequence, mining has received a new impetus, and attention has been directed to the adoption of a more speedy and less expensive system of amalgamation. The different modes of refining and working the metal are too numerous, and, in general, too complicated, to be here alluded to.

The numerous uses and applications of silver are well known. In its pure state it is too soft for coin, plate, and most ornamental purposes; but alloyed with copper in proper proportions, it becomes hard, without being materially impaired in colour. The *standard silver* of British coin is an alloy of 11 oz. 2 dwt. of pure silver, and 18 dwt. of copper, to the pound troy; and this weight is coined into 66 shillings. In the arts, silver is extensively used, particularly for silvering or plating other metals; and for this purpose, silver-leaf and solutions of silver are applied much in the same way as in gilding. The oxide of silver is used for colouring porcelain; and the iodides and nitrates are the ingredients upon which the new processes of Daguerreotype and Calotype mainly depend. The only pure acids which act upon silver are the nitric and sulphuric, producing respectively nitrates and sulphates of considerable importance. The nitrate, for example, is the strongest and most manageable caustic known in surgery, being applied as a common black wash, or as *lunar caustic*, which is merely the nitrate melted, and run into moulds after evaporation. A solution of two drachms of the nitrate of silver in an ounce of water, coloured by a little sap green or Indian ink, forms the marking ink of the laundress; and when a nitric solution of silver is mixed with alcohol, a violent effervescence ensues, and *fulminating powder* is produced. This powder is one of the most dangerous compounds known, exploding with violence upon the slightest friction of hard bodies, or when struck, rubbed, or heated. It is used in the preparation of lucifers, percussion-caps, Congreves, and the like.

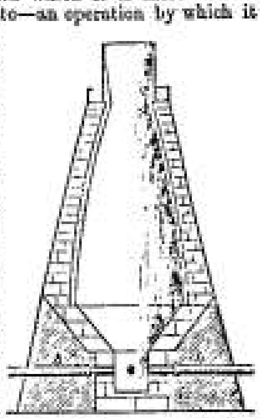
Respecting the supply of the precious metals—gold and silver—Mr M'Culloch reckons the total available annual produce of the South American and Mexican mines at £5,600,000; of the United States, £100,000; the European, £750,000; and the Russo-Asiatic, £2,600,000—making in all £9,050,000. The total annual consumption he sets down at £6,050,000—namely, for the United Kingdom, £2,500,000; France, £1,000,000; Switzerland, £450,000; the rest of Europe, £1,600,000; and North America, £500,000. Commenting on the future supply of these metals, the same authority remarks, 'that there are not merely probable, but good grounds, on which to anticipate a large future increase of the annual produce of the mines and washings in most parts of the world. The late increase of the latter in Russia has been quite extraordinary; and if it should go on for any considerable period, it would have a powerful influence over the value of gold, and would not only sink it as compared with silver, but as compared with all other things not produced with the same increased facilities. It is reasonable, also, to suppose that the produce of the South American mines should be gradually increased. The anarchy which has so long disgraced and desolated the country cannot continue for ever; and means have lately been taken for reducing the price of quicksilver, the high cost of which has latterly contributed more than anything else to paralyse the efforts of the miners.'

Iron.

Every person knows, or ought to know, says a high authority; the manifold uses of this truly precious metal. It is capable of being cast into moulds of any form; of being drawn out into wires of any desired strength or fineness; of being extended into plates or sheets; of being bent in every direction; of being sharpened, hardened, and softened at pleasure. Iron accommodates itself to all our wants, our desires, and even caprices; it is equally serviceable to the arts, the sciences, to agriculture, and war; the same ore furnishes the sword, the ploughshare, the scythe, the pruning-hook, the needle, the graver, the spring of a watch or of a carriage, the chisel, the chain, the anchor, the compass, the cannon, and the bomb. It is a medicine of much virtue, and the only metal friendly to the human frame. The ores of iron are scattered over the crust of the globe with a beneficent profusion, proportioned to the utility of the metal; they are found under every latitude and every zone, in every geological formation, and are disseminated in every soil. It has also been well remarked by another authority, that he who first made known the use of iron may be truly styled the Father of Arts and Author of Plenty.

The metal thus eulogised is of a peculiar gray colour, and strong metallic lustre, which is capable of being heightened by polishing. In ductility and malleability it is inferior to several of the metals, but exceeds them all in strength and tenacity. At common temperatures it is hard and unyielding; it is, too, one of the most infusible of metals, its fusing point being 3480° of Fahrenheit; but this disadvantage is counterbalanced, for all practical purposes, by its possessing the property of *welding* in high perfection. Iron is not a dense metal, its specific gravity being only 7·78. When exposed to air or water, it absorbs oxygen with rapidity, and becomes an oxide, or rusts. It is attracted by the magnet, and may itself be rendered permanently magnetic. It is found *native* in very small quantities; but, as already stated, its ores, amounting to about twenty in number, are all but universally diffused. Of these ores, about ten are worked by the miner either for the sake of the metal they contain, for use in their native state, or for some principle (as sulphur, arsenic, chromic acid, and the like) which they contain. The chief metal-yielding ores are—the red oxides of iron, included under the name of red hæmatite; the brown hæmatite of the mineralogist; the black oxide, or magnetic iron ore; and protocarbonate of iron, either pure, or in the form of clay iron ore. The three former occur in veins or nests in primary formations, and supply the finest kinds of iron, as those of Sweden and Hindoostan; while clay ironstone, from which most of the British iron is extracted, occurs chiefly in the coal formation, imbedded in the clays and shales, either in bands or nodules.

The forms in which the metal commonly appears in the arts are cast iron, malleable iron, and steel; substances of such immense and varied importance, that a short outline of their nature and mode of production cannot fail to interest the intelligent reader. The ore being brought from the mine, and broken into fragments, the first process is that of roasting or calcining it in the open kilns, in order to drive off the water, sulphur, and arsenic, with which it is more or less combined in its native state—an operation by which it loses one-sixth of its weight. The roasted ore is then transferred to the blast-furnace, which is usually a large pyramidal building, with arched openings at each side for the insertion of the blast pipes. Of late years, blast-furnaces have been built of a round shape, called the cupola furnace, which form is by many preferred. The inside is either cylindrical or square, widening from the top to near the bottom, when it is suddenly contracted, and terminates in the hearth or crucible in which the metal is received.



The blowing pipes, *b b*, as shown in the accompanying sectional drawing, are situated a little above the hearth on each side, and the air is forced into the furnace by means of an engine adjoining the furnace. Into this furnace the ore, or *mine*, as it is called, is put, along with coke as the combustible agent, and lime to act as a flux. By the combustion of the coke an intense heat is raised, which softens the ore; the limestone combines with the earthy ingredients of the ore, and the metallic particles fall down into the hearth or crucible. When it is properly fused, a tap-hole is opened in the crucible, and the metal is allowed to run out from time to time, and conducted into moulds formed of sand, for the various articles made of cast iron; or it is conveyed into channels for the *pigs*—the form in which cast iron is sold as a raw material, and the produce of which averages in Britain about 60 per cent. The term *pig iron* was given by the workmen: the metal being run off from the furnace in a main channel, which they call the *sow*, and the bars at right angles to it, like *pigs* attached to the teats of their mother. The quality of pig iron depends upon the nature of the ore and fuel employed; but it is common to divide it into foundry iron and forge iron—the former being adapted for castings, the latter for malleable purposes.

To convert pig into *bar* or malleable iron, it is first refined, an operation chiefly conducted in the 'puddling-furnace,' by exposure to a strong heat, while the melted metal is diligently stirred, and a current of air plays upon its surface. By this means any undecomposed ore is reduced, earthy impurities rise to the surface as slag, and carbonaceous matter is consumed; and the more thorough the separation of these, the better the iron. As the purity of the metal increases, its fusibility diminishes, until at length, though the temperature remain the same, the iron becomes solid. It is then, while still hot, beaten under the 'forge hammer,' or subjected to the operation of rolling, by which its particles are compacted, and its tenacity greatly increased. By these several processes the metal is converted from a fusible, hard, and brittle substance, to a tough and elastic bar, which is hardly fusible; and which, from its property of yielding and altering its form under the hammer, has acquired the name of *malleable* iron. There are various qualities of malleable iron, according to the processes followed; and what is strange, the most perfect processes will not bring the iron of one district up to the same standard as another, nor will the forging of one season be equal, even from the same furnace, with the forgings of another season.

Bar iron is converted into *steel* by being exposed to the action of heat, in contact with carbonaceous matter. Steel is thus a peculiar stage of iron, depending on the quantity of carbon which it contains, though we are unable to give a criterion for that quantity. Pig iron contains more carbon than steel, and steel about 1 per cent. more than wrought iron. Steel is therefore an intermediate step in the transition of pig to wrought iron. It has consequently been produced by melting these substances together; by which means the pig iron has imparted to the wrought iron so much of its carbon, as would serve to reduce it to a kind of steel. There are three kinds of steel—blistered steel, shear steel, and cast steel. *Blistered steel* is made by placing alternate layers of wrought iron and carbon in a furnace exposed to considerable heat. The steel thus made is found to contain small bubbles or blisters, and the process is termed 'conversion' or 'cementation.' *Shear steel* is made by choosing proper pieces of blistered steel, about three feet long, and 1½ inch square. Half-a-dozen of these are heated in a box with a flux, such as sand or clay, to the required pitch. These being hammered under a tilt, are welded into what is called single shear; the process performed over again gives double shear steel. This article, properly prepared, and cast into ingots, becomes *cast steel*. Before the introduction of Heath's process (which consists in smelting shear steel with an admixture of carburet of manganese), all which was to be worked into a fine edge, was made of iron procured from one mine only—that of Dannemara in Sweden. It was consigned to one house at Hull, at a cost of £38 per ton, and in quantities not exceeding 1100 tons per annum. Since the adoption of Heath's process, steel having all the beauty of cast steel, and all the welding advantages of shear steel, can be manufactured from any sort of iron, at a rate not exceeding £15 per ton.

The most remarkable, as well as the most useful of the properties of steel, is the power which it has of changing permanently its degree of hardness and elasticity by being *tempered*—that is, by undergoing certain changes of temperature. No other metal, says Thenard, is known to possess this property, and iron itself acquires it only when it is combined with a minute portion of carbon. If steel is heated to redness, and suddenly plunged in cold water, it is found to become extremely hard, but at the same time it is too brittle for use. On the other hand, if it be suffered to cool very gradually, it becomes more soft and ductile, but is deficient in strength. The process of tempering is intended to give to steel instruments a quality intermediate between brittleness and ductility, which shall insure them the proper degree of strength under the uses to which they are exposed. For this purpose, after the steel has been sufficiently hardened, it is partially softened, or let down to the proper temper, by heating it again in a less degree, or to a particular temperature, suited to the degree of hardness required, after which it is again plunged in cold water. Different methods have been pursued for determining the temperature proper for giving the requisite temper to different instruments. One method, which answers sufficiently well in practice, is to observe the shades of colour which appear on the surface of the steel, and succeed each other as the temperature increases. Thus at 430° of Fahrenheit, the colour is pale, and but slightly inclining to yellow: this is the temperature at which lancets are tempered; at 450°, a pale straw colour appears, which is found suitable for the best razors and surgical instruments; at 470°, a full yellow is produced, suitable for penknives, common razors, &c.; at 490°, a brown colour appears, which is used to temper shears, scissors, garden hoes, and chisels intended for cutting cold iron; at 510°, the brown becomes dappled with purple spots, which show the proper heat for tempering axes, common chisels, plane irons, &c.; at 530°, a purple colour is established, and at this degree the temper is given to table-knives and large shears; at 550°, a bright blue appears, used for swords and watch-springs; at 560°, the colour is a full blue, and is used for fine saws, augers, &c.; at 600°, a dark blue, approaching to black, has become settled, and is attended with the softest of all the grades of temper, used only for the larger kinds of saws.

The uses of these three substances—cast iron, malleable iron, and steel—are so numerous and varied, that it would be impossible, even within the limits of our sheet, to give anything like a satisfactory detail. In one or other of its forms, iron is now employed for almost every purpose to which wood, or any of the other metals, can be applied in the arts of civilised life. In agriculture, architecture, ship-building, the fabrication of machinery, railways, the construction of implements and utensils either for the objects of war or peace, and in the formation of all those articles which come under the designation of *hardwares*, its importance is pre-eminent—conferring upon Britain a wealth, power, and pre-eminence which, but for the presence of her coal and iron, she could never have attained. But though iron is thus important, abundant, and common, it is by far the most difficult of the metals to bring into a state fit for use; and the discovery of the methods of working it seems to have been long posterior to the use of gold, silver, and copper. At what time it began to be made in this country, there is no means of ascertaining: iron-works are said to have been established by the Romans in the Forest of Dean in Gloucestershire; but be this as it may, it is not till a comparatively recent period that the manufacture began to assume anything like a national importance. 'Down to the seventeenth century,' we quote the Cyclopædia of Commerce, 'the ore was entirely smelted with charcoal; and there was a considerable number of furnaces in those districts where wood and iron were plentiful, particularly the Weald of Kent, Surrey, and Sussex; but in course of time, wood-fuel becoming scarce, the trade was threatened with decay. Many attempts were made during the seventeenth and early part of the eighteenth century, to retard the decline by the use of pit-coal, but without effect; the simple hand-worked bellows, or the more powerful water-movement, which produced a sufficiency of blast for charcoal, having little effect upon coal; and the number of furnaces, which in 1619 was estimated by Lord Dudley (who in that year obtained a patent for smelting with coal) at 300, fell off towards the middle of the eighteenth century to 59. Science, however, came to the rescue of one of our greatest staple manufactures. In 1760, Smeaton erected a cylinder blasting-machine for the Carron Company, which, after some improvements, enabled the same furnace that formerly yielded 10 or 12 tons weekly, to produce 40. Shortly after this, Watt's improvement of the steam-engine, and its application to iron-works, not only revived the trade, but enabled it to distance all foreign competition. Ores that formerly could not be worked with profit, either from their inherent intractableness, or from the small proportion of metal they contained, were now advantageously submitted to the furnace, and more metal was extracted from the richest ores. Various improvements also took place in the manufacture of bar iron, particularly by the substitution of hammering machinery for hand labour; by Mr Cort's invention of "puddling" (1783)—the great distinction of coal-made iron—and also by that gentleman's patent (1784) for the rolling of iron; while at the same time the extent of the iron-works was greatly enlarged, and improvements made in the form of the furnaces. Of recent inventions, by far the most important is the substitution of the *hot* for the cold blast, by artificially heating the currents of air impelled into the furnace. This discovery of Mr Neilson of the Clyde Iron-Works, operates by obtaining a larger quantity of metal with a less degree of fuel. In 1829, with cold air, 1 ton of iron consumed 8 tons 1 cwt. of coal; in 1833, with hot air, the same quantity of iron was procured with only 2 tons 5 cwts. of coal.'

The result of these successive improvements and inventions presents the statistician with some of the most astonishing facts in the history of British manufactures. In 1740, the quantity of iron made in the United Kingdom did not exceed perhaps 25,000 tons; after the cylinder invention, it rose in 1796 to 124,879; in 1802 it was estimated at 170,000; in 1823 it rose to 702,584; in 1839 to 1,512,000; and at the present time it cannot fall much short of 2,000,000 tons! It is true that the trade is subject to rapid and extensive fluctuations, the production rising and falling to the amount of several thousand tons, and the price ranging from £6 to £14, or even higher, a ton; but the immense demand now made by railways both at home and abroad—by ship-building, bridge-building, and the like—is not likely to suffer any considerable decline for several years to come. The other countries producing iron to any extent are—France, Belgium, Sweden, Saxony, Austria, Spain, and the United States; the whole furnishing an aggregate supply somewhat less than that of Great Britain, though in the last-mentioned country the trade has increased prodigiously since the application of the hot-blast to American anthracite has proved successful. At home, the chief seats of the iron trade are—Staffordshire, Shropshire, South Wales, Yorkshire, Derbyshire, and Lancashire in England; Lanarkshire and Stirlingshire in Scotland; in Ireland there are no iron-works of importance. The manufacture of hardwares, machines, engines, iron-steamers, locomotives, &c. is now more generally diffused throughout the country, though Birmingham and the towns around it still maintain their supremacy in general hardwares; Sheffield in cutlery;* Manchester, Glasgow, and Dundee, in machinery; Glasgow and Liverpool in ship-building; and Carron in cannon and other heavy castings. At present (1847), the annual value of this metal, including under that term every form of cast and malleable iron, may be safely estimated between nine and ten millions; while the annual value of hardware, manufactured partly from iron and other metals, is not less than eighteen millions. This last estimate is exclusive of watches, plate, jewellery, &c. which are valued by Mr Jacobs at somewhere about three millions.

Copper.

This was one of the earliest known of the metals, and not less extensively used than known by the nations of antiquity; its tenacity and durability rendering it the best substitute for iron, ere man had learned to reduce that valuable but more refractory metal. It derives its name from the island of Cyprus, where it was extensively mined and smelted by the Greeks, who employed it, either pure, or in an alloyed state, in the fabrication of their domestic utensils and implements of war. It is a metal of a beautiful red colour, and considerable lustre, very malleable and ductile, but more capable of being hammered into leaves than drawn into wire. In tenacity it yields to iron, but surpasses gold, silver, and platinum—a wire of only 1-10th of an inch being strong enough to support a weight of 300 lbs. Its specific gravity is about 8·9, and its fusing-point 2000° Fahrenheit—that is, nearly a white heat. It is found occasionally in a native state in films, strings, or amorphous masses, but in no considerable quantity. The most remarkable masses of native copper hitherto dis-

* The English cutlery manufacture is very extensive, and is excelled by that of no other country, though now nearly approached by that of Belgium. We append the following account from Bigelow's 'Technology' in illustration of what may be termed one of the *ultimate applications* of the metal now under description:—'The inferior kinds of cutlery are made of blistered steel welded to iron. Tools of a better quality are manufactured from shear steel, while the sharpest and most delicate instruments are formed of cast steel. The first part of the process consists in forging, and is varied according to the kind of article to be formed. Common *table-knives* have the blade forged of steel, and welded to a piece of iron, out of which the shoulder, and part which enters the handle, are made, the shape being given to them by hammering in a die and swage. They are afterwards tempered and ground. *Forks* are made by forging the shank, and flattening the other end to the length intended for the prongs. The prongs are made by stamping the metal at a white heat between two dies, the uppermost of which is attached to a heavy weight, and falls from a height. The shape is thus given to the fork, leaving, however, a flat thin piece of metal between the prongs, which is afterwards cut out with a fly press. They are subsequently filed, pointed, bent, hardened, and polished.

Blades of *penknives* are forged from the end of a rod of steel, and cut off, together with metal enough to form the joint. The small recess in which the nail is inserted to open the knife, is made with a curved chisel while the steel is hot. *Razors* are forged from cast-steel, much in the same manner as knives. The anvil is commonly a little rounded at the sides, for the purpose of making the sides of the razor a little concave, and the edge thinner. In forging *scissors*, the shape is given to the different parts by hammering them upon different indented surfaces called "bosses." The bows, which receive the finger and thumb, are made by punching a hole in the metal, and enlarging it by hammering it round a tool called a "beak" iron. The halves are finished by filing and grinding, and afterwards united by a joint. *Saws* are made from steel-plates rolled for the purpose, and have their teeth cut or struck by a machine, finished by filing, and set by a suitable instrument. *Axes, adzes*, and other large tools, are forged from iron, and have a steel-piece welded on of the proper size, to form the edge.

To enable the steel to be wrought, it is brought to its softest state; but after the shape is given to the instrument, the steel is hardened and tempered by the methods already described. The remaining part of the manufacture consists in grinding, polishing, and setting the instrument, to produce a smooth surface and a sharp edge. The *grinding* is performed upon stones of various kinds, among which freestone is perhaps the most common. These stones are made to revolve by machinery, and move with prodigious velocity, so that the surface, in some cases, passes over six or seven hundred feet in a second, and stones have been burst by their own centrifugal force. For grinding flat surfaces, like those of saws, the largest stones are used; while for concave surfaces, like the sides of razors, smaller stones are used, on account of their greater convexity. The internal surfaces of scissors, forks, &c. which cannot be applied to the stone, are ground with sand and emery, applied with instruments of wood, leather, and other elastic substances. The last polish is given by a material composed chiefly of the oxide of iron. The edges are lastly *set* with hones and whetstones, according to the degree of keenness required. The test used by cutlers for determining the goodness of the edge and point of a lancet is, that it shall pass through a piece of soft leather without sensible resistance. *Needles* are polished by tying them in large bundles with emery and oil, and rolling them under a heavy plank till they become smooth by mutual attrition. The shape is previously given, and the eye made with a steel punch.

covered are said to be one in Brazil, which weighed about 2620 lbs., and another in the bed of a stream to the south of Lake Superior, which measured not less than 15 feet in circumference! The great source of the commercial supply is, as in the case of the other metals, from ores, of which the most common and productive are copper pyrites—that is, copper in certain combinations with sulphur and other metallic impurities. In this state it is found in almost every mineral district in beds—as the *kupfer-schiefer*, or copper-slate, of Germany—but more commonly in veins in primitive and secondary mountains. Copper mines are largely worked in England, Chili, Cuba, Germany, Sweden, and Siberia; less extensively in France, Spain, Hungary, and Norway; and recently, with great promise, in the southern parts of Australia.

The English mines, says an authority already quoted, were scarcely worked prior to last century; they are chiefly situated in Cornwall, where the most common ore consists of copper, iron, and sulphur, in nearly equal proportions, and is called yellow copper ore, or copper pyrites; veins are also worked in the counties of Devon, Anglesea, and Stafford. Owing to the want of fuel in Cornwall and Devon, the ores, after being dressed—that is, ground and sifted—are shipped from these counties to South Wales, to be calcined and smelted, principally to works situated on the navigable rivers of Swansea and Neath; the smaller quantity of material being thus carried to the greater, while the vessels load back with coal for the use of the mining steam-engines. The reduction of the ore is a tedious and complex process. 'It is first roasted in a reverberatory furnace, by which much of the sulphuret of iron is converted into oxide, while the sulphuret of copper remains unaltered. The product of this operation is then strongly heated with siliceous sand; the latter combines with the oxide of iron to a fusible *slag*, and separates from the heavier copper compound. When the iron has, by a repetition of these processes, been got rid of, the sulphuret of copper begins to decompose in the flame-furnace, losing its sulphur, and absorbing oxygen; the temperature is then raised sufficiently to reduce the oxide thus produced by the aid of carbonaceous matter. The last part of the operation consists in thrusting into the melted metal a pole of birchwood, the object of which is probably to reduce a little remaining oxide by the combustible gases thus generated.' The quantity of copper yielded by the ore is commonly about 8 or 9 per cent.; and the fuel consumed ranges from 15 to 18 parts for every part of metal produced.

The quantity of copper mined in Britain in 1820 amounted to 8127 tons; now it is considerably more than double that quantity, and valued at little short of £2,000,000. This supply is more than sufficient for the demand of the United Kingdom; hence considerable shipments in pigs, sheets, nails, wires, &c. are made to the East Indies, China, United States, West Indies, Brazil, Canada, and Holland. Besides the produce of British mines, considerable quantities of ore have of late been imported from Chili, Cuba, and Australia. All this, however, is likely to be materially affected by the recently patented process of smelting the ore by electricity—a process which is said to effect in a couple of days what formerly required the labour of three weeks! The saving of fuel, besides, will be so vast, that, in Swansea alone, the smelters estimate their annual saving in coals at no less than five hundred thousand pounds. Hence it is clear that the price of copper must be so enormously reduced, as to bring it into use for a variety of purposes from which its cost at present excludes it. The facility and cheapness of the process, too, will enable the ore to be largely smelted on the spot. The Cornish mine proprietors are anxiously expecting the moment when they can bring the ore which lay in the mine yesterday into a state to be sent to market to-morrow, and this at the very mouth of the mine. In Australia, also, the operation of this discovery will be of the utmost importance. Ten thousand tons of copper ore were sent from Australia to England in 1846, to be smelted at Swansea; and the result was only 1600 tons of copper. But Australia in future will smelt her own copper by a 36 hours' process: saving all this useless freight of the 8400 tons of refuse, and saving also the cost of the old and expensive process of reduction.

The uses of copper are numerous and highly important, the metal ranking next to iron in real commercial value. It is used, as is well known, for coin, for sheeting or sheathing the bottoms of vessels, for boilers, and a great variety of implements and utensils; in the manufacture of blue and green colours; and in medicine. Alloyed with zinc, it forms *brass* and *pinchbeck*—the former containing from 28 to 34 per cent. of zinc. In the formation of brass, the zinc may either be added directly to the melted copper, or granulated copper may be heated with calamine and charcoal powder. *Gun-metal*, a strong and valuable alloy, consists of 90 parts copper and 10 of tin; *bell* and *speculum metal* contain a much larger proportion of tin, and are consequently brittle and less durable. A good *bronze* for statues is made of 91 parts copper, 2 parts tin, 6 parts zinc, and 1 part lead. The bronze of the ancients was an alloy of copper and tin; and the *argentane* or German silver of the moderns is a compound of copper, tin, and nickel. *Or-molu* is the name given to a particular alloy of 52 parts zinc and 48 copper; and the *Bidery-ware* of India—so called from a town of that name—is a compound of copper, lead, tin, and zinc, rendered black by immersion in a solution of sal-ammoniac, saltpetre, common salt, and blue vitriol. All these alloys are of infinite use, entering into the fabrication of almost every species of machinery, implement, utensil, and ornament—from the drawing, pointing, and heading of a pin, or the stamping of a button, to the casting of a statue, or the founding of a ponderous field-piece. Though thus vieing with iron in its applicability to the purposes of civilised life, its salts and solutions, unlike those of that metal, are highly poisonous; hence the frequent evils arising from the use of neglected or ill-cleaned culinary utensils of copper. Water containing copper in solution is changed into a bright blue by the addition of a little hartshorn or liquid ammonia; and by immersing a piece of polished steel in any liquid containing copper, the surface will soon become coated with a film of the latter metal.

What is called *bronzing* is a method of colouring wood, iron, plaster of Paris, or other material, so as to imitate bronze, but which has, in reality, little connection with that alloy. The process is thus indicated in Webster's Cyclopædia: 'First, the article is to be painted of a dark colour, such as bronze acquires when it has been very long exposed to the air, or when buried under ground. This colour is produced by grinding a mixture of Prussian blue, verditer (a precipitate of oxide of copper with lime), and spruce ochre in oil. What is called *bronze powder*, sold in the shops, is now to be applied, just before the oil-paint is quite dry, to the prominent parts, where the metal is supposed to have acquired some lustre by being rubbed against. The bronze powder may be laid on by a ball of cotton wool, or in a similar manner.' Bronzing thus effected is now much in request; it has the advantage of wearing well, keeping clean, and giving effect to other colours. *Lacquering* is a somewhat allied process, and consists in applying a peculiar varnish either to brass-work, to prevent its tarnishing, or to give tin and articles covered with silver-leaf the appearance of brass. The ingredients of such a varnish are wholly non-metallic, consisting chiefly of turmeric, anotto, saffron, gum-lac, amber, and the like, dissolved in alcohol.

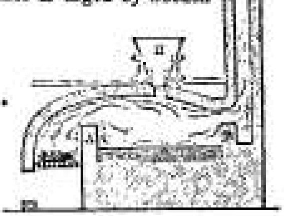
Lead.

This is another of the metals which have been long and extensively used in the arts of civilised life. It has a grayish-blue colour, with a bright metallic lustre when newly cut, but soon tarnishes, and assumes a dull earthy aspect on exposure to the air. Its texture is close, like that of gold and silver; its specific gravity is about 11·45; and it is very malleable and ductile, but soft and unelastic. It is one of the least sonorous of the metals; melts at the low degree of 610° Fahrenheit; soils the fingers when rubbed; and emits a peculiar odour. Though readily oxidised by exposure to the air, the oxidisation does not proceed far; hence its durability for roofing, and other external purposes. 'Perfectly pure water,' says Brande, 'put into a clean leaden vessel, and exposed to the air, soon oxidises and corrodes it, and delicate tests discover oxide of lead in *solution* in the water; but river and spring water exert no such solvent power. Hence it is that leaden cisterns are used with impunity for the preservation of common water; and that the crust which forms upon the metal effectually prevents all further action. As this crust partly consists of carbonate of lead, which is very poisonous, great care should be taken to prevent its diffusion through the water upon any occasion, as by scraping or cleaning the cistern.' Natural water, highly charged with carbonic acid, cannot, however, under any circumstances, be kept in lead, or passed through leaden pipes with safety.

Fourteen or fifteen ores of lead are known to mineralogists; but that of *galena*, a sulphuret of the metal, is the only one occurring in sufficient quantities to become an object of mining and metallurgy. It is found but sparingly in the primitive crystalline rocks, more plentifully in the transition schists and slates, and most abundantly in the transition and mountain limestones. The principal lead-mining countries are Britain, Saxony, Bohemia, and other states of Germany; Spain, France; and Missouri in the United States. The lead mines of Britain are of great importance; and those of Derbyshire are said to have been worked prior to the Roman invasion. The most productive at present are situated in Northumberland, Cumberland, Durham, Derbyshire, Flintshire, Isle of Man, and at Leadhills in Scotland. Nearly the whole produce is derived from galena, in the proportion of about 85 per cent. of pure metal.

When lead ore comes from the mine, the first operation is to wash and sort it into heaps of different qualities; this is done either by putting the ore into a trough, and stirring it, or filling a sieve, the meshes of which are made of iron, and immersing it in a vat full of water. Another process is to put the ore upon a *grid* or screen, which consists of a number of bars of iron placed parallel to each other, about an inch apart. Over this grating a stream of water flows, which washes away all impurities, and also separates the small pieces of ore from the large. The smaller pieces are then collected into a finer sieve, and washed again, and all pure ore which may still be amongst them is carefully picked out with an iron scraper or *crimp*. This washing is greatly facilitated by the specific gravity of the metal. The ore containing most galena sinks first, and is found next the bottom of the vat; a second quality of ore will be found on the top of this, and the inferior kinds above it. When the sieve is immersed in the water, it is shaken pretty severely, which causes the ore in a manner to float, and allows the heavier pieces to sink to the bottom. The mixed ore—that is, such as contains stone and other impurities in the lump, along with pure galena—is then sent to the grinding-mill. This consists either of a series of stampers, which pound the ore, or of a pair of fluted cylinders, through which the ore is made to pass: it is afterwards ground to the requisite fineness by smooth rollers. The mixed ore, after being ground, is again washed, and the pure galena separated from the impurities.

There are two kinds of furnaces used in the smelting of lead ore—a reverberatory furnace, (see fig.), called a *cupola*, and the other known by the name of the *Scotch furnace*. The former, in the interior, is generally 8 feet long, 6 wide, and 2 high at the centre. The fire is placed at one extremity, and is separated from the smelting part by a wall, A, which is built about half the height of the furnace. The hearth upon which the ore is placed is composed of furnace slags, and it slopes from the wall which separates it from the fire to the other end, B, of the furnace, and is hollowed from the sides to the centre. This is enclosed by an arched roof, in the middle of which is a small aperture for admitting the ore from a hopper, H, placed above it. The Scotch furnace is much of the same nature as the above, except that the hearth, sides, and sole-plate are made of cast-iron, from two to three inches thick. The roasting is performed with peat and coke, and the furnace is urged by wooden bellows. About 20 cwts. of ore are usually put into the furnace at a time, which is spread equally over the hearth with a rake. For the first two hours no regular fire is made, a gentle heat merely being kept up by putting small coal on the furnace, the doors of which are kept shut. This is called the roasting process, which is performed principally for the purpose of dispelling all sulphureous vapours from the ore. At the end of two hours the fire is raised, and the metallic lead soon begins to flow from the ore. The smelter and his assistant now stir the ore at intervals, and a shovelful of quicklime is thrown in. This is done in order to liberate the oxide of lead from the ore, and allow it to react upon any sulphuret which may have resisted the roasting. The heat is again increased, and the stirring continued. In about four hours from the commencement the furnace receives its greatest heat, after which a tap-hole is opened, and the lead runs into an outer basin. From this it is cast in semi-cylindrical moulds, and receives the name of *pigs* or bars.



Metallic lead is employed for numerous purposes in the arts:—rolled into *sheets*, it is used for roofing, lining of cisterns, tea-boxes, &c.; cast into *pipes*, it is employed for conducting of water, gas, and the like; and alloyed with arsenic, and dropped through perforated trays from lofty towers, it forms *shot* of various sizes. Alloyed with tin in different proportions, it constitutes *solder* and *pewter;* and with antimony and tin, it forms *type* and *stereotype metal*. Combined with oxygen, it constitutes *massicot*, a protoxide of a pale yellow colour; *litharge*, also a semicrystalline protoxide, obtained in separating silver from lead ores, enters largely into the composition of flint-glass; *red-lead*, a deutoxide, is extensively employed as a pigment, and also in the manufacture of flint-glass; *white-lead*, a carbonate of the metal (See 'CHEMISTRY,' p. 302), is a well-known paint; as is also the beautiful yellow chromate; while the acetate of lead, commonly known as *sugar-of-lead*, is employed for various purposes in the arts and in medicine.

In the reduction and application of lead to the above purposes, a considerable amount of mechanical and chemical ingenuity is required. Thus in the preparation of sheet-lead, a plate is first cast, and then subjected to successive 'millings' between heavy rollers, which extend and reduce it to the desired thickness. The thickness is regulated by screw-work, which keeps the rollers apart, so as to produce a sheet varying from half an inch to the thinness of the finest writing-paper. Still greater ingenuity is exhibited in pipe-drawing. A 'plug,' or thick short pipe, is first cast in a mould; a mandril, or steel rod, of the desired bore is inserted in this pipe, which is then drawn by machinery through a succession of gradually-decreasing holes on a steel-plate or die. 'In producing a two-inch pipe, no fewer than sixteen dies are employed, the diameters of which descend in a regular series. The hole through the die is conical—that is, larger on one side of the die than on the other; and the lead enters the hole at the widest part, whereby a process of compression is undergone; but at a certain point in the operations a 'cutting die' is introduced—that is, one wherein the lead is at once exposed to a cutting edge, the result of which is, that a thin film is cut or scraped from the whole surface of the pipe.[1] The elongated pipe is now removed from the mandril, coiled up, and sent to the plumber. We have stated that shot is formed by dropping an alloy of lead and arsenic through perforated trays or colanders, from the top of lofty towers, into a cistern of water beneath; the same result is more economically obtained by dropping the metal from the surface to the bottom of some waste coal-shaft, as is done at Newcastle. The perforations of the colanders are of sizes ranging from 1-5th to 1-20th of an inch in diameter; and on passing through these, the melted metal assumes a globular form, cools partially in falling, and ultimately settles in the cistern in drops less or more spherical. These are next assorted by being passed through sieves, which retain all imperfect forms; and still further by being passed over an inclined plane of polished iron, when the well-shapen shot descend with an impetus sufficient to carry them into a trough at some distance from the end of the incline, while the imperfect forms travel slowly, and drop 'dead,' as the workmen express it, almost over the verge of the plane. The dark glossy hue of shot is obtained by churning it with powdered black-lead in revolving cast-iron barrels, a process which also assists in producing a still more spherical form. Leaden bullets are cast in moulds; but all the former modes of casting, cutting, and rolling shot are now abandoned. None of the chemical preparations of lead involve any peculiar difficulty either in their manufacture or application. The only contingent evil is their poisonous character, which manifests itself more or less on the constitutions of painters, plumbers, white-lead-makers, and the like. Lead indeed is a metal requiring very cautious use in any form, and ought to be avoided in the manufacture of all culinary, dairy, brewing, and other utensils employed in the preparation of human food.

The amount of lead annually smelted in Britain is estimated at 60,000 tons or thereby; which, at the present price, would make the value of the produce little short of £1,000,000 sterling. About 15,000 tons are annually exported, partly in pigs, and partly in sheet, shot, red-lead, and litharge.

Tin.

Tin was known to the ancient nations of the Levant, who obtained it chiefly from Spain and Britain. It is a white brilliant metal; has a slight taste and smell when rubbed; is malleable to a considerable degree, but is inferior in ductility and tenacity. Its hardness is intermediate between that of gold and lead; its specific gravity is about 7·3; it melts at 442° Fahrenheit, and at a white heat takes fire and burns with a bright flame. It oxidises but slowly on exposure to air and moisture; hence its value in coating or tinning more oxidisable metals, as iron. Tin is rather a rare metal; and is principally found in primitive rocks, where it occurs chiefly in veins, but partly also disseminated, and in beds. There are only two ores of the metal known—the double sulphuret, which is rare; and the native peroxide, from which the commercial supplies of the metal are obtained.

This latter ore is found abundantly in Cornwall and the western district of Devonshire; in Germany, Bohemia, and Hungary; in Chili and Mexico; and in Malacca and Banca in the East Indies. The tinstone of Britain is chiefly obtained from mines; but considerable quantities are sometimes discovered in alluvial soils—the debris of rocks in which the ore was originally imbedded. Repeated washings, by means of running water, being the chief process by which the ore is separated from such debris, the name of *stream work* is commonly applied to this method of obtaining it. On one occasion, the water being excluded from a branch of Falmouth harbour, a bed of rounded masses of tin ore, from two to ten feet thick, was found fifty feet below a bed of alluvium—£50,000 is said to have been made by this discovery.

The ore, in whatever way obtained, is first broken into small fragments, then pounded in stamping-mills, washed, sifted, and roasted. It is next reduced by smelting with coal and a flux of lime, under a very strong heat, which is kept up for eight or nine hours. The liquid tin, on being run off from the slag, is still mixed up with iron, arsenic, and other impurities, and has to undergo fresh smeltings, after which it is cast into granite moulds capable of containing about 3 cwts. each. In this form it is known as *block* or *bar-tin*—a term generally used in contradistinction to *grain-tin*, which is obtained from stream-ore, somewhat differently treated. After the stream-tin ore has been dressed and pounded, it is smelted with wood-charcoal, run off into iron vessels, and there kept liquid by a gentle heat, till, by repeated agitation with pieces of charcoal, all impurities are expelled. It is finally removed by ladles, and poured into small moulds. The grain or stream-tin so obtained is of superior quality, and is employed by dyers, and for the finer purposes.

The uses of tin are both numerous and important. Besides being employed in the formation of a variety of utensils, it is largely used in *tinning* copper and iron-plate, to protect them from rust—an art which originated in Saxony, and was made known in Britain about two centuries ago. It consists in carefully cleaning the surface of the plate with sal-ammoniac, or with muriatic acid, rubbing it well, and then immersing it in melted tin, by which it acquires a thin and equable coating. Vessels are coated internally by heating them, pouring in a certain quantity of melted tin, and then rotating them, so that the tin may come in contact with every part of the surface. Alloyed with antimony, copper, bismuth, and lead, tin forms *pewter;* it enters into the composition of *bell-metal, type-metal,* and *solder;* it is used in the process of enamelling; in silvering, or rather tinning, looking-glasses (see p. 330); in coating pins; by dyers and calico-printers as a *mordant* when solved in muriatic acid; largely in the form of *foil* or leaf, which is made by beating; its oxide is much used in polishing, under the name of *putty-powder;* and the *purple of Cassius*, so called from its inventor, is a union of protochloride of tin with perchloride of gold.

The annual produce of the British tin mines is estimated at 4000 tons, worth from £65 to £80 a ton. About 1500 tons of unwrought tin are annually exported, principally to France, Italy, and Russia; and this, exclusive of tin, pewter-wares, and tinplate, to the value of £400,000 yearly, sent to the United States, Italy, Germany, France, the colonies, &c. The amount of crude tin brought from the East is very variable, ranging generally between 500 and 1500 tons per annum.

Mercury or Quicksilver.

This is a well-known metal, of a brilliant silver-white colour, fluid and mobile at ordinary temperatures; hence the name *live*, or *quick*, silver. In this property of fluidity, it differs from all other metals—never being solid, unless when subjected to a degree of cold equal to 40° below zero. In this condition it has been obtained by arctic explorers, who, under extreme depressions of temperature, found their barometers and thermometers useless, and who, for curiosity's sake, have shot bullets of it from their muskets. When solid, it is found to be malleable, a fact of no practical importance, however, as it instantly passes into the fluid state on being brought under a higher temperature than — 40°; it boils and vaporises at about 660° Fahrenheit. Its specific gravity is about 13·57; thus ranking above all other metals, with the exception of platinum, gold, and tungsten. It is found native in small quantities—that is, in minute dewy globules; but for commercial purposes it is always extracted from the ore called *cinnabar*. This ore is a bisulphuret of the metal, of a red colour (except in the hepatic variety, which is gray), massive and crystallised, occurring in veins, and distributed variously through the matrix of the veinstone. It is found but sparingly in the primitive rocks; the principal deposits of the mercurial ores being, in all parts of the world, in the middle secondary strata; that is, in the upper portions of the coal-measures, and in the magnesian limestone and new red sandstone. In these formations the ore occurs either in irregular veins, or is combined with the sandstones, bituminous schists, and indurated clays.

The most productive mines of cinnabar are those of Almaden, near Cordova in Spain, of Idria in Austria; and of Huancavelica in Peru, at an elevation of 14,500 feet above the sea. Quicksilver is also produced in several of the Chinese provinces, and sparingly in one or two localities in Rhenish Bavaria, Bohemia, and Hungary. The mines of Idria, which were discovered in 1497, yield annually about 150 tons of the pure metal; but could readily supply four times that amount, were it not for certain absurd restrictions imposed upon the produce by the Austrian government. The veins at Almaden, which range from 12 to 20 feet in thickness, have been worked for nearly three thousand years; at all events, Pliny records that the Greeks imported red cinnabar from Spain seven hundred years before the Christian era, and that Rome in his time annually received 700,000 pounds from the same province. At present, the produce of metal may be from 1100 to 1200 tons, giving employment to upwards of 4000 miners and smelters. The usual method of reducing the ores is by distillation. The minerals brought out of the mine are broken up, picked by women and children, pulverised, and sometimes washed. In some places the richer ores are separately burnt; but it is more usual, and considered more economical, to mix the richer with the poorer ores, and expose the whole mass together to the action of heat in closed retorts, which also contain a certain proportion of limestone. The retorts, filled with the mixture of ore and limestone, are ranged, to the number of twenty or more, in recesses of a furnace; and heat being applied, each retort is made to communicate with a vessel of water, in which the vapours of the mercury are condensed. In the mines of Idria a ruder method is adopted; the ores are roasted in a kind of oven, and the vapours ascend into condensers, where the little drops of mercury collect, and are conducted into a porphyry vessel placed to receive them.

The imports of mercury into this country, chiefly from the mines of Almaden, are about 2,300,000 pounds annually, of which little more than an eighth are retained for home consumption. The remainder is re-exported, principally to South America, Mexico, the United States, and the East Indies; while smaller shipments are made to Russia, Belgium, and other countries. During the war, when the intercourse between Europe and America was interrupted, the price of quicksilver rose to such a height in the latter country that it answered to import it from China; but since the peace, this traffic, we believe, has been abandoned. From the peculiar character of the metal, it is transported either in iron bottles, in small leathern bags, or, as from China, in short joints of the bamboo. Mercury is often adulterated by an admixture of lead, bismuth, zinc, and tin; in which state it is less lustrous, becomes covered with a whitish film, and is not so mobile, or readily divisible into minute globules.

Mercury is principally employed for *amalgamation* with other metals, chiefly gold and silver, so as to extract them from their ores; and it is almost solely for this purpose that it is imported into South America and Mexico. It is used also in gilding, in silvering mirrors, in filling thermometer and barometer tubes, in various philosophical apparatus; and in chemistry it furnishes the only means of collecting, in the pneumatic trough, such gases as would be absorbed by water. In medicine it is employed in several forms: the whitish insipid powder termed *calomel* is the protochloride of mercury; and the acrid, nauseous, white substance known as *corrosive sublimate* is the bichloride. This sublimate has recently been extensively applied as an antiseptic in the prevention of the dry-rot in timber, in the mildewing of sailcloth, and the like (See No. 47). Mercury is also used in the making of *vermilion*, that beautiful pigment being prepared from an artificial cinnabar, composed of 8 parts of mercury and 1 of sulphur. When sulphur and mercury are triturated together in a mortar, the former gradually disappears, and the whole assumes the form of a black powder, denominated *ethiops mineral*; if this powder be heated red-hot, it sublimes, and on a proper vessel being placed to receive it, a cake is obtained, of a fine red colour, which, when reduced to powder, forms the vermilion of commerce. An amalgam of mercury and silver is generally used by dentists for stopping hollow and decayed teeth.

Antimony.

This metal was discovered by Basil Valentine in 1490, and has since been extensively employed in medicine, in the composition of printing types, stereotype plates, music plates, and the like; and also in the manufacture of the white metal utensils now so generally used as substitutes for silver. When pure, it is of a silver-white colour, is brittle, has a specific gravity of 6·7, and melts readily at a red heat. When heated in open crucibles, it gradually combines with the oxygen of the atmosphere, and flies off in the form of a white vapour. It is the oxide, or rather oxides of the metal (for there are several) which are used in medicine, their general effects being purgative, sudorific, and emetic. The metallic ore of commerce contains sulphur and other impurities, and is much more easily fused than the pure metal, which has a hardness about that of gold. Its tenacity is also considerable—a wire of 1-10th of an inch in diameter being capable of supporting a weight of 10 lbs.

Antimony ore is found at Rosenau in Hungary, in Saxony and the Hartz, in Spain, France, Siberia, Mexico, the Indian Archipelago, and in Cornwall and Ayrshire in our own island. As yet the ore has been imported into this country chiefly from the East; but the recently-discovered veins in Ayrshire are likely soon to yield the main supply. It is usually of a lead-gray colour, is crystallised, possesses considerable splendour, and is very apt by the uninitiated to be mistaken for an ore of lead. *Crude* antimony is the name given in commerce to the sulphuret of the metal, after being separated from the impurities of the ore by fusion with charcoal; and *regulus* of antimony is the pure metal, after being separated from the sulphur, by being mixed with tartar and exposed to heat. The powder of the sulphuret is very black, and was employed by women in ancient times to stain their eyebrows and eyelids.

Antimony is never applied to any useful purpose as an independent metal, in consequence of its brittleness and liability to corrosion; but it forms several valuable and extensively-employed alloys. Thus, alloyed with lead, in the proportion of 2 to 6, and a small addition of copper, it constitutes the metal used for printing types; mixed with lead alone, the compound forms the rather brittle plates upon which music is engraved; and an alloy of 112 lead, 18 antimony, and 2 block tin, forms the stereotypes from which the present sheet is printed. These alloys have the property of expanding as they cool: the consequence of which is, that the types come out of the moulds with sharp and well-defined edges. Hard pewter is made of 12 parts of tin and 1 of antimony; and the Britannia or white-metal spoons and teapots now so much in use are composed of 100 tin, 8 antimony, 2 bismuth, and 2 copper. Antimony also unites with iron, forming a hard whitish alloy; and the smallest portion entering into the composition of gold, renders that otherwise soft and ductile metal brittle and unmalleable. The manufacturer of pastes or factitious gems employs the oxide of antimony to give colour to his so-called beryls, Oriental topazes, and yellow diamonds. Six parts dry nitrate of potash, two sulphur, and one sulphuret of antimony, reduced to a fine powder, form the blue or Bengal light used as a signal at sea.

Bismuth.

This metal, known to Agricola in 1530, is of a brittle crystalline texture, brownish-white in colour, nearly 10 in specific gravity, and fusible at the temperature of 497°. Its hardness is between that of copper and lead; it is scarcely malleable, breaks under the hammer, and cannot be drawn into wire. Bismuth is by no means a common metal, and is usually obtained in a combined state in Cornwall, France, Bohemia, Saxony, and Sweden. As met with in commerce, it is generally mingled with impurities of iron, arsenic, or other metals.

It is used as a *flux*—that is, for communicating fusibility to other metals; *solder*, for example, consisting of 1 bismuth, 5 lead, and 3 tin—an alloy which melts at a lower temperature than lead. It is also employed in the formation of some kinds of pewter, printers' types, and various metallic mixtures. Eight parts of bismuth, 5 of lead, and 3 of tin, constitute the fusible metal, sometimes called Newton's, from its discoverer, which melts at little more than 200°, or under the heat of boiling water, and may be fused over a candle in a piece of stiff paper, without burning the paper. A small addition of mercury aids the fusibility; and such alloys are sometimes used in taking casts of anatomical preparations. Bismuth forms the basis of sympathetic ink; and the powder called *pearl-white*, used in medicine, is obtained from the nitrate of the metal, which, when dropped into water, falls down in that form. The nitrate has also been employed as a mordant for lilac and violet dyes in calico-printing. Some of its forms seem likewise to be employed in the preparation of cosmetics, for a story is told of a lady, who, on visiting one of the watering-places in Germany, emerged from the bath as a 'lady of colour,' the chemical action of the mineral water having turned almost to blackness a cosmetic containing bismuth, which had been previously applied to the face.

Zinc.

Though known as early as the beginning of the sixteenth century, the numerous and important applications of zinc, or *spelter* as it used to be called, are for the most part of very recent date. Its distinguishing characteristics are, bluish-white colour and lustre; specific gravity 7; at common temperatures, tough and intractable; but heated to between 220° and 320° Fahrenheit, it becomes malleable and ductile, so that it may be hammered out, rolled into sheets, and even drawn into wire of such tenacity, that 1-10th of an inch in diameter is capable of sustaining a weight of 26 pounds. Heated beyond that point—say between 400° and 500° Fahrenheit—it again becomes so brittle, that it may be reduced to powder in a mortar. It melts at 700°; and heated beyond this, it takes fire in the open air, and burns with a brilliant bluish flame. The metal is obtained from two ores—namely, *calamine*, a native carbonate; and *blende*, a native sulphuret. These ores occur in two geological positions—namely, either in the carboniferous or in the magnesian limestone, associated with galena, and sometimes with the ores of cadmium.

Zinc ores are found in Britain, especially in Flintshire, Derbyshire, and Cumberland; but the quality of the British metal is inferior to that of Germany, from whence, via Hamburg, about 170,000 cwt. are annually imported, commonly as ballast for ships bringing wool. Of this amount, about one-half is kept for home consumption, and the remainder for exportation, chiefly to India, which, previous to 1820, obtained her supply from China. 'These ores,' says Brande, 'are roasted and mixed with charcoal; the mixture is put into a kind of crucible, closed at top, and perforated at bottom by an iron tube, which passes through the grate of the furnace into water; and the vapour of the zinc distils downwards through the tube, and is condensed in the water. The first portions are impure, containing arsenic, and often cadmium, in which case the vapour burns with what the workmen call a *brown blaze*; when the *blue blaze* appears, the zinc is collected.' The above is the English method of reduction; in Germany and the Netherlands the principle is much the same, but somewhat differently applied.

Zinc being a cheap and light metal, its specific gravity varying from 6·8 to 7·9, and one which, when superficially oxidised, long resists the further action of air and water, it is now employed as a substitute for lead in lining cisterns and baths, covering roofs, forming water-spouts, and the like. It has also been used of late in the manufacture of kitchen and dairy utensils, but not without doubt as to its being deleteriously acted upon by the presence of acids. It is likewise wrought into buttons, and other small wares; and zinc-plates have been a considerable while in use in the transfer of printing, under the title of *zincography*. Its sulphate and oxide are employed in medicine; and with copper it forms, as already described, the well-known alloy, brass. Though the action of water upon zinc be scarcely appreciable, after it has once been coated with the oxide, yet the addition of a little acid (as sulphuric) dissolves and removes this coating, and further oxidation proceeds with rapidity. It is this action which renders zinc so powerful a generator of electricity in the voltaic pile or battery. (See VOLTAIC ELECTRICITY, pp. 265-8.)

Cobalt.

Cobalt, discovered by Brandt more than a century ago, is a reddish-gray brittle metal, somewhat soft, fusible at a temperature a little below that required for the fusion of iron, of 8·5 specific gravity, and possessing magnetic properties. The finest ores are found in Saxony, where it received its name (*kobold*, a devil); a term applied to it by the miners, who considered it unfavourable to the presence of the more important metals. It is never employed in the arts in the metallic or separate state; but the impure oxides of the metal, called *zaffre* and *smalts*, are extensively used as colouring materials.

Thus the oxide of cobalt is an invaluable article in the manufacture of porcelain and pottery, all the blue colours of which are derived from that substance. When fused with glass, it communicates a blue tint to that material, without impairing its transparency; and what is especially valuable, this colour is not impaired by very high temperatures. So great is the colouring power of oxide of cobalt on vitrifiable substances, that 1 grain gives a full blue to 240 of glass! Cobalt blue, or Thenard's blue, is a beautiful pigment, prepared from the phosphate of cobalt, and now largely employed by decorative painters, and sometimes by artists, as a substitute for ultramarine. Smalts, of which we annually import about 146,000 lbs., are prepared principally in Norway and Germany, by melting oxide of cobalt with siliceous earth and potash. *Zaffre*, of which we import more than double that amount, is manufactured chiefly in Saxony and Prussia.

Nickel.

This metal, discovered by Cronstad in 1751, is of a brilliant white colour resembling silver; ductile and malleable, and capable of receiving a high polish; specific gravity about that of cobalt. It is difficult of fusion, but melts at a lower temperature than iron: it undergoes little or no change by exposure to air and moisture. According to Brande, it is found in all meteoric iron; but its principal ore is a copper-coloured mineral found in Westphalia, and called *kupfer-nickel*, nickel being a term of detraction used by the German miners, who expected from the colour of the ore to find that it contained copper. The cobalt ores are the most fruitful sources of this kupfer-nickel, or speisse, which is reduced to the metallic state by roasting, dissolving, evaporating, and other processes. Alloyed with copper, nickel forms argentane, or German silver; and since this compound became an object of commercial importance, the extraction of the metal has been undertaken upon a considerable scale. It is also employed in potteries, and in the manufacture of porcelain. It is, to a certain degree, susceptible of magnetism, and mariners' compasses may be made of it. The alloys of nickel, from their whiteness, hardness, and infusibility, form excellent bases for the manufacture of electro-plate.

Manganese.

This is a very brittle metal, of a dusky white colour, and without either malleability or ductility, having a specific gravity of 7. The substance known in commerce under that name, however, is the peroxide, or the black oxide of the metal. It occurs native in the Hartz Mountains, in Piedmont, in the Mendip Hills in Somerset, and the counties of Devon and Aberdeen. It is found in a variety of forms: most commonly it is of an earthy appearance, and mixed with other ingredients; but sometimes in crystals of a black colour and metallic lustre. This mineral was described by Scheele, in 1774, as a peculiar earth; but in the same year Gahn showed that it was the oxide of a true metallic substance. The metal separately is of no known use, but the peroxide, as a source of oxygen, is largely employed in the decomposition of common salt for the production of chlorine for bleaching. It is also used by potters and glass-makers as a glaze or pigment; and lately it has been used in calico-printing as the source of certain brown colours. Still more recent investigations have shown that a certain proportion of manganese added to steel manufactured from British iron, produces a cast-steel nearly equal to that obtained from Swedish iron. From its cheapness, peroxide of manganese is now the only substance used by the chemist for the production of oxygen gas for experimental purposes. The ore of manganese, known in England by the name of *black wadd*, is remarkable for its spontaneous inflammation with oil. The pure metal can only be kept in closely-stoppered bottles, under naphtha, like potassium; because, when in contact with air, it is rapidly oxidised, and falls into a dark brown powder.

Arsenic.

This metal, discovered by Brandt in 1733, is exceedingly brittle, of a strong metallic lustre and white colour, running into steel-gray. Its specific gravity is 5·9; it volatilises, emitting a strong odour of garlic before it fuses, at a temperature of 365°, and is readily inflammable. The pure metal, however, being very soft, is of little value, and is not used in the arts. It is the softest of all the metallic bodies, and so brittle that it may be easily reduced to a very fine powder by trituration in a mortar. The arsenic of commerce is the white oxide of the metal, or, more accurately, *arsenious acid*—a compound which is obtained chiefly in Bohemia and Saxony, in roasting the cobalt ores for making zaffre, and also by sublimation from arsenical pyrites. In this state it is generally met with in cakes, brittle, white, faintly sweetish in taste, and more or less translucent; for medicinal purposes, these cakes undergo sublimation, in order to get rid of sulphur and other impurities. In the shops it is usually sold in the form of a white smooth powder, not unfrequently adulterated with chalk or gypsum—an adulteration, however, which can be easily detected by burning a little, when the arsenic volatilises, and the additions remain.

Arsenious acid, though one of the most virulent poisons, is used in medicine, forming a notable ingredient, for example, in what are called ague drops. It is also employed as an ingredient in *Scheele's green* and other dyes, in the manufacture of flint-glass, and by candlemakers, to impart to their candles a white and waxy appearance. With sulphur, arsenic forms two compounds, known in commerce by the names of *realgar* and *orpiment*; the former a red sulphuret found in Bohemia and Saxony, and used as a pigment, as well as in pyrotechnical compositions; and the latter a yellow sulphuret, found native in China, South America, &c. and produced artificially in Saxony, and employed in dyeing and calico-printing. The finer native varieties are reserved for artists.

With respect to the poisonous qualities of arsenic: 'When it has been taken in large doses,' says Mr Brande, 'it produces violent spasmodic pains of the stomach and bowels, attended by a sense of heat and constriction in the mouth and throat, an increased flow of saliva, tightness about the head, itching of the face and neck, and nausea. These symptoms are succeeded by vomiting and purging, and excruciating pains; the pulse, at first full, hard, and frequent, sinks, and becomes irregularly feeble; and clamminess of the skin, cold sweats, purple spots, and convulsions, precede death. Should the patient escape this catastrophe, it often happens that hectic fever, paralysis, and mental and bodily debility, attend him for the remainder of his days. It is often said that the bodies of persons poisoned by arsenic are very prone to putrefaction; but this does not appear to be always the case. After death, the stomach and bowels are usually found inflamed, but often slightly so; and it appears, from Sir Benjamin Brodie's observations, that this poison kills by some peculiar action upon the heart and nervous system. The treatment of persons thus poisoned consists in promoting the vomiting by an emetic, composed of a solution of twenty grains of sulphate of zinc in two ounces of water, aided by copious draughts of warm barley-water or gruel; but the most effective means of getting rid of the arsenic is by the use of the stomach-pump, which, when immediately resorted to, has often saved the patient. The only ready means of ascertaining the presence of white arsenic is by heating the suspected substance upon a red-hot coal, or in the flame of a candle, when it will emit the peculiar arsenical odour resembling that of garlic; but the treatment of persons poisoned by arsenic, and its detection in doubtful cases, must be left to the medical man and the chemist. It is impossible too strongly to represent the evil which results from the unfettered sale of arsenic, and from the unwarrantable use of it as a poison for rats, and as a veterinary remedy; for it is thus that it finds its way into culinary vessels, gets accidentally mixed with articles of food, and that bottles which have contained it are used for beer, wine, and other beverages. Its sale should be rigidly prohibited by all save regularly qualified druggists.'

Platinum.

Platinum, or platina, was unknown in Europe till about the middle of the last century, when it began to be imported in small quantities from South America. It is of a whitish silvery colour; hence its name, from the Spanish word *plata*, silver. It is the heaviest, the most difficult of fusion, the most ductile, and the most flexible of the known metals, having a specific gravity of 21·0, and capable of being hammered into leaves, or drawn into wires, of extreme tenuity. Its hardness is intermediate between that of copper and iron; and though very infusible, it is malleable, and capable of being welded at a white heat, either one piece to another, or to a bit of iron or steel. It is not in the least affected by the action of air or water, and is not attacked by any of the pure acids; but is dissolved by chlorine and nitro-muriatic acid. In scarcity, beauty, ductility, and indestructibility, it is thus hardly inferior to gold. When a perfectly clean surface of platinum is presented to a mixture of oxygen and hydrogen gas, it has the extraordinary quality of causing them to combine, so as to form water, and often with such rapidity as to render the metal red hot.

As already stated, platinum was discovered about 1741; but it attracted little notice until the mode of purifying it, and rendering it malleable, was discovered by Dr Wollaston. It is found in the metallic state in Brazil and Peru; at Antioquia in South America; in Estremadura in Spain; and latterly, in considerable quantities, in the Uralian Mountains. Its appearance, in the rough state in which it is imported, is that of small grains or scales, of a metallic lustre, darker than silver, and extremely heavy. In this state it is combined with palladium, rhodium, titanium, iron, gold, or other metals. The particles are seldom larger than a pea, but pieces have been found as large as a hazel-nut; and in 1831, a mass of native metal was discovered in Demidoff's gold mines in Russia, weighing upwards of 20 lbs.!

The perfection with which vessels of platinum resist the action of heat and air, of most of the acids, and of sulphur and mercury, renders them peculiarly valuable in many chemical applications; so that, notwithstanding the high value of the metal which is between four and five times its weight of silver, it is now much employed for crucibles, retorts for the distillation of sulphuric acid, mirrors for reflecting telescopes, by gunsmiths, and others. Its property of being welded, either one piece with another, or with iron and steel, admits of many useful applications in the arts. From its scarcity and indestructibility, it has been proposed to use it for coinage; and we believe coins of the respective values of 3, 6, and 20 silver roubles are now current in the Russian empire.

Palladium.

This rare substance was discovered in 1803 by Dr Wollaston, when experimenting on the ores of platinum, which it greatly resembles in colour and lustre. A native alloy of gold with palladium is found in Brazil, and imported into England. The pure metal is ductile and malleable, has a specific gravity of 11·5, and its fusibility is intermediate between that of gold and iron. It is oxidised and dissolved by nitric acid; its properties, however, are yet imperfectly known, nor is it, so far as we know, applied to any economical purpose, unless sometimes for the graduated scales of astronomical instruments. The Wollaston medal of the Geological Society of London is very appropriately made of palladium.

Rhodium.

Rhodium, so called from the Greek word *rhodon*, a rose, on account of the red colour of some of its salts, was discovered in 1803 by Dr Wollaston, associated with palladium in the ore of platinum. It is of a whitish colour, difficult of fusion, and extremely hard and durable, with a specific gravity somewhat less than that of palladium. It forms valuable alloys with the other metals, particularly steel, and would be extensively employed in the arts, could it be obtained in abundance. As an alloy with steel, it has been used for the points of metallic pens.

Chromium.

Chromium—from the Greek word *chroma*, colour—discovered by Vauquelin in 1797, is a metal resembling iron in colour, brittle, and difficult of fusion. It is rarely to be found in its metallic state; but several of its compounds, as chromate of iron, and chromate of lead, are well known in commerce. The former, a compound of oxide of chrome with protoxide of iron, is found in Unst in Shetland, in France, and near Baltimore in America. It appears massive, or in crystals of a dark colour and imperfect metallic lustre. It is employed in the manufacture of chromate of potash, a yellow salt, largely manufactured for the use of calico-printers. Chromate of lead is found native in the gold mines of Beresof in Siberia, in the Ural Mountains, and in Brazil, and is easily prepared, by mixing chromate of potash with a soluble salt of lead. It occurs massive and crystallised, of a deep orange-red colour; but when reduced to powder, it becomes orange-yellow. It forms an excellent pigment, and is used both in oil and water colours, in calico-printing, and in dyeing. The other compounds chiefly in use are the *oxide of chromium*, employed to give a green colour to glass and to porcelain; and *chromic acid*, which, from its property of destroying most vegetable and animal colouring matters, is advantageously employed in calico-printing. It is this acid which gives colour to the ruby; and the green of the emerald is owing to the oxide of chroma.

Cadmium.

This metal was discovered by Professor Stromeyer of Gottingen about the beginning of 1818. It occurs chiefly in Silesia, combined to the extent of between 2 and 11 per cent. with several ores of zinc, and is reduced to the metallic state by a somewhat complicated process of solutions and precipitations. The pure metal has the colour and lustre of tin, and is susceptible of a fine polish. It is soft, easily bent, filed, and cut, and soils like lead any surface rubbed with it. It is harder and more tenacious than tin, and emits a creaking sound, when heated, like that metal. It is very ductile, and may be drawn out into fine wire, and hammered into thin leaves without cracking at the edges. Its specific gravity is somewhat less than 9; it is very fusible, melting at a point much below redness. Its scarcity prevents its employment in the arts; but its oxide and sulphuret, which respectively produce fine brown and orange-yellow colours, are said to be used as pigments. The sulphate of cadmium has been applied to the eyes for removing specks of the cornea.

Vanadium.

Vanadium, from *Vanadis*, a Scandinavian deity, was discovered so recently as 1830 by Professor Sefström of Fahlun, in iron prepared from the iron of Jubberg in Sweden. It has also been detected in a lead ore from Wanlockhead in Scotland, and in a similar mineral from Zimapan in Mexico. 'Vanadium,' we quote Dr Ure, 'is white; and when its surface is polished, it resembles silver or molybdenum more than any other metal. It combines with oxygen into two oxides and an acid. The vanadate of ammonia, mixed with an infusion of nutgalls, forms a black liquid, which is the best writing ink hitherto known. The quantity of the salt requisite is so small, as to be of no importance when the vanadium comes to be more extensively extracted. The writing is perfectly black. The acids colour it blue, but do not remove it, as they do tannate of iron: the alkali, diluted so far as not to injure the paper, does not dissolve it; and chlorine, which destroys the black colour, does not, however, make the traces illegible, even when they are subsequently washed with a stream of water. It is perfectly fluent, and being a chemical solution, stands in want of no viscid gum to suspend the colour like common ink. The influence of time upon it remains to be tried.'

Osmium—Iridium—Tungsten, &c.

On account of their rarity, the remaining metals—osmium, iridium, tungsten, molybdenum, &c.—have not as yet been applied to any economical purpose. Even were they less rare, so far as their properties have been determined, they would not afford any advantage which may not be obtained by the use of the ordinary metals. As elementary substances, the reader will find details of their history, nature, and properties in the article 'Chemistry.'

The Metalloids.

This term is given to a class of substances which are undoubtedly metallic, but which cannot be kept in that state unless carefully excluded from the action of air and water. They are the rare and scanty products of the laboratory, and are of themselves of little practical value; but united with oxygen, they form the *alkalies*, *alkaline earths*, and *earths* so important in the operations both of nature and of human economy. They are the triumphs of modern chemistry, which has already determined the existence of fourteen, and hinted the probability of others. Those known are—potassium, sodium, lithium, barium, strontium, calcium, magnesium, aluminium, glucinium, yttrium, erbium, terbium, zirconium, and thorium. An account of the nature and properties of these substances has been given under 'Chemistry;' and the principal earths and alkalies of which they form the bases have been described in the sheet devoted to 'Mining and Minerals.'

THE STEAM-ENGINE.

The apparatus which, after numerous improvements by Watt and others, has assumed its complete form of a *Steam-Engine*, and has been universally adopted as a convenient and economical means of impelling machinery, is dependent on the properties of water and heat for its source of power. It seems necessary, therefore, that a preliminary account of these properties should be given, embracing some notice of the different kinds of fuel which are employed to convert the water into steam. These being understood, the reader will be better prepared to follow a description of the various parts which enter into the construction of the engine, taken in the widest sense of the word, and the mode in which these are arranged so as to obtain the maximum of power, in their application to machinery, navigation, locomotion, and the like.

PROPERTIES OF WATER—STEAM.

Water, which forms the grand agent in the steam-engine, is not a simple substance, but consists of two elements (see Chemistry), the natural condition of which, when free under the ordinary circumstances of our globe, is uniformly gaseous. These two distinct elements are oxygen and hydrogen; which combining together in the proportion of one by bulk of the former, with two by bulk of the latter, constitute the compound *water*. But water, as it is found in nature, though it is essentially composed of the gases now mentioned, does not consist solely of these, inasmuch as whether it be taken from springs, from lakes, from the sea, from rivers, from melted snow or ice, or from rain, or from any other source, it contains other substances held in solution, and which affect its character—rendering it, indeed, often totally unfit for those purposes to which it is usually applied. When freed from these substances—which may be accomplished by careful distillation—the water is considered by chemists as *pure*.

The substances which are dissolved by the water, and which render it impure, are either solid—such as lime, magnesia, and iron; or gaseous—such as the elements of the air, oxygen and nitrogen, and carbonic acid. The proportion of solid matter varies considerably. In the waters of the sea which surrounds our shores, the amount of solid matter is estimated at about 3½ per cent.; while in river water, which has been allowed to settle or precipitate its mechanical impurities, the proportion is often less than one or even one-half per cent. The quantity of gaseous matter varies, but not so much as that of the solid matter. In rain water, there is usually noticed 2½ per cent. of atmospheric air, but in which the usual proportion between the oxygen and nitrogen is not preserved, as there is 32 of oxygen out of the 100, the remainder being nitrogen, whereas 21 is the proportion of oxygen in atmospheric air. Carbonic acid gas also is found in water; and notably so in that of certain mineral springs.

On boiling the water, these gaseous bodies are set at liberty, and the solid substances, such as the compounds of lime, are deposited, and form thick incrustations on the boiler. It is only the pure matter of oxygen and hydrogen—the actual water, as it may be termed—which is required in the working of the steam-engine; the other substances, whether aëriform or solid, being not only useless, but even injurious. It will be seen that there are particular contrivances devised in the structure of the steam-engine to remove these.

Water is a fluid at ordinary temperatures, but may become *solid* on the one hand, or *aëriform* on the other, by changes in the amount of caloric (heat) with which it is supplied. These two remarkable changes in the condition of water occur at specific temperatures: it becomes solid at 32° Fahrenheit, and passes off in the state of vapour or steam when the temperature is raised to 212°. On the fluid being cooled down to 32°, it becomes ice—this temperature being named the *freezing point* of water. When the temperature is increased so that the thermometer indicates 212°, or the *boiling point*, the water becomes steam or vapour, assuming that condition in which its elastic force is applied to act as a moving power.

On the water passing off in this new form or condition, two very remarkable phenomena take place—namely, the fluid expands to a very great extent, the vapour occupying nearly 1700 times the space which the fluid occupied from which it was generated; and at the same moment an immense quantity of caloric or heat enters into the water while becoming steam, and disappears—which heat, from the circumstance that it cannot be discovered by the thermometer, is usually termed *latent*, in contradistinction to that which affects the thermometer, and which is accordingly designated *sensible*.

When the water has assumed the state of vapour, it is invisible, being as perfectly transparent as atmospheric air; and in this form it becomes obedient to those laws which affect gaseous or aëriform bodies, supposing always that the usual increased temperature is maintained (212° Fahrenheit) to preserve it in this new state; for on withdrawing the caloric, it then returns or *condenses* to its liquid inelastic condition. This elastic state of the vapour may be suddenly destroyed by bringing it in contact with a large quantity of cold water—a process essentially a part of the greater number of steam-engines. In this state of vapour the temperature is 212°, or the same as that of the water from which it is generated. This may be easily determined by placing a thermometer in boiling water, and then in the steam which arises from it.

Under the usual conditions in which water is made to boil, as in an open vessel on the fire, the temperature indicated by the thermometer is commonly about 212°, the water acquiring at that temperature sufficient elastic force to overcome the weight of the atmosphere. But it is to be observed that the pressure of the air must tend to retard the water expanding into vapour: it will follow, therefore, that if we reduce the pressure on the surface of the water, the escape into the state of vapour will take place at a lower temperature, as was first observed by Dr Cullen, and subsequently more minutely detailed by the late Professor Robison. The latter has, indeed, established the general proposition, that vapours are produced from fluids *in vacuo* (where all atmospheric pressure is removed) at 140° of Fahrenheit below the temperature at which these fluids naturally pass into vapour, under the usual pressure of the air. Water, for instance, which usually boils at 212°, in this case would boil at 72°—a temperature of the atmosphere frequently observed in the summer months of this country; and ether, which boils at 96°, a temperature nearly corresponding with that of the human body (being lower only by 2°), *in vacuo* would boil at 44° below zero, or at a temperature lower than that which would suffice to render mercury solid.

The thin aërial fluid called the *atmosphere*, or commonly the air, is a distinct material substance surrounding the globe, and possessing considerable weight. That the air is actually a material substance, may be easily shown by connecting a thin glass flask, provided with a good stopcock, with the exhausting tube of an air-pump. The air can in this manner be withdrawn, and the flask will be found to weigh less than before. One hundred cubic inches of air, when perfectly dry, weigh, according to the very careful investigations of

Dr Prout, 31·0117 grains; the temperature of the air being 60° Fahrenheit, and the pressure of the air, as indicated by the barometer, being equal to 30 inches of mercury. If, instead of air (the oxygen and nitrogen which constitute the atmosphere), an atmosphere of mercury were to envelop the globe, which would have the same weight as the air, it would be about 30 inches above the level of the sea; and if, in like manner, instead of the air, the fluid water were substituted, it would be nearly 34 feet above the level of the sea. Hence we say that the pressure of the air is equal to a column of mercury 30 inches in height, or to a column of water 34 feet high; or, in other words, whatever extent of surface we have, the pressure of the atmosphere is equal to the pressure or weight of 30 inches of mercury, or of 34 feet of water, over a similar surface.

The amount of this pressure, estimated by the extent of surface, is as 14·67 lbs. on the square inch, or nearly 15 lbs. In other terms, the weight of air pressing on a square inch is 15 lbs., and the weight of the column of mercury is 15 lbs., and the weight of the column of water is also 15 lbs. That is, the column of air, whose basis is exactly a square inch, extending from the surface of the globe to the highest or extreme range of the atmosphere (nearly forty-five miles), is equivalent to the column of mercury which is only thirty inches in height, or to a weight of 14·67 lbs. It is this weight, then, which the water has to overcome before it can pass into vapour. The greatest pressure of the atmosphere will be at the surface of the earth; and as we ascend above the sea level, this pressure will gradually decrease, less air being above us, and in a corresponding ratio the atmospheric volume will become thinner or more rare.

By attending to these circumstances, we perceive that when the pressure is lessened, water boils at a lower temperature than 212°; and therefore that we have not merely to consider the temperature to which the water is exposed, but also the amount of the weight of the atmosphere at the time, or the height of the mercury in the barometer tube. For example, at Quito, which is 10,000 feet above the level of the sea, water boils at 194°; while at Geneva, ebullition begins at 209°, that city being 1200 feet above the sea.

The law, then, as regards the pressure of the atmosphere is, that the boiling temperature is uniformly the same when the barometer is at the same height. If we employ the thermometer of Fahrenheit, it will be found that the boiling point is exactly 212° if the barometer indicate 30 inches; but if the boiling point rise to 213°, then the barometer also will ascend to about 30½; and conversely, if it be 211°, the barometer conversely also will fall to about 29½. It is obvious, then, from these facts, that the boiling point is an index of the height of the barometer; and, on the other hand, that the height of the barometer will give the point of ebullition according to the thermometer of Fahrenheit, or any other which may be used. (See Meteorology and Pneumatics).

Experimentally, the effect of a diminution of pressure on the temperature at which water boils may be shown by the common air-pump. If a jar of water, at the temperature of 178°, be placed under the large bell receiver, and the air be withdrawn so as to reduce the pressure very speedily, the water will be found to boil at the reduced temperature. The pressure at which this takes place, as measured by the barometer, is equal to half the ordinary weight of the air, or 7½ lbs. on the square inch. If the barometer be retained in the jar, it will be found to indicate 15 inches when the ebullition takes place. Should the barometer fall lower before the boiling commences, then it will also be noticed that the thermometer points to a lower temperature, corresponding always in an exact ratio.

Steam, or the vapour of water, when produced at the usual pressure of the atmosphere, is commonly denominated *low-pressure*, in opposition to that which is formed at a higher pressure than that of the air, and accordingly named *high-pressure* steam. In common language, however, the term low-pressure is applied to the steam which has even a force of several pounds on the square inch, and therefore formed at a temperature higher than 212°. The steam is in this case condensed in working the engine, and receives this general name because the pressure does not range higher than a few pounds.

In order to produce steam of greater pressure or force than that obtained by boiling water in the open air, means must be adopted to confine the vapour as it is generated from the water. If we have a stout copper vessel, containing a considerable quantity of water, and provided with stopcocks which can be properly closed, and then expose it to heat, a quantity of vapour will be disengaged; but as it cannot fly off, all the stopcocks being closed, it must necessarily, in proportion to its density, compress the fluid below, and proportionately prevent any further escape of vapour. But the heat being continued and increased, vapour will then rise, which in like manner will increase the degree of compression on the water, for the density of the first disengaged vapour will now be increased by this new accession of vapour, and the further formation of vapour will be checked until the heat is again so far increased as to be able to overcome resistance offered by the pressure of the vapours. In this manner steam, of any degree of elasticity, may be generated from water merely by having a firm and stout vessel capable of bearing great pressure, in which the vapour is to be formed.

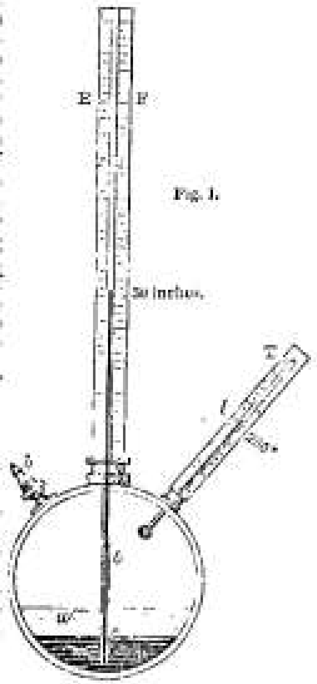


Fig. 1.

The generation of steam in this manner, and the relation between the temperature at which it is produced and the pressure upon it, and its consequent force or elasticity, may be illustrated by the apparatus represented in the adjoining cut, fig. 1. A copper vessel is procured, sufficiently strong to bear a considerable heat and a great degree of pressure. It is provided with three apertures, as in the figure. The aperture at the summit has a barometer tube (E F) fixed in it, open at both ends, but at the same time perfectly air-tight, so as to prevent all communication between the interior of the vessel and the external atmosphere. The upper extremity of the tube is immediately in contact with the atmosphere, while the lower is very near the bottom of the vessel. In the lower part of the vessel there is a quantity of mercury (*m*), into which the under extremity of the barometer tube dips. At one side of the vessel an aperture receives a thermometer (T), which is securely fixed, so as to be perfectly air-tight, and introduced obliquely, so that the bulb rests a little above the middle height of the vessel. The other or third aperture (*b*) is provided with a stopcock, which admits of being opened or closed at pleasure. The vessel is now to be supplied with water (*w*), filling it to the middle, and heat is to be applied by a furnace below. It is apparent that if the heat be applied and continued while the stopcock (*b*) is open, the air will fill the upper portion of the boiler, and the ordinary pressure of that body will be exerted on the surface of the water. The water will therefore, as already noticed, boil when the temperature 212° of Fahrenheit is indicated by the thermometer. But if we now shut the stopcock, so that there is no longer escape for the steam, the temperature of the water gradually rises, because the heat is continued, and the steam accumulating in the upper part of the boiler, exerts, first on the water, and immediately on the mercury beneath, a force or pressure equal to its increased elasticity. The mercury is, however, in an open tube, or rather is placed between the extremity of an open tube and the water and its vapour. Accordingly, if the force of this vapour is greater than what is requisite to overcome the pressure of the atmosphere, the mercury will be forced into the tube, and in proportion to the increasing force which the steam possesses, will the mercurial liquid ascend. In proportion, then, as the heat continues to be applied, the mercury will be seen to rise in the barometer tube, indicating the force which the steam exerts on the surface of the water in the boiler, while the actual amount of the heat at which the water is passing off into vapour will be shown by the thermometer.

But, as already stated, if the height at which the mercury stands corresponds in a distinct ratio with the temperature, it will be sufficient to ascertain either the one or the other, so as to know both. Suppose the column of mercury has risen nearly 15 inches, then we know that the pressure which the steam has is equal to half an atmosphere, as indicated by the mercurial tube, over and above the actual pressure of the atmosphere, so that the whole pressure exactly amounts to an atmosphere and a half. But the thermometer will also have risen, and now will point out a temperature of 230° Fahrenheit—water at that temperature, when converted into vapour, having a force equal to an atmosphere and a half, according to the usual mode of expression. If the heat be still continued, the further ascent both of the mercury in the barometer tube and of the mercury in the thermometer will be observed; and when the former stands at 30 inches, the latter will indicate exactly 250°, as may be seen in the diagram. But as 30 inches is equal to one atmosphere, and as the tube was open admitting the pressure of the air, the vapour of water was able to overcome the resistance of two atmospheres; or water under a pressure of two atmospheres boils at a temperature of 250° Fahrenheit, and the vapour possesses that strength in elastic force.

Suppose the thermometer (T) now stands at 250° (*l*), and the stopcock (*b*) be suddenly turned, an immense volume of steam, formed under the high pressure, suddenly escapes; the mercury in the tube (*t*) falls rapidly, and the thermometer also equally descends, until it attains the temperature of 212°. The mercury will fall down to the level it had immediately under the water, and steam will now be produced as under ordinary circumstances. The moment, however, the stopcock is shut (the heat still being kept steadily applied), the thermometer will begin to rise, and the column of mercury begin to ascend.

The application of the heat may be continued, in a good stout vessel, up to a greater elevation than what is now described, causing the production of steam of a still higher pressure, and, of consequence, greater elastic force, the barometer and thermometer mutually reflecting each other. It is in this manner that the high-pressure steam, as it is ordinarily called, is generated; but in proportion to the temperature at which it is produced, so is the danger to be apprehended from the bursting of the boiler, unless proper precautions are adopted.

The accompanying table gives the correspondence observed between the temperature at which the water boils, the density of the steam generated, and the force or elasticity it possesses in inches of mercury and atmospheres:—

Temperature Fahrenheit.	Sp. gr., air at 60° being 1.	Pressure in inches of a column of mercury.	Pressure in pounds on the square inch.
212°	0·404	30	14·7
222	0·453	35·00	17·15
233·80	0·557	45·00	22·05
242·50	0·61	52·50	25·785
250·20	0·915	60·00	29·4
274·70	1·33	90·00	44·1
320·60	2·5	180·00	88·2
350·00	3·61	270·00	132·3
450·00	10·75	900·00	441·

By this table we observe that the elastic force of the vapour produced from water rises in a rapid ratio above the ordinary temperature of boiling. If, for example, we take the temperature of water at 350°, the specific gravity of the vapour produced, air at 60° being 1, will be 3·6; and it would have a force equal to maintain a column of mercury 270 inches high, or 22 feet 6 inches, if no atmosphere pressed on the mercury; and 240 inches of mercury, if the atmosphere pressed on the fluid in the tube; the total sum of pressure on the square inch being then equal to 132·3 lbs., or corresponding exactly with the weight of nine atmospheres.

Tables have also been drawn up from experiments, illustrating the force of vapour from water at temperatures below the ordinary boiling point, thus—

Temperature.	Force of vapour in inches of mercury.
32°	·200
50	·375
80	1·00
100	1·86
150	7·42
180	15·15
200	23·64
212	30°

From these tables, it is apparent that there is an invariable correspondence between the force of the vapour of steam and the temperature at which it is generated; hence the one may be given as the rule of the other. For instance, if it is required to know the force with which the steam is working in any machine, the thermometer, which is preserved in a case air-tight, and introduced into the boiler where the steam is generated, will indicate the temperature of the water, or of the steam (for they are always the same; that is, at whatever temperature water boils to afford steam, the steam so produced is of the same temperature). On ascertaining, then, the temperature by a reference to the table, we find the corresponding force of the elastic vapour (the steam). An example will be sufficient to show this most clearly:—When the thermometer stands at 212°, and steam escapes from the water, we know it is then able to support a column of mercury 30 inches high; and a column of mercury 30 inches high is equivalent to the pressure of 1 atmosphere. The steam, then, is of the kind called low-pressure. If, however, the temperature indicated be 250°, then opposite in the table we find 29·4 lbs. pressure on the square inch, and 60 inches of mercury; but as 29·4 lbs. is double the weight of the atmosphere on the square inch, and also as 60 inches of mercury is double the height of the column which the air will support, the steam must then be acting with a force equal to 2 atmospheres.

The force with which steam acts increases in a greater ratio than the temperature at which it is generated. If, for example, the pressure be equivalent to 1 atmosphere at 212°, at 250° it will be equal to 2 atmospheres; that is, in the addition of heat equal to 38° of Fahrenheit above 212°; and at 293·7, which is little more than the difference between 212° and 250°, which gives only an increase of 1 atmosphere, the pressure is equal in all to 4 atmospheres, or double that above 250°; and so on, as will be seen in the former of the preceding tables.

Mr Tredgold gives the following rule to ascertain the elastic force of the vapour of water, in inches of mercury, at any given temperature of Fahrenheit's thermometer:—To the given temperature 100 is to be added, and the sum divided by 177. The quotient is to be raised to the sixth power, which is the force required. If, for example, the temperature be 307°; to this 100 added gives 407. This, divided by 177, gives 2·3, of which the sixth power is nearly 148, the elasticity of the vapour, in inches of mercury, almost equivalent to 5 atmospheres. This rule, it is to be observed, only refers to the vapour produced from pure water; when it is mixed with a considerable proportion of saline matter, as in the case of sea-water, a different divisor must be adopted, which is to be regulated by the temperature at which the water boils, for the point of boiling varies with the amount of salt in the water. Water saturated with common salt contains about $\frac{12}{32}$ portions of that matter, and its boiling point is about 226°. The divisor to be used in this case is 185 instead of 177, and the elastic force of the steam will then be found not to exceed 113 inches.

The existence of any body in the aëriform state is only a contingent condition of matter; some, called *gases*, have naturally no tendency to pass into the fluid or solid form; others, however, called *vapours*, are maintained in the gaseous state by the influence of heat—and on withdrawing it, speedily resume their ordinary condition. Steam belongs to this class of bodies, and on being cooled, immediately condenses or returns to the fluid state. The white cloud produced on steam escaping from the safety-valves of boilers, or from high-pressure engines, is *not* steam, in the strict acceptation of the word, for steam is invisible, but the water formed by the condensation of the steam in consequence of the cold air with which it now mixes. The extent to which the water expands is variously estimated; but it seems to be very nearly that 1 cubic inch of water becomes 1 cubic foot of steam, or the space occupied by 1 cubic inch of water, when converted into steam, is nearly 1700 times greater—correctly as 1 to 1696.

In the state of vapour, steam may be in two distinct and very different conditions: it may be immediately in contact with the water whence it is formed, or it may be in a vessel distinct and separate from all connection with the water. In either condition it is a distinct aëriform body, and possesses all these properties peculiar to that class of bodies, it being always understood that the heat is maintained sufficiently high to preserve it in this particular condition—namely, of vapour. Aëriform bodies—and consequently water, when in the aëriform condition—have a property quite peculiar, denominated their elasticity. This essentially consists in a disposition of all the particles, whereby they have a tendency to recede outwards, or fly from the centre, so that they spread themselves out into a more extended space. If, for instance, we have a bladder partially filled with air under the receiver of an air-pump, and then exhaust the air, it will be found, that as the exhaustion proceeds, the bladder expands, and ultimately will be burst, by the expansive force of the air within. Aëriform bodies have a tendency, accordingly, to expand indefinitely, were there not causes which counteract this disposition.

The first of these is the pressure to which they are subject, and the second is the attraction of gravitation, by which all particles of matter are drawn down towards a centre, and which is incessant in its action. A similar power is also exercised by the application of cold, which diminishes the repulsive tendency. As there is a constant force counteracting this disposition to expand, the elasticity of a gas or vapour is in the exact ratio of this counteracting force. Gases, as they are capable of expansion, so they may also be condensed or diminished in bulk. But in this condensed state, as they then occupy a less space, there necessarily must be an increase in the density or specific gravity. Thus, if the space occupied by any gaseous body be equal to 100 cubic inches, and these 100 cubic inches weigh 31 grains, on compressing these to one-half, so that they only occupy 50 cubic inches, each cubic inch will obviously contain double the amount of matter it previously had, and therefore, whatever was previously the weight of the cubic inch, it will now be double. But with this increase of density there is an increase of elasticity; for as the elasticity of a gas is directly proportionate to the force which compresses it, and as this force has diminished the bulk by one-half, hence, as the density is doubled, the elasticity is increased in the same ratio. The elastic force of a gas, therefore, is directly in proportion to its density, and in the inverse proportion of its bulk.

Incidental to the formation of steam, it has been observed that there is a great quantity of heat which disappears on the vapour being formed, and which cannot be discovered by the thermometer, but is again given out when the vapour returns to the state of water. The most singular and most important practical fact connected with this property is, that whatever be the temperature at which the water is boiled to form steam, the sum of that temperature, and the number of degrees of latent caloric, is always the same. Suppose the water boils at 212°, and the quantity of latent caloric absorbed be equal to 1000°, the sum of these will be exactly 1212°. But if the water boil at 112° (under diminished pressure), the latent caloric will then be 1100°, to make up the aggregate sum 1212°; and in like manner, if, under increased pressure, the water be made to boil at 312°, the quantity of latent caloric will only be 900°. Hence steam formed at a low pressure, or at the ordinary temperature of the air, does not require a different amount of fuel that it may undergo this change, than the same vapour generated at 100° higher, or any other temperature; for the sum of the latent and sensible heat is always the same—1212°, as measured by the thermometer of Fahrenheit. To convert, accordingly, a given weight of water into steam, the same amount of fuel is required at all temperatures.

The condensation of steam by water may be easily shown by taking a flask with a small quantity of water in it, and, exposing it to a temperature sufficient to produce ebullition, steam will rapidly be formed, and all the atmospheric air expelled. A cork (previously ascertained to fit accurately) is then introduced into the neck of the flask, which is at the same time withdrawn from the fire. The flask, now full of the vapour of water, is introduced into a vessel of cold water with the neck inverted; on the cork being withdrawn, the cold water immediately absorbs the heat of the expanded vapour, and is forced in by the pressure of the atmosphere, so as completely to fill the vessel, if it contained nothing but steam. The application of this additional property of steam, and the mode of bringing it into play, will be specially detailed under the description of the steam-engine. It is owing to this important property—namely, the great degree to which it can be condensed by cold water—that a vacuum is produced, and the steam-engine rendered complete in almost all its parts.

The chief properties of water, then, as converted into steam or vapour, may be briefly enumerated:—Expansion—the matter in this new condition of vapour occupying about 1700 times the space it occupied as water; the disappearance of a great amount of caloric, which bears always a definite proportion to the temperature at which the water passes into steam; the exertion or display of a definite elastic power, bearing a fixed ratio to the temperature at which it is generated; the natural return of steam to the state of water, either on gradually withdrawing the heat, or on suddenly bringing it in contact with cold water.

Fuel—Heat.

Accessory to the consideration of water and its various properties, physical as well as chemical, is the history of the different matters which are employed to give out heat, and to convert it into steam. The consumpt of coal or fuel, of whatever kind it may be, constitutes one of the most serious obstacles in the extension of the steam-engine, and especially in its application to long voyages. The great object is to produce the greatest amount of heat at the least possible expense of fuel. Charcoal, or the substance carbon, is, properly speaking, the principal ingredient in the combustible matters which are usually taken to produce heat. It constitutes the main bulk of coal, of coke, of anthracite, which is a species of natural coke, and of wood in all its varieties. (See No. 29.)

During the process of combustion, the quantity of heat which is disengaged can be precisely determined; as, for instance, by ascertaining how much of a given amount of combustible matter is required to raise the temperature of water from 32° to the boiling point (212°). In a series of experiments made on this subject, Despretz obtained the following results, which are here arranged in a tabular form:—

		Pounds of water.
1 Pound of charcoal	heats from 32° to 212°	78
... ... charcoal from baked wood	... ...	75
... ... baked wood	... ...	36
... ... wood containing 20 per cent. water	... ...	27
... ... bituminous coal	... ...	60
... ... turf	... ...	25 to 30
... ... alcohol	... ...	67·5
... ... olive oil, wax	... ...	90 to 95
... ... ether	... ...	80
... ... hydrogen	... ...	236·4

In this process of combustion, the chemical action consists in the union of the oxygen supplied from the air with the inflammable matter, whether carbon alone, hydrogen alone, or both together. The amount of heat depends exclusively on the quantity of the oxygen consumed, as the important fact has been determined, that the heat evolved was always in a direct ratio with the oxygen lost. Thus in a series of experiments, it was discovered that

		Pounds of water.
1 Pound of oxygen with hydrogen	raises from 32° to 212°	29½
... ... charcoal	... ...	29
... ... alcohol	... ...	28
... ... ether	... ...	28½

The importance of this subject is sufficiently obvious, when we consider the immense number of steam-engines incessantly at work, and the enormous annual consumpt of coal. In long voyages in steam-vessels, the greater part of the cargo is necessarily composed of coal instead of merchandise, and thereby one of the chief objects of steaming is virtually defeated.

It is here to be carefully noted, that to raise water to the boiling point, and to convert water into steam, do not imply the same thing, though they both imply the application of heat steadily to the fluid matter. This arises from the great quantity of latent caloric which the steam requires, and which amounts by calculation, as well as by careful experiment, nearly to 1000° of Fahrenheit; that is to say, if it takes a given time, with an equal and uniform quantity of heat, to raise water from 32° to 212° (180°), it will require that time multiplied by 5½ to convert the water into steam. But in one period (namely, the time required to raise the water to the boiling point), as much heat as raised the water 180° was added, and 180° multiplied by 5½ gives exactly 1000°. It is to supply this great quantity of latent caloric that so immense an amount of coal is consumed by the steam-engine. For if 1 lb. of the best coal raises 33·3 lbs. of water from 32° to 212°, then 1 lb. will only suffice to convert 5·5 lbs. of water into steam. Or while 1 lb. of coal raises 33·3 lbs. of water to the boiling point, it will require about 5½ lbs. more of the same kind of fuel to convert all that water into steam.

To convert the coal into those chemical compounds, during which the evolution of heat takes place, a very great proportion of air is required. For the atmospheric air contains four-fifths of its bulk of matter, which does not in any manner assist combustion. Two and a half pounds of oxygen, or nearly 30 cubic feet, are requisite for the combustion of 1 lb. of coal; 150 cubic feet, therefore, of atmospheric air will supply this. It has, however, been found that one-third of the air which enters the furnace passes through it without directly contributing to the process of combustion, but withdraws heat. The actual amount, therefore, of air required is in round numbers about 220 cubic feet.

In these observations made regarding the boiling point of water, whether in the open air or under varying degrees of pressure, the water is to be held as pure, or nearly so. For when it is mixed with much saline matter, the temperature at which it boils is raised. Water, it may be noticed, saturated with common salt, boils at a temperature of 226° Fahrenheit. The temperature at which water containing various proportions of salt boils is given in the annexed table:—

	Amount of salt.	Temp.
Common water,	0	212°
Sea water,	1/33	213·2
Boiler water,	2/33	214·4
... ...	4/33	216·7
... ...	6/33	219
... ...	8/33	221·4
... ...	10/33	223·7
Salinated water,	12/33	226

In steam-boilers, where the water used contains a great quantity of saline matter, a particular process is resorted to called *blowing out*, by which the heavy water impregnated with saline matter is removed, and the salts prevented from accumulating. From such a mechanism not being known at the time, the 'City of Edinburgh' steam-ship, on her first voyage to Leith, had her boilers so obstructed and rendered useless by the immense accumulation of salts, that it was found necessary to clear the boiler out on the voyage, while she proceeded under canvas during the time. Some further remarks are to be found under the description of the marine steam-boiler.

HISTORY OF THE STEAM-ENGINE.

It appears, by careful examination of the records of history, that the action of steam for producing motion (though not then proposed to be applied to practical purposes) was known as early as 130 years B. C. This was produced by an instrument denominated an *æolipyle*, described by Hero of Alexandria, of which a figure is annexed, and which may be considered the original of the steam-engine. The æolipyle is formed by a globular metallic vessel, which rests on pivots, at and where it can revolve with perfect facility. Two tubes proceed from this ball at right angles to the pivots, shut at the extremities, but with a small aperture at the side, whence steam may escape. The pivots are the extremities of tubes connected with a boiler below, as marked in the sketch. On the boiler being heated, steam passes by the pivot tubes (C B) into the cylinder, from which it issues by the little aperture (F) at the side of the cylinder tube (E). As the steam escapes, it rushes out with great force; and as it acts on the side opposite to the aperture, it forces it and the cylinder to move round in the contrary direction. One tube will suffice. The same action may be shown even in a more simple manner, as is often done by glass-blowers. A small glass globe is formed, and two arms

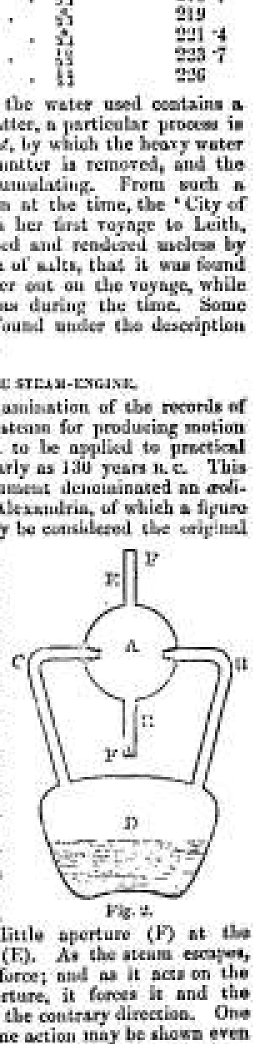


Fig. 2.

are attached to it, which are cylindrical tubes. In the globe a quantity of water is introduced, and on applying heat below, the same action takes place. It is of course necessary that the globe should be properly balanced and supported.

The next notice of steam-power worthy of our attention is in the seventeenth century. In the year 1663, a work was published by the Marquis of Worcester, named, in the language of that period, 'A Century of the Names and Scantlings of such Inventions as at present I can call to mind to have Tried and Perfected.' The following extract, describing what he terms a 'fire waterwork,' seems distinctly to convey the idea of a steam-engine:—'An admirable and most forcible way is to drive up water by fire, not by drawing or sucking it upwards, for that must be as the philosopher calleth it, *intra sphæram activitatis*, which is best at such a distance. But this way *hath no bounder* if the vessel be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full of water, stopping and screwing up the broken end, as also the touch-hole, and making a constant fire under it; within twenty-four hours it burst, and made a great crack; so that, having a way to make my vessels so that they are strengthened by the force within them, and the one to fill after the other, I have seen the water run like a constant fountain stream forty feet high; one vessel of water, rarefied by fire, driveth up forty of cold water. And a man that tends the work is but to turn two cocks, that one vessel of water being consumed, another begins to force and refill with cold water; and so successively; the fire being tended and kept constant, which the self-same person may likewise abundantly preform in the interim between the necessity of turning the said cocks.'

In 1698, Mr Savery, or Captain Savery, obtained a patent for a steam-engine, which was the first introduced to raise water. The principle of his plan consisted in injecting steam into a vessel connected with a vertical pipe, dipping into the water to be raised, and then condensing it by cold water, so as to form a vacuum, or at all events a space in which there is vapour of very feeble elastic force. By the pressure of the atmosphere, the water was then driven up until it attained a height proportionate to the pressure of the atmosphere, diminished by the force of the uncondensed vapour. By a peculiar but simple disposition of the valves, the return of the water was prevented; but as the water could not in this manner be elevated higher than 26 feet (64 feet by force of steam), the plan was not adopted to any extent.

The next decided and most important improvement which took place in the progressive advance of the steam-engine, was that of having a piston introduced into a cylinder, and when it is at the bottom, directing a current of steam so as to raise it, this steam to be condensed by being cooled. A vacuum is thereby produced, and the pressure of the atmosphere forces the piston down to the bottom of the cylinder. A rude and imperfect idea of this plan was suggested by Papin (a celebrated Frenchman, who discovered the Digester, and invented the safety-valve) about 1690, but laid aside. Engines were invented and constructed on this principle in the year 1713 by Newcomen and Cawley.

The engine so constituted is commonly called the *atmospheric engine*, because the power is derived from the pressure of the air, the steam being used merely to form a vacuum against which the atmosphere is to act. As this engine constituted a very important era in the history of steam, a short account, with a diagram of it, is subjoined (fig. 3), more especially as it shows in bold contrast the many and great advantages that resulted from the application of the genius of Watt to the steam-engine. There are three essential parts in the engine—the boiler, in which the steam is produced; the cylinder, in which it is condensed; and the beam, where its movements alternate with the ascent and descent. The boiler (B) is placed over a proper furnace, and built in with bricks. The summit of the boiler has a pipe or tube which communicates with the cylinder (C), situated immediately above. The

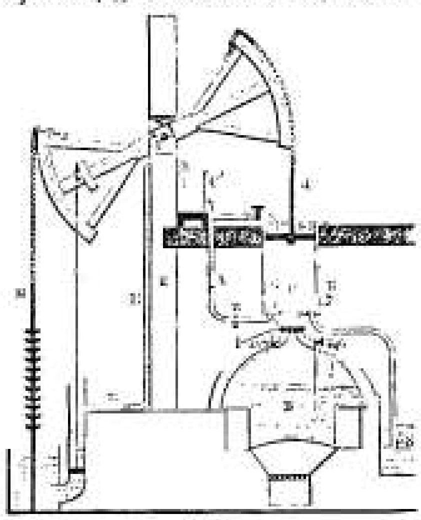


Fig. 3.

communication between the cylinder and the boiler is protected by a valve (V), called the *regulator*, or regulating-valve, so that the admission of steam may be regulated at will. The boiler is provided with gauge-cocks (G G), as will be noticed under the head of *boiler*, and also with a safety-valve (S V), which is not loaded to any great extent, as the engine works at a low pressure. The cylinder, which is placed above, is made of cast-iron, and nicely bored, so as to permit the free working of the metallic piston, but at the same time to prevent the access of air or steam. The piston (P), in short, works like the piston of a common syringe. There are four apertures in the cylinder, while it is also open at the summit. There are, first, that marked V, the valve of communication between the boiler and cylinder; second, that at the left inferior angle in the opening of the pipe (A), which transmits the water for condensation, armed with the stopcock (R) named the *injection-cock*. This pipe leads from the cistern (C'), which is kept constantly supplied with cold water by the action of the small pump attached to the beam, raising the water, and carrying it along the tube or water-pipe (E E).

At the opposite angle, below H, an aperture is observed, being the commencement of the eduction-pipe, by which the water injected for condensation is removed to a cistern beneath. This pipe is conveyed a considerable way down into the cistern, and is protected with a valve at its extremity, opening outwards, so as to permit free passage of the water from the cylinder, but none to regurgitate from the cistern. The fourth aperture, opposite the opening of the injection-pipe (H), is also supplied with a valve opening outwards. It is commonly known by the name of the *blowing-valve* or *snifting-valve*. It is through this valve that any air in the cylinder is expelled before the engine operates.

On a large support (E) a beam (I) is placed transversely across, which moves on an axis at I. This beam has one arched head at either extremity, to both of which chains are attached. On the one immediately above the cylinder the chain is continued down to the piston-rod (M), into which it is fixed, so that, as the piston ascends and descends, there will be a similar movement of the arched head of the beam. To the other end the chain is connected with the pump-rod, by which the water is to be brought up. But the pump-rod is made heavy, so that it naturally draws down this extremity, and elevates the piston-rod.

The mode in which this engine is worked is the following:—The fire being properly raised, and steam freely formed, the valve (V) is opened, to allow the entrance of the steam. The snifting-valve (H) is now forced open, and the air escapes along with the steam, until the cylinder is full of steam. The regulator-valve (V) is now shut, and the stopcock (R) on the pipe A being opened, the cold water is injected, and condenses on the steam. But as a vacuum is effected by the condensation of the steam, the pressure of the air, now acting with a force equal to 15 lbs. on the square inch on the surface of the piston, carries it down to the bottom of the cylinder, and consequently raises the other end of the beam to which the pump-rod (N) is attached. In this manner the water is raised from the mine; and by a repetition of the movements already noticed, a constant discharge of water results.

There were not a few impediments to the free working of this engine, one of the most laborious of which was the incessant attendance of a person to open and shut the stopcocks alternately as it was required. This was accomplished by catches (scoggans) worked by the beam, or strings connected with the lever of the valves and the beam—an invention of a boy, Humphrey Potter, to avoid the trouble that constant attendance on the levers demanded. By means of a plug frame fixed to the beam, invented by Beighton, the engine was made to work the valves with great regularity—a most important practical advance in making the steam-engine work itself, and adjust its own valves. The analogous part of this machinery in the modern double-acting engine is to be observed in the eccentric.

This, the atmospheric or Newcomen's engine, had many and very striking advantages over all others previously proposed. It may indeed be considered the basis of the engine subsequently modelled by Watt. But there were very serious defects in it, as the reader will shortly find from the description of Watt's engine. It is here sufficient briefly to enumerate them:—Much steam must, then, be lost during the process of the heating of the cylinder after each condensation; for it must always at least be raised to the temperature of the steam before the steam can, as such, continue in it, and be in any degree efficient; and on the other hand, the cold air which follows the descent of the piston must necessarily withdraw a considerable portion of heat. By the calculations of Watt, it was estimated that *three* times as much steam was expended in this manner as would have been equal to work the engine—a loss, therefore, equal to 75 per cent. Nevertheless this, as has been correctly observed, 'was the first really efficient steam-engine; that is, the first engine which could be applied *profitably* and *safely* to the most important purposes for which such machines were required at the time of its invention.'

The happy conception which formed the first step in the career which has immortalised the name of Watt, was that of *condensing the steam without cooling the cylinder.* After the notion of separate condensation had occurred to him, all the other details of the engine were of comparatively easy introduction. His first improvement constituted what has been termed the 'single-acting engine.' In this form of the engine the steam was admitted only above the piston, at first the vacuum being below it. When the piston had gained the lower part of the cylinder, the communications between the steam-pipe and cylinder, and also between the condenser and cylinder, were closed; and through the medium of a tube communicating laterally, the steam which was above, diffused itself below the piston, so that on either side it was subject to an equal force. But on the other extremity of the beam there was a weight, which raised the piston up, and the steam all necessarily flowed below the piston. On the communication between the condenser and cylinder being made free, a vacuum was induced, and the steam-pipe being then opened, a rush or current of steam proceeded to the upper part of the piston, and the movements were repeated as before.

This form of engine was not by any means well suited for the purposes of communicating motion to machinery, in consequence of the inequality of its action; but it served admirably for the purpose to which it had been first applied—namely, that of raising water from mines. It is, however, in a great measure, even for that latter purpose, superseded by the double-acting engine of Watt, which we shall now describe in detail.

DESCRIPTION OF THE STEAM-ENGINE.

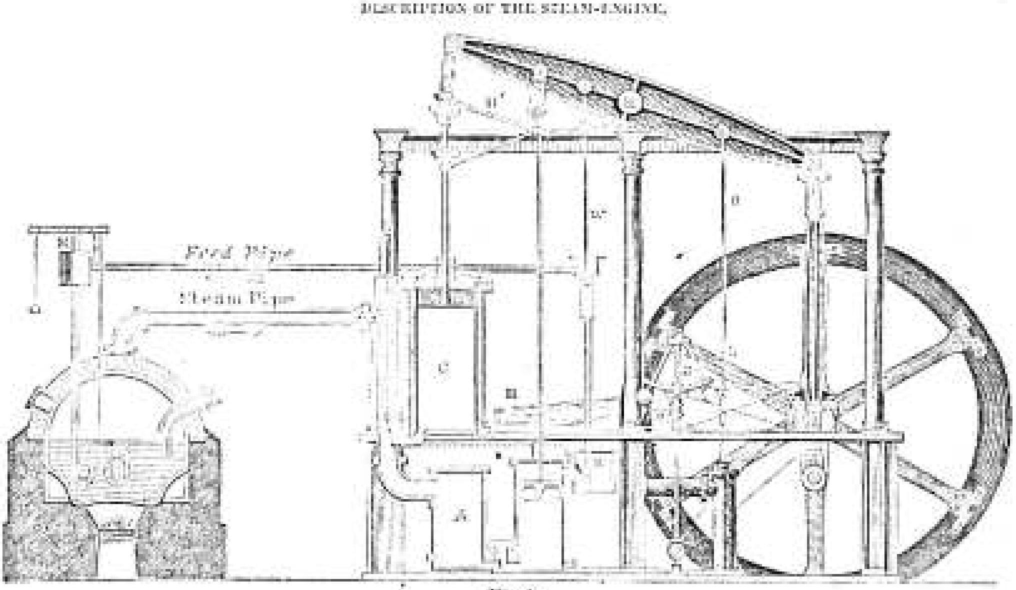


Fig. 4.

The entire apparatus of a steam-engine is comprehended in two distinct parts—the *boiler*, which generates the steam, and the *engine*, by which the duty of the steam is performed. It is necessary, however, to remark, that there are various kinds of engines, differing as to mechanism. Two grand divisions may be formed of them—1*st*, Those in which condensation takes place, or low-pressure engines; and 2*d*, Those in which there is no condensation, or high-pressure engines. In the first class we have the common atmospheric engine, invented by Newcomen; then the double-acting engine of Watt, working by pressure and condensation, or working by pressure, expansion, and condensation; so, also, in the second class, we have engines working only by pressure, and engines working by pressure and expansion. Fig. 4 is an outline of what may be esteemed the most complete engine of the condensing class, with the boiler and connecting pipes.

We shall now proceed to describe the various parts of this most ingenious apparatus. And first, of

The Boiler.

The boiler, as its name implies, is the large iron vessel in which the water is exposed to the action of heat, so as to be converted into steam. In its structure and connection with the cylinder (that part of the engine in which the steam acts), it constitutes a very beautiful illustration of different pieces and forms of machinery all happily arranged, so as to contribute to one important end. In examining the boiler, we have to attend to the following leading parts or portions of mechanism:—The form of the boiler, the feed-pipe, the steam-pipe, the damper, the steam-gauge, the gauge-cocks, the safety-valve, the internal safety-valve, the man-hole, and the furnace. Fig. 5 is a representation of the several parts on a minute scale:—

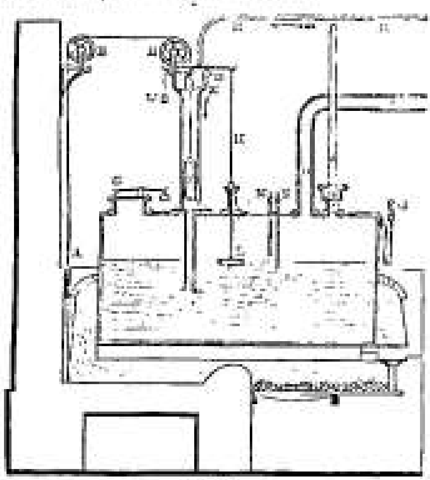


Fig. 5.

Various forms have been proposed for the low-pressure boiler. That which is chiefly used, as here represented, is called the wagon-shaped; it is fashioned in a semi-cylindrical manner above, the sides being nearly perpendicular, while the face is gently concave or hollow. When the pressure is not great—that is, does not exceed six or eight pounds on the inch—this form of boiler is sufficient for the generality of purposes. The chief object in selecting the form of the boiler is, that it may permit the water to pass speedily into vapour with the smallest amount of caloric, as little as possible being given off to the surrounding matters and atmosphere. For it is here to be observed, that when two bodies at different temperatures are placed contiguous to each other, the warmer of the two soon becomes cooler, and the colder becomes warmer, so that, after a given lapse of time, they both have the same or a common temperature. It becomes, therefore, an object of the utmost moment to place the boiler in such a position that as little heat as may be can escape from it. This is effected by building it in brickwork, or matters which are bad conductors of caloric.

Whatever form may be selected for it, it has two main pipes—one which conveys the steam from it (O), and the other which, as it supplies it with water to generate the steam, is called the *feed-pipe* (R).

It is further provided with several other highly important and essential parts; these are, the *steam-gauge*, which indicates the elasticity or force of the steam which is formed; the *gauge-cocks*, by which it is known whether the boiler is supplied with the proper amount of water or otherwise; the *safety-valve*, so denominated by way of distinction, which allows a free egress to the steam when pressing beyond a certain force, and thereby preventing any danger from explosion; the *internal safety-valve*, which obviates any risk of the sides of the boiler collapsing by the pressure of the atmosphere, should, from any circumstance, the force of the steam become inferior to that of the external air. To these there is to be added the *man-hole*, which is for the object of cleaning the boiler out when requisite.

The feed-pipe is a very ingenious arrangement by which water is brought to the boiler. It proceeds from a cistern (E) situated immediately above the boiler, and extends into the boiler a little lower than its middle height.

The water which is conveyed to this cistern is drawn from the hot well (H)—(a part of the engine connected directly with the condenser, and afterwards to be noticed)—by means of a pump worked by the engine (W), fig. 4. As this water is of considerable warmth, a proportionate saving accrues in using it. The water, however, does not enter this tube to pass to the boiler always in a continuous stream, independent of the condition of the boiler as to its being scantily or liberally supplied with water; but, by an ingenious arrangement, it is made to descend in such a continuous current, so as exactly to be equivalent to the amount of water expended in the formation of steam. This is accomplished in the following mode:—A valve is situated at the bottom of the cistern, which is made to open upwards, on the rod being raised which connects it with a lever (D). This lever is so placed as to move on a fixed point at the upper part of the cistern. At one extremity of it a small wire (K) is attached, running through a steam-tight aperture in the boiler, having a float (L) at its termination resting on the water. To counterpoise this, there is a weight (W) suspended at the other extremity of the lever connected with the cistern. As this float is balanced in the water, when it is rapidly evaporated, it will follow the water level, and as it descends, will necessarily bring down the arm of the lever to which it was connected; the other arm will be elevated in a corresponding manner. But the valve in the feed-pipe being attached to a rod which is fixed to the lever, will be carried upwards as it is raised, and the water will pass down, until the float, being raised in a corresponding degree, will enable the other arm of the lever to which the counterpoise was attached to fall, and thereby bring down the other end of the lever, and close the valve. By this arrangement, as long as there is a sufficient supply of water, from which the cistern can be filled, there will always be a sufficiency running down in a continuous stream to feed the boiler for the production of steam.

The steam-gauge (Q) is adapted to the boiler, in order that the engineer may always be able to know the elastic force of the steam. Its form and principle are illustrated by fig. 6. A tube, curved in the form of the letter U, is connected with the boiler from which the steam is disengaged. This tube is open at both extremities—(perfectly analogous to the tube rising from the centre of the stout copper vessel in which the principle of the formation of high-pressure steam was explained, p. 386)—one of which is immediately exposed to the air or vapour in the vessel, while the other is directly under the influence of the pressure of the atmosphere, whatever that may be. Into this tube mercury is introduced, which, supposing the boiler to be full of air, or of steam having the same tension as the atmospheric air, will have the same level in both legs of the tube; should, however, the fluid ascend in A, that in B falling in a corresponding degree, the steam pressing on B must have a greater force than the external atmosphere, and the difference in the levels of the mercury in the two limbs will indicate the excess of the force of the steam above one atmosphere. Every two inches' difference in the levels indicates a pressure of 1 lb. on the square inch. Conversely, the fluid mercury falling in A, and rising in B, indicates that the steam is *not* of pressure equal to that of the air, the proportion of which is to be determined in the same manner. This tube may be constructed either of glass or of iron. If a metal tube is employed, a thin wooden rod is introduced, with a float in the open end A, so that the distance of the mercury from the level of the summit of the tube is easily ascertained.

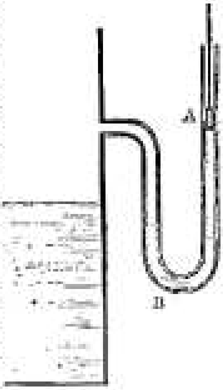


Fig. 6.

The gauge-cocks (M N) are two pipes or tubes armed with stopcocks, passing vertically downwards into the boiler. These tubes are of unequal length. One descends somewhat more than the third of the depth of the boiler from the summit, the other somewhat less; so that the former dips in the water, while the other opens into the air or steam a little above the water level. When the boiler is filled with its proper amount of water, and steam duly formed, on opening the stopcock of the longer tube, water will be discharged; and on opening the shorter, steam will escape. If, however, there be an excess of water, so that the less also dips into it, water will be projected from both; and again, if from inadvertency the water be deficient, so that the longer tube dips into air or vapour, the water-level being below it, steam, on both the stopcocks being opened, will escape freely.

The safety-valve (G) is designed to permit the free escape of the steam when it is generated of greater elasticity than is required, or the sides of the boiler are well able to resist. If we suppose the boiler can bear a pressure of 20 lbs. on the square inch at every part of its surface, and there were no valves, should the force of the steam be increased so as to exert a pressure of twenty-one lbs., the walls would necessarily yield, and an explosion be the result. If, on the other hand, we suppose that the engine will work well with an elasticity of 4 or 5 lbs. on the square inch, it is apparent, that so long as the elasticity does not increase, the steam will pass by the steam-pipe freely to the cylinder, and the steam-gauge in the boiler will indicate the pressure to be that now stated. But, while things are in this state, if we were to render one point of the boiler so weak that a force of 10 lbs. would be too great for it, and the steam were to acquire an elasticity sufficient to overcome that, a rupture necessarily would take place at that point, or the boiler would burst. The valve is then to be considered as a part of the boiler, which yields to a pressure much less than that which would be capable of bursting the boiler, but which permits a pressure to be made sufficiently strong to allow the free working of the cylinder with steam of or under a definite pressure. The mode in which the valve is frequently made to work is by the steelyard. This is a lever having a support fixed close by a tube communicating with the boiler. The aperture of this tube is closed by a plug or plate, which is fixed to the lever, and weights are arranged in the usual manner to the extremity of the lever. If the atmosphere and the weight fixed to the end of the lever are unable to resist the elasticity of the steam which is generated in the boiler, its greater pressure forces the plug upwards, and the tube being opened, the steam escapes.

It is apparent that if the tube were open, steam could not be generated of higher pressure than one atmosphere; again, if the boiler were made of sufficient strength to bear the pressure of 16 atmospheres, it could be heated sufficiently so as to give steam to that force without danger. But as the safety-valve may be loaded with a pressure ranging from 1 lb. on the square inch to 100 or more, it is evident, that so long as we are secure of the positive strength of the boiler, we may cause steam to be generated of any given strength, within the range determined, merely by adding or subtracting from the pressure on the safety-valve. From different causes—as, for instance, the valve adhering to the tube, or corrosion taking place, or the aperture being too small—it is occasionally inefficient, and from this explosions may arise, should the force of the steam be greatly augmented.

In some boilers two safety-valves are employed, the one being at a much lower pressure than the other; so that when it yields, the engineer has a clear intimation of the increasing elasticity of the steam, and then can easily adopt precautionary measures. It has been strongly recommended that in every instance there should be two valves. Justly, indeed, has the observation been made, that the more valves the better, as it is altogether improbable that they can all be obstructed at the same moment.

A plug of fusible metal is occasionally used in boilers which are raised to a very high temperature. The fusible metal is an alloy of different metals, which are so apportioned to each other, that the mass will melt at any given temperature. (See METALLURGY.) Now, it has been already stated that steam of higher elastic force than that of the air can only be formed at a higher temperature than 212°; when, therefore, steam is generated of a greater elastic force, it must be at a proportionally higher temperature; and if, then, there is a fusible plug which liquefies or melts at that particular degree of heat, it will be melted, and an outlet at once given to the vapour and water; it will be, in other words, the same as a valve. However ingenious in theory this invention may seem (and it certainly has considerable credit), it does not so happily correspond in practice, as it is found that the metals melt unequally; or, in other words, that the most fusible melts at the low temperature, and is retained in the small cells of the less fusible, so that the whole may not be fused until a temperature is obtained 100 or 200° higher than what was arranged or anticipated; and accordingly, by trusting to this alone, every danger that might occur from an explosion is to be apprehended.*

* 'The bursting of boilers'—we quote the Penny Cyclopædia—'present very different phenomena, being sometimes a simple rent in the metal, allowing the harmless escape of steam and water; and at others accompanied by an explosion in its violence equal to that produced by gunpowder. It has hence been conjectured that on these occasions some explosive gases are formed in the boiler; but this does not appear probable, nor is reconcileable with any known physical laws, while the elastic force of steam is capable of indefinite increase, and is quite adequate to produce any mechanical effect whatever. It is always difficult to get any satisfactory evidence as to the facts of an explosion of a boiler; the terror of the moment prevents the survivors from accurately recalling the phenomena immediately antecedent, while those who, from their proximity, would be best capable of affording this evidence, are either killed, or are too interested in exculpating themselves to be impartial witnesses. With regard to the formation of explosive gaseous compounds in the boiler, it is generally admitted that hydrogen gas is the only ingredient of such that can be formed; and that is obtained by the decomposition of the steam when in contact with the red-hot iron; but pure hydrogen is not explosive; and to render it so, it must be mixed with oxygen or atmospheric air. It has been suggested that the latter may be introduced along with the water by a defect in the feeding-pump; but the proportions of the air and of the hydrogen must be definite to produce an explosion; and it is difficult to suppose that in such a situation either should continue to accumulate till the quantity is exactly that necessary to produce an explosion. In short, this explanation of the subject is beset with difficulties which have not yet been removed, though the attention of scientific men both in Europe and America has been frequently directed to it.'

The furnace under the boiler is so arranged that the fuel is thoroughly consumed; and further, so that a draught of air may have free access to the fuel, which may be increased or diminished by means of a damper (A), worked on the wheels B B, when the steam is coming off too rapidly or too slowly for the demands of the engine. This object is effected by a contrivance somewhat analogous to the mode in which the supply of water is regulated for the feed-pipe, through the medium of the float and valve connected with the cistern. (See p. 392.)

The Engine

Is that part of the steam-engine where the force or power is developed by the action of the steam, and thence, by appropriate machinery, adapted to whatever objects it is desirous to give the impulse of a first moving power. There are a number of parts essentially belonging to the engine, each of which requires to be considered separately, in order that the mechanism of the whole may be rightly understood. These parts are —the cylinder, the condenser, the air-pump, the hot well, the cold water-pump, the beam, the crank, the fly-wheel, the governor, the eccentric and valves, and the indicator. For the convenience of description, these parts and the minor subordinate pieces of mechanism may all be arranged under two heads—*1st*, Those relating to the steam; and *2d*, Those connected with the motion, the regulation of the valves, &c. The engine now to be described is that called the *double-acting engine*, so named in opposition to the *single-acting engine*, in which the piston is forced downwards by the steam, but is elevated by a weight attached to the remote extremity of the beam. It is so called because the motion *downwards* and the motion *upwards* are both effected solely by the agency of the steam.

The *cylinder* (C, fig. 4) is the stout iron vessel into which the steam is introduced, and by its elastic force, according as it is alternately admitted and withdrawn below and above, causes the piston-rod to ascend and descend by an alternate and almost uniform movement. This iron vessel is steam-tight at the aperture where the piston-rod moves, and is equally so at the different apertures by which the steam either enters or escapes, these apertures all being securely protected by valves. When the piston has arrived at the top of the cylinder, the lower part is full of steam. To produce a vacuum, so that the piston may be readily depressed by the introduction of steam above, this vapour below must be removed. For this purpose the cylinder has a valve at its lower surface connected with the condenser (an apparatus immediately to be described), and on this being opened, the steam rushes into it and is condensed. But while this has taken place, the passage to admit the steam above the piston is opened, and as it enters immediately, by its elasticity it depresses the piston to the bottom part of the cylinder, constituting the downward movement.

But the piston has now arrived at the lower part of the cylinder, and it is required to raise it to the summit again. This is effected by the very same arrangement as that employed to bring it down. The steam which is in the cylinder above the piston is now, by the shifting of the valve, allowed to communicate freely with the condenser, escaping from the upper aperture in the cylinder. In this manner a vacuum is produced above, and the steam simultaneously being admitted from below, the ascent of the piston takes place to the upper part of the cylinder. By a continued succession of this alternate ascent and descent, motion is communicated to the beam, and thence transferred to whatever object it is desired to affect.

The *condenser* (A, fig. 4) is the next part to be described. The position of it is under and at a little distance from the cylinder, with which it communicates directly by a pipe or tube. The condensation of the steam by the aid of cold water, it will be remarked, is effected at a distance from the cylinder. This, indeed, constituted the chief improvement of Watt. The condenser may be considered as a vessel with three apertures in it—one leading from the cylinder, protected by a valve; another leading from it to the air-pump, also protected by a valve, permitting the free passage of matter, whether water or gases, to the air-pump, but not allowing any backwards into the condenser; and the third or last tube, which allows fluids also to escape, but has no communication with the air-pump, the fluids being discharged into the cold water which surrounds all this part of the machinery: this is usually named the *snifting-valve*. But there is also another aperture, through which the cold water is admitted to the condenser; this is regulated by the injection-cock. This cold water, when it is thrown in, immediately condenses or absorbs the vapour of steam, so that a vacuum, comparatively speaking, is formed.

The condenser-gauge is intended to determine the force of the vapour which may be in the condenser, for it must be observed, that a complete vacuum is scarcely ever produced. The extent of the vacuum it is essential to know, in order that the engineer may precisely ascertain how far it is working correctly. It may here be observed, that water can exist in the form of vapour even at very low temperatures. The force or elasticity it possesses is to be determined in the ordinary mode by a bent tube containing mercury, open at one extremity to the condenser, and at the other to the atmospheric air—the same principle, in short, as was applied to the estimation of the force of steam in the boiler.

Immediately contiguous to the *air-pump* is the hot well (H), into which the hot water from the condenser is brought, and any aëriform bodies remaining in the condenser. The piston of this air-pump being drawn up by means of the connection it has with the great cross-beam, a vacuum is produced; but at the lower part of the air-pump there is the valve communicating between it and the condenser. This valve, however, opening towards the air-pump, not in the other direction, the fluids pass immediately towards the air-pump. On the descent of the pump, the fluids are necessarily driven back, but their return to the condenser is altogether prevented by the structure of the valve; accordingly, from the compression they are exposed to, they open the valves of the air-pump piston, and are carried to the upper part, where they are gathered together. On the ascent of the piston taking place, they are carried up by it and brought into the hot well.

As the piston which works the air-pump is attached to the great arm of the beam, it is apparent that its operation is carried on steadily while the engine is acting; and accordingly, that the water formed by the condensed steam, as well as the water which produced the condensation, is incessantly being removed from the condenser, and successively brought to the hot well.

To supply this part of the engine, there is a pump which brings cold water into the cistern in which the condenser is placed. From the character of the water which it conveys, it is technically named the *cold-water pump* (O, fig. 4). At the point, then, where the heated water is drawn from the condenser, and brought into the hot well, the course of the water, proceeding from its fluid state in the boiler, then as steam, and finally condensed, may be said to be concluded. The water, however, it was observed, in the state of steam, acquires a great amount of heat, somewhat more than five times the heat required to raise it from the freezing to the boiling point. It is then returned by means of a tube to the cistern which is placed above the boiler, and supplies the feed-pipe leading to the boiler. The mechanism employed here has already been detailed. It will therefore be apparent, that a quantity of the water which was at the beginning in the boiler, is returned again to it, having previously passed through the state of steam, and having been condensed—performing a complete circle of changes.

The air-pump is not merely subservient to removing the water generated in the condenser, but it effectually removes the gases which are found associated with the steam, and which exist always in a certain amount, more or less, in water. These, indeed, were they to accumulate in the condenser, would as effectually interfere with the production of the vacuum there, and the consequent efficiency of the engine, as the accumulation of heated water, which would be incapable of dissolving the steam or condensing it, as the common term is. The air-pump is usually made to equal one-fourth of the cubic contents of the cylinder.

There is not, perhaps, any piece of mechanism so complete in all its various parts as the steam-boiler, or all these parts which are immediately subservient to the purpose of forming the steam—conveying the steam to the cylinder, condensing it, and again returning it in the form of water, from which it was originally produced, to be again converted into the same powerfully elastic body by the agency of heat. If, indeed, the condensation could be effected by other means than the agency of water, all the steam might be returned to the boiler, and thus, in an unceasing circle, the amount of water at first started with would suffice.

At first sight it might appear that these were all sufficient to determine the movements of the steam-engine, but there are other parts which are no less essential to the perfection and uniformity of its movements. These are, the eccentric rod, the governor, and the indicator.

The *eccentric rod* (R, fig. 4) is designed to work the valves, which were formerly managed in a very different manner, by means of catches or lappets fixed to the air-pump, and so placed as to elevate levers, which opened and closed the valves at the proper intervals. These valves require to be worked in a vertical manner, so that the steam may alternately enter and be shut off from the aperture into the cylinder at the top and bottom; and the regularity of the movement of these valves is indispensable to the permanent uniformity of action in the engine.

The eccentric consists of a circle of metal connected with a revolving axle, while the centre of the circle differs from the centre round which the revolutions of the axle are performed. It receives the name *eccentric*, because it is out of the centre (*ex*, the Latin for *out of*, or *away from*). If we suppose a circular metallic plate made with a shaft fixed in it, on which it revolves, but which is not in the mathematical centre—that is, the real centre of the circular plate—and if we suppose the diameter of the circle to be four inches, the exact centre will be two inches, or the radius of the circle will have that length. If, then, the shaft is fixed into the metallic plate firm in the middle of the radius—that is, at one inch from the circumference, and therefore at the same distance from the centre—it is obvious that, as the metal plate revolves so as to complete half a circle, three-fourths of the whole diameter will be placed exactly to the outer side of the axis on which it revolves; and on the revolutions being completed, the three-fourths will then be on the interior side, as the axis on which the plate revolves is permanently a fixed point. Round this eccentric a ring is adjusted with screws, to which metallic rods are fixed. As the eccentric revolves, the ring does not associate in the rotatory movement; it will, however, be carried to the right and left by the movement of the centre of the eccentric, as it comes round the axle. And as, in the case we have proposed for illustration, the distance between the real centre of the ring and the centre of revolution is one inch, the attached rod will be moved twice that space to either side during the revolution which the horizontal axle performs.

In this manner a rectilineal movement is procured from one that is circular; and by means of levers arranged at the extremity of the rod around the eccentric, the valves are alternately elevated and depressed, so as to permit the free entrance of the steam to the cylinder above the piston, while free exit is given to it below to the condenser, and then to permit the equally free ingress of the steam below the piston, while the escape of it from above is equally free to the condenser. Whatever variation may be given to the levers employed, the principle is the same, in so far as a horizontal lateral movement is obtained through the medium of the eccentric.

In the escape of the steam, either of increased elasticity or increased quantity, it is obvious that the movements of the engine will become more rapid, and so much accelerated as not to be adapted to the work it is intended that it should perform. It became, therefore, an object of the highest importance to regulate the quantity of steam as it was transmitted from the boiler by the steam-pipe to the cylinder. To accomplish this, Watt ingeniously applied the mechanism so long employed in water-mills, and which is almost universally known by the name of the *governor* (Z, fig. 4). The nature of this piece of mechanism will be understood by the annexed fig. A spindle or upright rod, with a pulley on its lower part by which it is moved, receiving motion through a strap attached to the shaft or axle, has two balls, which revolve along with it.

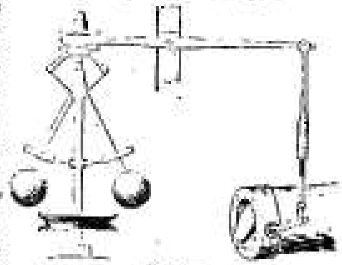


Fig. 7.

Those balls, by the means of joints, may be separated considerably from, or brought nearer to, the spindle. Two levers are connected with the rods to which the balls are attached, having a free movement on other levers similar in length and thickness, but which meet in a metallic ring movable upwards and downwards on the spindle. Immediately above the ring, a lever is placed transversely across the ring, fixed at one point, but connected to another which is bent, to the end of which the throttle-valve of the steam-pipe is attached. This valve, it may be here noticed, is intended to regulate the supply of steam, allowing it to escape when horizontal in full stream, and obstructing it proportionately as it assumes a vertical direction. When, therefore, the engine acts with increased speed or velocity, and the main shaft to which this spindle is attached is revolved with a proportionate degree of rapidity, the balls will recede to a greater distance from each other, and accordingly the levers acting on the throttle-valve will raise it so as to diminish the flow of steam. But if the shaft revolves slowly, the spindle also having its velocity regulated by it, the balls will naturally approximate each other, and the lever will now so act on the valve as to throw it completely open, and thereby permit the steam to enter in a full current to the cylinder, and accelerate the motion. Whatever is the velocity of the axle, such also will be in a proportionate ratio the velocity of the spindle, and in a corresponding manner will the position of the throttle-valve, either to close or enlarge the opening, be modified.

The *indicator* is a piece of mechanism devised by Watt, by means of which the force of the steam, and the state of exhaustion in the cylinder, are known at the different periods of the stroke of the piston. It is a small cylinder 8 inches long and $1\frac{3}{4}$ inch in diameter, communicating directly with the cylinder, and supplied with a piston. If the force of the steam in the cylinder exceeds the pressure of the atmosphere, the piston of the indicator then rises, and if it be less, is depressed. A tracer is connected with the indicator, by which a curve is drawn on paper, indicating the variations occurring in the pressure of the steam.

Hitherto those parts only have been detailed which are immediately related to the course of the steam. There remain now to be described those parts more directly, or rather essentially, connected with the regulation of the motion: these are the beam, the crank, and the fly-wheel.

The *beam* is the large and strong mass of iron moving on a centre, and resting on a large pillar or pillars, firmly secured to the base of the machinery and floor. It is so fixed on the summit of the pillar, that it may move freely on its centre, so that the extremities can alternately rise and fall with the alternate elevation and descent of the piston: the pump-rods attached to the beam are also worked in the same manner, and so were the valves formerly; but the latter are now generally acted on by the eccentric, which has been already explained.

In the single-acting engine, where the steam is employed to depress the piston, and a weight at the end of the beam to elevate, the connection between the piston and the beam is by means of a chain, as the force acted on the beam only during the descent of the piston. When the double-acting engine is in play, the beam is pulled down by the piston-rod, and a chain would be sufficient for this end; but when the piston ascends, any force communicated from it to the beam, through the medium of the chain, would be totally lost; for as the piston was carried upwards, the chain would relax, and the beam remain in the condition it was at the beginning of the movement upwards. A different mode of connection, therefore, is required, of such a mechanism, that the inflexible connection between the arch-head of the beam and the piston-rod may push the beam upwards.

A number of different plans were proposed to effect this end, one of which was the suggestion of Watt—namely, to attach to the end of the piston-rod a straight rack, which could play in a similar rack formed on the arch-head of the beam. But this did not suit well, for the movement in the stuffing box of the cylinder, if not of the most equable and smooth character, rendered the working of the cylinder inefficient, by allowing the steam to escape, or the air to enter. This plan, then, was ineffectual; and it, as well as others, have all yielded to that most elegant disposition of mechanical forces to which the term *parallel motion* is given (H, fig. 4).

The movement produced by the ascent of the piston and its descent, acting on the beam alternately, causing its elevation and descent, is to be converted into a perpetual circular movement, in order to adapt the engine for the great number of purposes for which it is usually employed. This is effected by the *crank*. This piece of mechanical apparatus is to be held merely as the handle of a wheel, which turns it round on any power being applied, as the hand of a man. The line stretching out like one of the radii of the wheel from the axis is called the *crank*; the rod, again, at right angles to it is called the *crank-pin*; while the rod at the other extremity is the *crank-axle*. In the steam-engine, then, a rod is attached to this crank, which (through the beam) is connected with the piston-rod in the steam cylinder; as it ascends and descends, an impulse is necessarily given to the crank, which causes one-half of a circle in the one movement, and one-half in the other. When we reflect on the nature of the movements produced, it is apparent that there are two distinct movements—one upwards and the other downwards; and consequently that there is a cessation of impulse at the alternate change of the direction of the force. For when the steam enters above the piston, it depresses naturally the piston to the bottom of the cylinder. It is then, however, intercepted previous to its being introduced below the piston, during which time there can be no moving power exerted. Again, when the steam is introduced below, the same succession of actions arise; and when the piston is at the summit of the cylinder, there is, for the same reason as in the movement downwards, no force exerted. These two points, then, at which there is no power acting on the crank so as to turn it round in either direction, are usually denominated *dead points*.

How, then, is the movement continuously carried on? What is it that prevents the action of the crank ceasing at these two points? The crank and axle have received from the engine a certain amount of motion, and as the motion which it has received continues after it has come to one or other of the dead points, it continues still to move in consequence of the momentum it has received, and with force sufficient to carry it beyond the range of the immovable point. But now that it is liberated from these points, it becomes immediately acted on by the piston-rod's connection through the connecting-rod. In this manner it is carried through the other half of the circle, until it comes to the other dead point, where, from a similar cause, it does not stand, but is urged round, and in this manner a continuous circular movement is effected. The fly-wheel, also, in a similar manner assists in clearing the dead points. The velocity with which the movement is carried on is not equal, for, in the first place, there are the two dead points through which the crank is worked solely by the impulse or momentum it had already received; and, in the second place, from the mode in which the connecting-rod plays on the crank, it must be greatest where the angle of these two is a right angle, and diminish proportionally as it recedes from that position to the dead point, where it is least. The reality of these dead points, and also of the unequal velocity, any one may easily see if he attend to the commencement of the motion of the engine, when the steam has not got sufficient force, when he will find that it cannot carry the crank beyond the point until it is urged with increased force; and the same will conversely be seen as the engine is stopping. The continuous movement being effected in this manner, it is apparent that it is not always at every point produced with the same force; and therefore that the action, though, in as far as the amount of force exerted be the same, yet it is unequally divided over a given time, as, for instance, a revolution of the crank. But this would not suffice in the very nice and equable movements and applications of force to which the steam-engine is now so universally applied in the various manufactures of this country. To render the machine as perfect as possible, the *fly-wheel* was constructed for this object. This is merely a large iron wheel attached to the axis turned by the crank, and consequently carried along with it in its revolutions. This wheel is made very heavy, with the object that it may produce uniformity in the motion by the momentum which it receives (L, fig. 4).

This arrangement has been found sufficiently perfect in the more ordinary cases, where an extreme degree of equality and nicety of movement is not required. Where such is an essential point, then the plan devised by Mr Buckle of Soho is that which is to be put in execution. By means of a wheel working in the rack of another and smaller wheel, the action of the engine is made subservient to draw a piston from the bottom of a cylinder, so as to leave a vacuum. When this piston was at the summit, and the vacuum below, the action of the steam being withdrawn, it necessarily was carried down by the pressure of the atmosphere, acting with a force of 14·67 lbs. on the square inch. A considerable amount of power was thus employed in producing a vacuum, which was regained by the atmospheric pressure. This arrangement was next adopted in flour mills with the most complete success, and subsequently has been carried into effect in other mills with equal success. From the uniformity of the movement so obtained, the quality of the material produced has been greatly enhanced.

Having described all the parts connected with the engine, we have now to consider the mode in which it is worked. The first point, after the steam has begun to be freely produced in the boiler, is to expel all the air which may be in the different parts of the apparatus by opening the valves, and allowing the steam a free transit, finally permitting it to escape by the snifting-valve. When nothing but steam fills the different cylinders, then the noise at the snifting-valve ceases, and the injecting-cock for the cold water is to be trimmed for the purpose of throwing in the cold water to produce the condensation of the steam.

The steam is now ready to act on the piston, and when it has moved it (whether admitted in a full stream, or expansively, it matters not) to the extremity of the cylinder, by the mode in which the valves are disposed, it passes immediately to the condenser, where the cold water playing on it, converts it to its original condition of water. The alternate elevation and depression of the piston being continued, and the steam passing eventually to the condenser, this latter part would soon be completely filled by the condensed water, so as to be totally unfit for its duty. This is obviated by the action of the air-pump, the valves of which are arranged so as to open only upwards. By means of the piston of this air-pump, the fluids are carried to the hot well. To this hot well a pump is attached, by which the water, which is of considerable warmth, is conveyed to the cistern (M, fig. 4) situated over the boiler immediately at the summit of the feed-pipe. The beam of the engine carries a rod by which this pump is worked, as well as another through which cold water is continually supplied. The valves by which the steam escapes from above and from below the piston, during its alternate ascent and descent, are opened and closed by the eccentric (R, fig. 4), and the force or power with which the engine should work is determined by the governor (Z), in the mode already explained, the continuity and the uniformity of the movement being mainly controlled by the fly-wheel and crank, or by the crank and pneumatic pump of Mr Buckle.

In this manner the engine continues its action as long as it is supplied with a due proportion of steam; and if there is a definite force with which it should act, on the supposition that there is always abundance of fuel and water, the amount of steam is definitely maintained by the governor and throttle-valve, and by the float in the piston the exact quantity of water is duly preserved; and also by the damper, a greater or less current of air enters the flues, either to increase the production of steam when it is tardy, or diminish it when generated in excess. By the proper arrangement of the valves, likewise, no danger can result from the boiler, and thus, in the strict sense of the word, it is a self-acting and self-adjusting machine; it does, in short, as has been truly said, everything but speak.

Marine Engine.

In the steam-engines employed in the navigation of vessels, there are certain modifications which it is requisite here to notice, and then briefly to point out the leading circumstances connected with this important application of steam, which will be more fully treated in a subsequent number.

The most striking peculiarity is the position of the beam in British steamers, which, instead of being placed above, is situated below, chiefly with the view of saving room, and is not single, but two, one at either side of the cylinder. To the upper portion of the piston-rod there is a cross bar, which is placed transversely across the cylinder, at right angles to the long axis of the ship, or from starboard to larboard, in nautical language. From the extremities of this transverse bar rods stretch down, connected interiorly to the termination of the beams, moving on pivots at both their connections with the cross head and beams. The other extremities of the beams are attached to a cross piece, on the centre of which the rod is fixed by which the crank is worked. The shaft of the paddles is firmly connected to this crank, so that it is worked along with the rod. In small vessels, only one engine is usually employed; but in vessels of considerable tonnage there are two, and their action is so adjusted, that while the one is at its fullest strain the other is in the reverse condition. In this manner the motion of the wheels is preserved uniform and equal. These forms of engine are usually called condensing, the steam being worked at high-pressure, and then condensed, a result which is very readily accomplished in consequence of the abundance of water.

Another form of engine is what is called the 'direct acting engine;' and as it emerges considerably above the level of the deck, it has also been designated by the apt name of the *steeple engine*. Engines of this kind are worked with air-pumps and condensers, and, as in the other marine engines, there is no fly-wheel. The chief advantage they possess is the small space they occupy, and thereby not only afford room for more merchandise, but further save the great weight necessarily incurred where the beam is employed. The peculiar kind of steam-engine called the *rotatory* (p. 396) has in some instances been applied to the propelling of vessels, but as yet with very indifferent success.

Another modification adapted to the steamboat, by which it is rendered unnecessary to have the beam and its appendages, is that proposed by Mr Witty, and termed the *vibrating engine*. The object is to obtain a circular movement from the vertical motion of the piston-rod. This is effected by the cylinder being suspended on an axis at its middle, so that it has an alternate movement forwards and backwards, vibrating in a manner analogous to a beam on its axis. In this manner there are two distinct movements of the piston-rod—the common one upwards and downwards, and this lateral movement, in which it is immediately connected with the crank.

In this form of the engine, the axes on which the cylinder moves are hollow tubes, one being the steam-pipe by which the steam passes to the cylinder, and the other being the eduction pipe, by which it is transmitted to the condenser.

There is a peculiarity in the arrangement of marine boilers, which it is necessary here to point out. This consists in the process of *blowing out*, as it is technically named. In sea water there is a considerable quantity of saline matter, about 3 per cent., which, accumulating in the boiler, not only retards the process of boiling, but is apt to give rise to explosions. To obviate these imperfections, hot water is permitted to escape freely from the boiler at stated intervals, and as the discharge takes place from the interior surface, the greater portion of the saline matter is carried off. In this mode a very serious obstacle was effectually removed; but this was not done but at a considerable expense, the loss being estimated at nearly 1-54th part by Mr Tredgold. For it is apparent that an immense quantity of heat must have been lost in the warm water employed for this purpose, and not subsequently converted into steam. After all, the plan is only partially effective, as a solid incrustation remains on the bottom of the boiler so hard as frequently to break the shovels employed in its removal. This incrustation is the cause of much waste, for, from its bad conducting power, the bottom of the boiler is often heated to redness before the required amount of steam is produced, thus causing not only loss of fuel, but rapid wearing of the boiler-plates.

A very ingenious method has been invented by Messieurs Maudsley and Field, which preserves a uniform standard of the quantity of salt in the water of marine steam-boilers. This is effected by means of pumps, called *brine-pumps*, which are worked by the engine, and remove from the boiler the strong solution of salt and water. These pumps discharge as much salt, combined with the small quantity of water, as the feed-pumps supply to the boiler, so that the quantity of salt remains almost always the same. Further, before this hot brine is discharged into the sea, it passes through a tube included in another, which is the feed-pipe supplying the boiler from the sea, so that the greater amount of its caloric is imparted to the water, and it is reduced to nearly 100° before it is thrown out.

If the steam can be condensed merely by the application of cold water to the outside of the vessel containing it, it is evident that a boiler might be filled with pure fresh water on leaving port, and this water be converted into steam, back again into water, a second time into steam, and so on in succession, without ever coming in contact with salt. This has been effected by Mr Samuel Hall, who is the patentee of several improvements in connection with marine-engines. His condenser consists of a flat vessel, in the bottom of which are a number of small apertures, and from these pipes in tubes are led to another similar flat vessel. Both vessels are air-tight. Into the top vessel the steam to be condensed is admitted, and passing through the tubes which are immersed in cold sea water, it is perfectly condensed on reaching the under vessel, from which the newly-formed water is drawn off by an air-pump. As the cold sea water becomes heated, it is pumped off, and a fresh supply admitted. This invention, which affords a more perfect vacuum than the old system, has been adopted in a number of cases with success, and is likely to come into extensive use. Various minor improvements have of late been effected on marine-engines, chiefly with a view to save space in the vessel's hold, and to dispense as much as possible with the cumbersome item of coal. Our space, however, will not permit us to notice these inventions.

The paddle-wheel by which the steam-vessel is propelled has undergone many modifications, for in the common mode in which the flat boards or float-boards are disposed, they both enter the water obliquely and leave it obliquely, occasioning a considerable loss of power; for it is apparent that their greatest effect must be when they are nearly in a vertical position. The complex nature of several of these wheels prevents their general employment.

The most important modification of the propelling apparatus is what is termed the *Archimedean Screw*, patented a few years ago by Mr F. P. Smith, and now very generally adopted. Vessels fitted up with screw-propellers present no unseemly paddle-boxes, are not so liable to be damaged by collisions or by shot, and are as swift and easily managed as those propelled by the old paddles. The screw is formed by radial arms or blades, twisted, as it were, round a central iron axis. The screw thus formed is fixed parallel with the keel, at the stern of the vessel, below the water, and consequently out of sight. A variety of forms of the 'screw' have been patented, chiefly differing as to the *pitch* or angle at which the blades are fixed on the axis. For sea-going vessels the screw will soon, in all likelihood, be the only mode of propulsion adopted, as its advantages, either alone or as an adjunct to ordinary sailing, are numerous and decided.

In Great Britain the engines adopted are those called *condensing*, and they usually work with a pressure of about 40 lbs. on the square inch. In America, the high-pressure engine is generally used; and Stevenson states he was in a vessel on the Ohio, where the common pressure used was 130 lbs. on the square inch!

High-Pressure Engines.

The distinguishing feature of this class of engines is the absence of all contrivances for forming a vacuum in the cylinder; and from the fact of no condenser being used, they are frequently termed *non-condensing engines*. As the steam used for moving the piston has to overcome the ordinary atmospheric pressure acting on it, its elasticity must be greater than in condensing engines. Thus, while in the latter steam of 3 to 5 lbs. on the square inch is used, steam of 40 to 50 lbs. is used in the former; and in some cases steam even of the great pressure of 120 lbs. to the square inch is employed. As the condenser, cold water pump, air-pump, cistern, &c. are dispensed with in the high-pressure engine, it is rendered more compact, and consequently less space is taken up by it. So early as 1720, Leupold produced a high-pressure engine; but the first invention which came into extensive use, was the engine of Messrs Trevithick and Vivian, constructed by them in 1802. Since that period they have come into very general use, being much cheaper than condensing engines; and we may add, that the steam, after working the engine, instead of being projected into the atmosphere, may be used for warming premises, heating water for baths, and similar purposes.

The forms of high-pressure engines are various. The crank-overhead-engine is the simplest form, and is very effective; engines with the crank under the cylinder are also much used; and a small size of this form, represented in fig. 8, is much used for driving small coffee-mills in grocers' shops. Their cost varies from £20 to £50 without the boiler. The most complex of all is the beam high-pressure engine. In general appearance it is much like the double-acting engine of Watt; but of course there is no condenser and its associated apparatus. High-pressure horizontal engines, the whole machinery of which lies horizontally, are coming much into use. Brunel's oblique-acting engine, we believe, is a very efficient form of high-pressure.

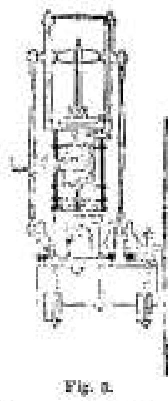


Fig. 8.

As there is greater danger to be apprehended from the use of high-pressure steam, the boilers of the engines are generally provided with two safety-valves—one locked up from the control of the engineer. The boilers are generally not so complex in their arrangements as those of low-pressure; indeed in all their arrangements simplicity is the leading characteristic. They perform their work well, do not require such close attention, and with a reasonable degree of care no danger of explosion need be apprehended. It may be mentioned here that locomotive engines for road and railway are all on the high-pressure system.

Rotatory Engines.

In this form of engine the cylinder, piston, crank, and fly-wheel, are all dispensed with; and a series of chambers or cavities, supplied with valves and traps, revolving round or turning with a central shaft, constitute the engine. As its name imports, the motion derived from the steam traversing these chambers is at once circular or rotatory, no reciprocating motion being produced; and in this lies the chief merit of the invention. Engines of this kind admit of being made very simple, free from complex arrangements, and their power can at once be applied without the intervention of other machinery. The varieties of rotatory engines patented are very numerous; but whether from any inherent error in their principle, amount of friction, or from some other cause, few of them have come into anything like extensive use. The simplest form of all is that introduced by Mr Ruthven of Edinburgh. It is the same in principle as the æolipyle of Hero; and we believe the engines fitted up by this gentleman are powerful, and give satisfaction. One of these which has come under our notice works with great efficiency, the pressure being from 30 to 70 lbs. on the inch. The length of the arms is five feet, the breadth five and a half inches, and the apertures from which the steam issues are one-fourth inch in diameter.

Locomotive Engines.

The form of engine adapted to the railway differs from those already described, these being stationary or fixed in large vessels, while here the smallest bulk possible is essentially required, at the same time as little weight as convenient. Accordingly we find, that in the arrangement of these engines, all that apparatus is rejected which is intended for condensation, and therefore high-pressure steam is used.

In the arrangement or disposition of the parts of the boiler and engine, there are certain peculiarities which require to be described. It is necessary to premise, that the great object is to effect as speedily as possible the conversion of a large quantity of water into vapour. This is accomplished by arranging the boiler in a peculiar manner. It is not one large mass, as in the marine boiler, or land boiler, with a great quantity of water in the centre, but an oblong cylinder, through which are disposed a vast number of brass tubes of a cylindrical shape, amounting to about ninety in number, arranged horizontally. These tubes communicate with the furnace, and the heated air passes through them as it proceeds to the chimney, in which manner an immense quantity of the caloric is applied to assist in the evaporation of the water; so that the boiler might, nevertheless, be considered merely the same as the common one, but with the chimney subdivided into an immense number of small tubes passing through it to the large vent hole or grand chimney. These tubes were suggested by Mr Booth, secretary of the Liverpool and Manchester Railway, and improved upon by Mr R. Stephenson, and constituted a great advance in the efficiency of the locomotive steam-engine.

In the sketch, fig. 10, is given a general exterior view of a locomotive, and in fig. 9 a longitudinal section of the apparatus. The boiler is seen forming the great bulk of the engine; its form is cylindrical, being about three feet in diameter, and eight in length. The numerous tubes, as they proceed through this part of the apparatus, are seen in transverse section in fig. 9, and longitudinal section, fig. 11. At the front of the engine is the smoke-box terminating in the chimney above, and below, there is the steam tube, and the cylinder and piston, which lie horizontally (A). At the back of the engine is the fire-box,

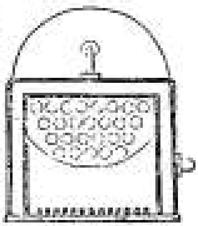


Fig. 9.

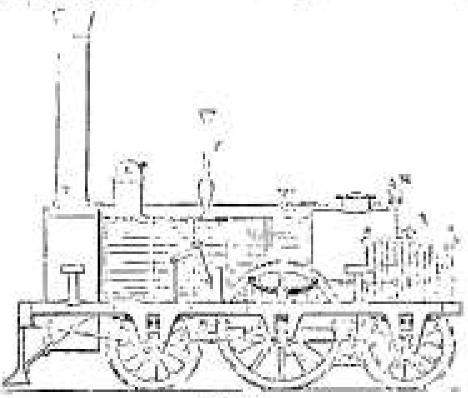


Fig. 10.

almost completely surrounded by water, and immediately behind this is the railed space (P) on which the engineer stands. On the upper surface of the engine, proceeding from the hind part forwards, there is the steam whistle (X), by which notice is given of the approach of the engine. A little anterior to it is the man-hole, by which the boiler can be cleaned, and such repairs made as are requisite. Still farther forwards, we arrive successively at the two valves (V' V), by which the safety of the boiler is secured. The first (V') is always under the control of the engineer; but the second, nearer the chimney (V), is loaded higher, but completely shut up. A round spherical eminence (B) is then perceived immediately behind the chimney, called the *separator*, in which the steam gathers before it is conveyed by the tubes to the cylinder. The cylinders (two in number) are placed below the chimney, and lie immediately before the front wheels (A, fig. 11), and the steam passes to them by the steam pipe (S) into the two cylinders, whence it escapes afterwards into the chimney. The reason why this tube rises so high in the large chamber is, that no water may descend to the cylinder, which might likely arise from the agitation the water suffers from the motion. At the point where the steam tube in the hot air chamber meets the connecting pipe with the boiler, a regulator is placed, for increasing or diminishing the flow of steam.

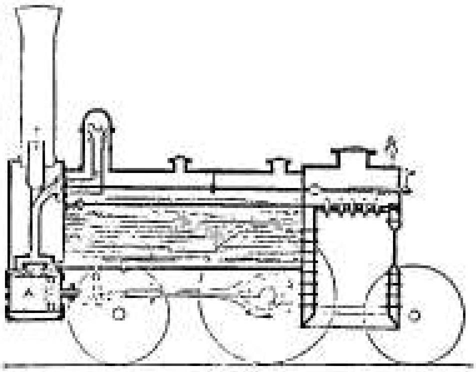


Fig. 11.

The steam, as it escapes from the cylinder by two pipes, meets in the common tube, and rushing upwards into the chimney, is in part condensed, and mainly contributes to the draught of the chimney, which otherwise would be totally inefficient to work the fire.

From the great number of the tubes which fill up the boiler, the locomotive engine is not attended with much danger in bursting; for these tubes being weak, compared with the external casing of the boiler, yield readily on any unusual increase of the elastic force of the vapour; the consequence is, that the fire is put out gradually. When one yields, a plug of wood is introduced, which is generally sufficient till the end of the run, or till arrival at the next station.

The eccentrics for working the valves, and allowing the steam to gain either side of the piston, are fixed to the main crank axle. Sometimes there are two pair of eccentrics, the additional one being for the movement backwards, when the engine makes a retrograde movement. The size of the steam cylinder is about twelve inches in diameter, and eighteen inches' stroke. The driving wheels are usually six feet diameter; and some of ten feet diameter have been tried on the Great Western Railway. Three cylinder engines of great power have been introduced by Mr Stephenson, their speed being upwards of seventy miles an hour!

The engine is always attended by a tender, in which the coke and water are conveyed. The mode in which the different coaches are arranged may be seen in the following number (26), where a train is figured with the engine and tender.

The power of a locomotive is estimated by the quantity of water which the boiler can convert into steam within a given time. Between 70 and 80 cubic feet is the average amount; but in the Bristol railway, so much as 200 cubic feet are evaporated within the same time. The quantity of fuel consumed in Stephenson's engine is about $\frac{1}{2}$ lb. for every ton per mile.

Duty of Engines.

The term *duty* is adopted to express the load which may be raised a given perpendicular height by the consumption of a given quantity of fuel. In engines used for the purposes of manufactures, or for navigation, it is difficult to calculate exactly the amount of resistance which the machine encounters; but where employed for pumping water, their performance is more easily determined. The highest duty performed by an engine in Cornwall, at Wheal Hope Mine, was raising nearly 47,000,000 lbs. one foot high by the combustion of one bushel of coals. Another engine at St Austell raised 95,000,000 lbs. one foot high by one bushel of coal. This enormous mechanical effect was so unusual, that doubts arose as to the correctness of the report; and in the presence of a number of witnesses the engine was again tried, when the result was, that it raised 125,500,000 lbs. one foot high, by the consumption of one bushel of coal.

Expansive Action of Steam.

Steam, as already observed, being a vapour, possesses consequently the expansive property peculiar to such bodies; and as the piston either descends or ascends by the impulse of the steam, it follows that the velocity of the stroke is not equal throughout. Suppose the piston is at the summit of the cylinder, and the steam enters above, the piston will then begin to descend, opposed only by its inertia and friction against the sides of the cylinder. But as the motion downwards continues, this becomes accelerated from its own inertia, and therefore the resistance being less than at first, the steam forces it downwards with increased velocity. The velocity will be at the *maximum*, or nearly so, when it has completed the descent. Watt, ever alive to all the modes of bringing the greatest effect from the steam, considered that a moving power, in addition to that obtained by the stroke of the piston, might be obtained and rendered practically available. We refer to a method of still doubling the effect of the steam, and that tolerably easy, by using the power of steam rushing into a vacuum—at present lost. This would do little more than double the effect, but it would too much enlarge the vessels to use it all: it is particularly applicable to wheel engines, and may supply the want of a condenser where the force of steam only is used. Open one of the steam valves, and admit steam until one-fourth of the distance between it and the next valve is filled with steam; then shut the valve, and the steam will continue to expand and to press round the wheel with a diminishing power, ending in one-fourth of its first exertion. The sum of the series will be found greater than one-half, though only one-fourth of steam was used.

This mode of using the steam expansively may be illustrated in the following manner:—If the piston is pressed by a weight of one ton, and can be raised four feet when the cylinder is supplied with steam of the ordinary pressure of one atmosphere, the same piston loaded with four tons will be raised one foot, if the cylinder be one-fourth full of steam of four atmospheres. When the steam of four atmospheres is admitted, it is cut off when the piston is raised one foot. But the piston has now received an impulse, and the steam, beginning to expand under it with a gradually diminishing force, is raised to the second foot, the volume now being doubled, and its elasticity only equal to two atmospheres. On the piston being elevated to the third foot, the volume of the steam will be trebled, and its pressure or elasticity now reduced to one atmosphere and a third. But when the piston is raised the fourth foot, the steam will have been quadrupled in volume, and the force equal to that of one atmosphere.

This principle is now much employed, and particularly in the Cornish mines, where it has been used with great success, the pressure of the steam in the pumping or drainage engines being four atmospheres. The benefit of working a steam-engine in this mode increases the earlier the steam is cut off, but not much after it is rarefied four times.

Steam cut off.	Power multiplied.
½	1·7
⅓	2·1
¼	2·4
⅕	2·6
⅙	2·8
⅐	3·0
⅛	3·2

Horse Power.

In forming the estimate of the power of a steam-engine, it is usual to refer to horse power as a standard. Different values have been given of the power of a horse;* but that generally adopted is, that it can raise a weight of 33,000 lbs. one foot per minute, and therefore a steam-engine capable of executing that work is rated at one-horse power. On a railway, this power is considered equal to transport 400 tons 1 mile per day; or a horse draws 200 lbs. at the rate of 2½ miles in an hour, continuously, over a pulley. The evaporation of a cubic inch of water, when converted into steam, affords a mechanical force capable of raising a ton one foot high. Fifteen cubic inches of water, therefore, when converted into steam, are equal to the power of one horse per minute, or 900 cubic inches per hour for each horse power.

To evaporate this, from 7 to 12 lbs. of fuel are required in the same time (one hour); but in marine engines, the quantity consumed is about 8 lbs.; the proportion of fuel they consume being as 2 to 3 compared with other engines.

Engineers possess rules for calculating the elastic force of steam and power of engines. The following may give an idea of the method of calculation:—

To find the power of an engine, multiply double the length of the stroke† by the number of strokes per minute, and we get the velocity of the piston per minute. If the engine works expansively, the mean effective pressure must be found. Multiply the square of the cylinder's diameter in inches by the mean effective pressure on the piston in pounds on the square inch, and by the velocity of the piston, point off these figures, and divide the product by 42, and the quotient will express the number of horses' power. Let the diameter of the cylinder be 36 inches, the length of stroke 4 ft., the number of strokes per minute 24, and the mean effective pressure on the piston 4 lbs. per sq. inch, then

```
8 Feet × 24 = 192 per minute.
  Diameter,        36
                   36
                  216
                  108
                 1296
Mean pressure,      4 lbs.
                 ----
                 5184
Velocity,         192
                10368
               46656
                5184
          42)995328(23,7 horse power.
             84
             155
             126
             293
```

Of the steam power at present employed in Great Britain, it is almost impossible to form an accurate estimate. Statisticians, however, reckon it as equal to about 2,000,000 horse power—an amount of animal force which could never, in reality, be brought into full operation without extensive derangement of our whole economic system. It is indeed beyond the scope of the ordinary terms of language to express the advantages resulting from the perfection and employment of the steam-engine. We have only to look abroad on the world, and see what mighty applications of this wonderful machine are everywhere visible. Steam navigation, railway travelling, automatic factory-labour, steam-printing, mining, and a hundred of other arts, have been brought to their present state only by means of its wonderful assistance. In its adaptation to mills and factories, steam is doubtless more costly than water-power; but being independent of situation or seasons, it is in general circumstances preferable. Its placid steadiness, and the ease with which it may be managed, are also great recommendations in its favour. As a motive power in the industrial arts, steam takes the precedence of all others; and viewing it as an economiser of labour and time, it must be assuredly pronounced as the greatest of modern mechanical contributors to human progress and comfort.

* The medium power of the horse is rated at 22,000 lbs. raised one foot per minute; but 33,000 is the standard applied by engineers to the steam-engine.

† The length of the stroke of an engine implies the space moved through by the piston in its ascent and descent, and consequently is equal to one complete revolution of the crank shaft; hence the reason why the length of the stroke must be doubled.

INLAND CONVEYANCE.

The artificial conveyance of person and property from one locality to another may be treated under two great heads—*Inland* and *Maritime*. To these science may in time add a third—namely, *Aërial;* but as yet, all the schemes and experiments in this department have been without any available result.* Confining our remarks, therefore, to what is real and practicable—roads, rivers, canals, and railways may be regarded as the main channels of inland transport; while the ocean alone forms the highway of maritime intercommunication. In the present sheet, we mean to direct attention to the history, construction, and maintenance of the former channels—subjects which belong exclusively to the recent science of Civil Engineering; reserving consideration of ocean transport, which requires the conjoint aid of the navigator and civil engineer, for a subsequent number. As a fitting introduction, both in point of information and interest, we may briefly advert to the modes of conveyance adopted by nations but little advanced in the arts of civilisation.

PRIMITIVE MODES OF CONVEYANCE.

The means adopted in early times for artificial transport were, as may be supposed, of the rudest kind, as is still the case in those countries which are little advanced in the useful arts. The most degrading species of conveyance that seems to have been practised, was the employment of human labour in bearing litters or palanquins, specimens of which, on a scale of barbarous splendour, are now seen in India, Burmah, and China.

The first and most obvious improvement in modes of transport, was the substitution of brute for human labour; and it is reasonable to conclude that the value of this practice could not have been long in being pressed on the attention of mankind. We find the term 'beasts of burden' used in the most ancient records, the animals meant being the ass, the horse, and the camel. No trace, however, exists of the progress from *burden* to *draught*, though it also must have taken place at a very early period. The ass and horse are equally adapted for carrying or drawing, but the camel exerts its power only by carrying; draught alone is suitable for the reindeer and ox, the backs of these animals not being fitted by nature for burden.

Burden.

From the earliest times, the camel, in its two varieties of camel and dromedary—respectively two-hunched and one-hunched—has been employed in the sandy regions of Asia as a beast of burden; and without its invaluable services in this respect, these countries could scarcely have been habitable. In ancient times, it formed the engine of carriage among the merchants of Arabia, and conveyed the products of India across the deserts to the populous and wealthy land of Egypt.

The camel is expressly suited by nature for inhabiting and traversing sandy and parched deserts, in which there are places of rest and refreshment only at wide intervals. 'It is the most temperate of all animals,' says Goldsmith, 'and can continue to travel several days without drinking. In those vast deserts, where the earth is everywhere dry and sandy—where there are neither birds nor beasts, neither insects nor vegetables—where nothing is to be seen but hills of sand and heaps of bones—there the camel travels, posting forward, without requiring either drink or pasture, and is often found six or seven days without any sustenance whatsoever. Its feet are formed for travelling upon sand, and utterly unfit for moist or marshy places; the inhabitants, therefore, find a most useful assistant in this animal, where no other could subsist, and by its means cross those deserts with safety which would be impassable by any other method of conveyance.

Camels are easily instructed in the methods of taking up and supporting their burdens; their legs, a few days after they are produced, are bent under their belly; they are in this manner loaded, and taught to rise; their burden is every day thus increased, by insensible degrees, till the animal is capable of supporting a weight adequate to its strength. The same care is taken in making them patient of hunger and thirst: while other animals receive their food at stated times, the camel is restrained for days together, and these intervals of famine are increased in proportion as the animal seems capable of sustaining them. By this method of education, they live five or six days without food or water; and their stomach is formed most admirably by nature to fit them for long abstinence. Besides the four stomachs which all animals have that chew the cud (and the camel is of the number), it has a fifth stomach, which serves as a reservoir to hold a greater quantity of water than the animal has an immediate occasion for. It is of sufficient capacity to contain a large quantity of water, where the fluid remains without corrupting, or without being adulterated by the other aliments. When the camel finds itself pressed with thirst, it has here an easy resource for quenching it: it throws up a quantity of this water, by a simple contraction of the muscles, into the other stomachs, and this serves to macerate its dry and simple food.

In Turkey, Persia, Arabia, Barbary, and Egypt, the whole commerce is carried on by means of camels; and no carriage is more speedy or less expensive in these countries. Merchants and travellers unite themselves into a body, furnished with camels, to secure themselves from the insults of the robbers that infest the countries in which they live. This assemblage is called a *caravan*, in which the numbers are sometimes known to amount to above ten thousand, and the number of camels is often greater than that of the men. Each of these animals is loaded according to his strength, and he is so sensible of it himself, that when his burden is too great, he remains still upon his belly, refusing to rise till his burden be lessened or taken away. In general, the larger camels are capable of carrying one thousand pounds' weight, and sometimes twelve hundred; the dromedary from six to seven hundred. In these trading journeys they travel but slowly; their stages are generally regulated, and they seldom go above thirty, or at most about thirty-five miles a-day. Every evening, when they arrive at a stage, which is usually some spot of verdure where water and shrubs are in plenty, they are permitted to feed at liberty: they are then seen to eat as much in an hour as will supply them for twenty-four. They seem to prefer the coarsest weeds to the softest pasture—the thistle, the nettle, the cassia, and other prickly vegetables are their favourite food; but their drivers take care to supply them with a kind of paste composition, which serves as a more permanent nourishment. As these animals have often gone the same track, they are said to know their way precisely, and to pursue their passage when their guides are utterly astray. When they come within a few miles of their baiting-place in the evening, they sagaciously scent it at a distance, and increasing their speed, are often seen to trot with vivacity to their stage.

The patience of this animal is most extraordinary; and it is probable that its sufferings are great, for when it is loaded, it sends forth most lamentable cries, but never offers to resist the tyrant that oppresses it. At

* For the principles of *aërostation*, or the art of moving through the atmosphere, see PNEUMATICS, page 240.

the slightest sign, it bends its knees, and lies upon its belly, suffering itself to be loaded in this position: by this practice the burden is more easily laid upon it than if lifted up while standing. At another sign it rises with its load, and the driver getting upon its back, between the two panniers—which, like hampers, are placed upon each side—he encourages the camel to proceed with his voice and with a song. In this manner the creature proceeds contentedly forward, with a slow uneasy walk of about four miles an hour, and when it comes to its stage, lies down to be unloaded.'

From Major Skinner's account of his 'Journey to India,' in the course of which he travelled twenty days with a numerous caravan from Damascus to Bagdad, we have the following lively picture of the mode of conveyance by camels:—

'I must give a description of our equipage, now that we are fairly launched on the great waste. I ride a white camel, with my saddle-bags under me, and a pair of water-skins, quite full, beneath them: over the saddle is my bed. A thick cherry-stick, with a cross at the end of it, serves to guide the animal: a gentle tap on the side of his neck sends him to the left, and one on the opposite makes him turn back again to the right: a knock on the back of his head stops him, and a few taps between the ears bring him to his knees, if accompanied by a guttural sound, resembling, as the Arabs say, the pronunciation of their letter *ikhe*. To make him move quickly, it is necessary to prick him with the point of the stick.

We passed over a perfect level this morning, strewed with flowers, and thick with pasture for the camels, where we are now resting. It is not usual here, as in many parts of the East, for the camels to wind in long strings, one after the other. Our numbers, amounting to fifteen hundred, are scattered over the surface in all directions, as far as the eye can trace. In travelling, the sheiks, or chiefs of the caravan, attended by the military part of their equipage, mounted on dromedaries, move in advance, while the loaded camels follow at some distance, in parallel masses, opening out, or changing the form, as the grass renders it necessary. They fall so naturally into military figures, that it is difficult to conceive their doing it without direction. We have several tents in the caravan. They are pitched so as to permit the camels belonging to each to lie in the intervals, where they are placed in *squads* for the night. They are by no means agreeable neighbours: for although they are not able to move from their place, they make a most unpleasant gurgling noise.

The rate at which a loaded camel travels is estimated at two and a-half miles an hour by almost every traveller. Our caravan has not, I think, exceeded this; but the variety of its movements has been very tiresome. There is so strong a resemblance to a voyage at sea in a passage across the desert, that I cannot divest myself of the belief that the moving mass is but a collection of small vessels, carried into a heap by the tide. Every man is ready with his stick to fend off the animal that approaches him: one push separates the camels, as it would separate a couple of boats; and they move away, quite unconscious of the circumstance, till another movement swings them together again.'

Turning to the new world, we find, from the remotest period to which the Peruvian records extend, that the aborigines not only used the llama and alpaca for food and clothing, but also employed them in their military and domestic service, as the Arabs do the camel. The llama was principally destined to carry burdens, although, compared with the Asiatic drudge, the difference in size and strength is considerable. Its load, according to Mr Walton, never exceeded 150 lbs., with which it was not required to travel more than three leagues per day; whereas in the working part of the twenty-four hours, the camel journeys double that distance with 800 lbs. or more upon his back. For this difference the Peruvians made up in the greater number of their beasts of burden, one drove sometimes exceeding five hundred head, whose subsistence on the road was entirely left to chance. Neither whip nor goad was used to urge them on: one llama, older and more experienced than the rest, led the way, the others following irregularly but quietly after. Owing to its docility and knowledge of its keeper, this animal evidently requires less training than the camel. It needs no rein—not even a pack-saddle—so long as the panniers or packages are well poised.

We need scarcely advert to the fact, that wherever civilisation has made any progress, the horse, the ass, and their hybrid the mule, have been used as beasts of burden—that is to say, in those countries which form their natural habitats. At what period the horse was first subjected to the purposes of man, we have no authentic record. He is mentioned by the oldest writers, and it is probable that his domestication was nearly coeval with the earliest state of society. Trimmed and decorated chargers appear on Egyptian monuments more than four thousand years old; and on sculptures equally, if not more ancient, along the banks of the Euphrates. One of the oldest books of Scripture contains the most powerful description of the war-horse; Joseph gave the Egyptians bread in exchange for horses; and the people of Israel are said to have gone out under Joshua against hosts armed with 'horses and chariots very many.' At a later date, Solomon obtained horses 'out of Egypt, and out of all lands,' and had 'four thousand stalls for horses and chariots, and twelve thousand horsemen.' Thus we find, that in the plains of the Euphrates, Nile, and Jordan, the horse was early the associate of man, bearing him with rapidity from place to place, and aiding in the carnage and tumult of battle. He does not appear, however, to have been employed in the more useful arts of agriculture and commerce; these supposed drudgeries being imposed on the more patient ox, ass, and camel. Even in refined Greece and Rome, he was merely yoked to the war-chariot, placed under the saddle of the soldier, or trained for the race-course. As civilisation spread westward over Europe, the demands upon the strength and endurance of the horse were multiplied, and in time he was called upon to lend his shoulder indiscriminately to the carriage and wagon, to the mill, plough, and other implements of husbandry. It is in this servant-of-all-work capacity that we must now regard him; and certainly a more docile, steady, and willing assistant it is impossible to find. For burden, the ass perhaps is more steady and enduring; but both are surpassed by the mule, which in Spain, South America, Mexico, and other countries destitute of good roads, affords one of the most available modes of commercial transport. Headed by one of superior sagacity, they move in long cavalcades, like the camel and llama, and with their gay caparisons, tinkling bells, and jauntily-dressed drivers, form a very picturesque object in the landscape.

Another primitive mode of carriage, and the last which we shall mention, is the employment of the huge and unwieldy but powerful elephant. At which time this animal was first subjugated, and trained to take part in the court and military equipage of the East, we have no means of knowing. His form appears on the most ancient Hindoo sculptures; he figures in their mythology; and he is spoken of with pride and veneration in their earliest records. In that fertile and luxurious region he had been trained for centuries before the names of Greece and Rome were known, and even long before the people of western Asia had passed from the primitive or pastoral condition. It was to Alexander the Conqueror that the western world was first indebted for the elephant;—he it was that made the sports of Persia and India familiar to the Greeks and Macedonians. The acquisition of the war-elephant gave new pomp and splendour to his squadrons, and his example was followed by degrees by other nations. In time, the Egyptians, Carthaginians, Romans, all made use of elephants, both to assist in the march, by carrying enormous loads of baggage, and to join the ranks, mounted by numbers of archers and spearmen, as here represented:—

Since the introduction of firearms and artillery, the war-elephant has been greatly abandoned even in the East, and is now chiefly used in carrying baggage, in doing other heavy work, and, above all, in adding to the 'pomp and circumstance' of Oriental authority. The present employment of the elephant in India, according to Von Orlich and other recent writers, is exceedingly varied—from the piling of firewood and the drawing of water, to the dragging of artillery and the carriage of royalty. When placed under the *howdah* (a covered seat for persons of rank), his back is protected by a thickly-stuffed hair cushion, over which is spread an ornamental covering. The howdah is made to contain two persons, and this is the amount of the travelling elephant's burden. The driver sits on his neck, immediately behind his ears, and guides him with an iron prong; and he is in general so docile, as to kneel for the parties to mount him. His great use, however, is as a beast of burden in a country where there are few or no roads; and since an ordinary elephant will carry as much as five camels, we can readily perceive their value in marching not only with the commanders and sick, but with the tents and furniture. He is equally serviceable as a beast of draught, pulling with ease what it would take ten horses to move; and it is for this reason that the Indian army have recently yoked him to their heavy artillery. Another power which the animal possesses, and one which is unknown to the horse or ox, is that of pushing; and if his forehead be protected by a pad, he will push forward weights which perhaps he could not draw. These, and many other duties, the elephant performs willingly, and, if gently treated and well fed, with a regularity of disposition which seems almost mechanical.

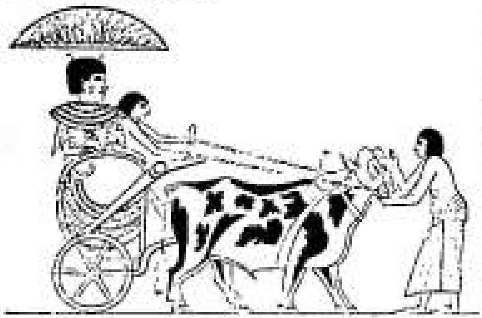
Draught.

The draught of the reindeer is employed in Lapland as the chief means of artificial locomotion, and is always exerted on a species of sledge, which, by its form, is suitable for gliding easily over the frozen ground or snow. The shape of the sledge somewhat resembles a small boat with a sharp prow, and flat in the rear, against which the inmate of the vehicle rests. The traveller is swathed in his carriage like an infant in a cradle, with a stick in his hand to steer the vessel, and disengage it from pieces of rock or stumps of trees that may happen to obstruct the route. He must also balance the sledge with his body, otherwise he will be in danger of being overturned. The traces by which this carriage is fastened to the reindeer are fixed to a collar about the animal's neck, and run down over the breast, between the fore and hind legs, to be connected with the prow of the sledge; the reins, managed by the traveller, are tied to the horns; and the trappings are usually furnished with little bells, the sound of which is agreeable to the animal. With this draught, the reindeer, if pressed, will travel from sixty to eighty miles in a day; but more frequently he does not travel more than forty or fifty, which is a good day's journey. Before he sets out, the Laplander whispers in his ear the way he has to go, and the place at which he has to halt, firmly persuaded that the beast understands his meaning. In the beginning of winter the Laplanders mark the most frequented paths, by strewing them with fir boughs; which, being frequently covered with new snow, alternately pressed by the sleighs, hardens them into a kind of causeway, which is the more smooth if the surface has felt a partial thaw, and been crusted by a subsequent frost. It requires great caution to follow these tracks; for if the carriage deviates to the right or left, the traveller is plunged into an abyss of snow. In less frequented parts, where there is no such beaten road, the Laplander directs his course by certain marks made on the trees.

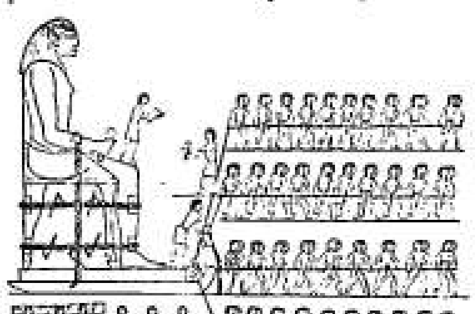
Amongst the Kamschatdales, Esquimaux, and other northern tribes, a peculiar variety of dog is almost universally employed as a beast of draught, and occasionally as one of burden. These animals are trained to draw the rude sledges that the Esquimaux, for example, are able to construct, which are about five feet long and two wide. The runners are generally made of pieces of wood and bone lashed together, with the interstices stuffed with moss, and the whole secured by a coating of ice, which is readily produced by the severity of the climate. The runner is shod with a plate of hard bone, and over this water is poured, to form another coating of ice, and this is renewed as often as it is worn off—a mode of shoeing which serves very well for nearly eight months out of the twelve. The dogs are harnessed by a collar, and a single trace running over their backs. They are not tied to each other, but each one is attached separately to the sledge, and at unequal distances, some even at twenty feet. The most docile dog is the leader, and his is the longest trace. A good leader is very attentive to the words of the conductor, and looks back over his shoulder with great earnestness to catch the word of command. Ten dogs make a full team, and will draw a sledge twelve miles an hour; and nine of them have been known to draw 1611 lbs. a mile in nine minutes. Three dogs drew Captain Lyon, in a sledge weighing 100 lbs., a mile in six minutes. On a good surface, six or seven dogs will perform in a day a journey of sixty miles, with nearly 1000 lbs. to draw. When there is no snow, the dogs are sometimes made to carry burdens in a kind of panniers, and one will travel thus with 25 lbs.

In Russia, and also in Canada, sleighs are used in winter for conveyance from place to place, the beast of draught being the horse. As the roads in many parts of Canada are very unsuitable for any species of travelling, it happens that sleighing over the hardened surface of the snow in winter is by far the best mode of communication in that country. It is almost unnecessary to add, that the sledge, which is the rudest kind of carriage for draught, has disappeared in all countries considerably advanced in improvement.

From the rude sledge, drawn with an incalculable degree of labour over the rough ground, the next important step in mechanical construction is to apply wheels, for the purpose of lessening the friction of the moving body. The first application of wheels to carriages is beyond the reach of record. Wagons are spoken of in the book of Genesis, from which it may be inferred that a knowledge of wheels was common in a very early age. It is further known that the making of wheels formed a distinct trade among the citizens of Thebes in ancient Egypt, three or four thousand years ago. The most elegant of the Egyptian carriages was a kind of gig, or light open chariot, on two wheels, called the *plaustrum*, which is thus described by Mr Wilkinson in his work on the Manners and Customs of the Ancient Egyptians:—'The plaustrum was very similar to the war-chariot and the curricle, but the sides appear to have been closed, and it was drawn by a pair of oxen instead of horses. The harness was much the same, and the wheels had six spokes. In a journey, it was occasionally furnished with a sort of umbrella, fixed upon a rod rising from the centre or back of the car; the reins were the same as those used for horses, and apparently furnished with a bit; and besides the driver, a groom or runner sometimes attended on foot, at the head of the animals, perhaps feeding them as they went. The annexed engraving represents an Ethiopian princess, who is on her journey through Upper Egypt to Thebes, where the court then resided:'—



From the researches of the same authority, we are enabled to form some estimate of the enormous trouble incurred by the ancient Egyptians in the transport of the heavy stones which they employed in building their temples. Some of these blocks weighed three or four thousand tons, and were usually conveyed from the quarries from which they were cut in flat-bottomed boats, on canals made for the purpose. Occasionally, however, when this mode of transport was unsuitable, the stone was drawn on sledges, perhaps some hundreds of miles, by oxen, or by human labour. The accompanying woodcut represents, in an abridged form, the mode of conveying colossal figures in stone from the quarries to the temples in which they were to be set up. 'One hundred and seventy-two men, in four rows



of forty-three each [we represent only as far as twenty each row], pull the ropes attached to the front of the sledge; and a liquid, probably grease, is poured from a vase by a person standing on the pedestal of the statue, in order to facilitate its progress as it slides over the ground, which was probably covered with a bed of planks, though they are not indicated in the painting. Some of the persons employed in this laborious duty appear to be Egyptians, the others are foreign slaves, who are clad in the costume of their country. Below are persons carrying vases of the liquid, or perhaps water, for the use of the workmen, and some implements connected with the transport of the statue, followed by taskmasters with their wands of office [but which we have not had space to include]. On the knee of the figure stands a man, who claps his hands to the measured cadence of a song, to mark the time, and insure their simultaneous draught. The height of the statue appears to have been about twenty-four feet, including the pedestal. It was bound to the sledge by ropes, which were tightened by means of pegs inserted between them, and twisted round until completely braced; and to prevent injury from the friction of the ropes upon the stone, a compress of leather or other substance was introduced at the part where they touched the statue.' Besides the great number of persons employed in drawing these huge blocks, it was customary for a band of some hundreds of soldiers to attend, perhaps for the purpose of overawing the slaves, and compelling obedience in their odious task. A more degrading means of mechanical conveyance it would be impossible to represent.

TRAVELLING IN PAST TIMES IN BRITAIN.

The modes of travelling and conveyance in Britain were of a comparatively rude and primitive kind till the latter part of the seventeenth century; and anything like comfortable and quick travelling cannot be said to have been known till a century later, when mail-coaching was introduced. In old times, people of a humble rank travelled only on foot, and those of a higher station on horseback. Noblemen and gentlemen, as much for ostentation as use, kept running footmen—a class of servants active in limb, who ran before them on a journey, or went upon errands of special import. The pedestrian powers of these footmen were often surprising. For instance, in the Duke of Lauderdale's house at Thirlstane, near Lauder, on the tablecloth being one morning laid for a large dinner-party, it was discovered that there was a deficiency of silver spoons. Instantly the footman was sent off to the duke's other seat of Lethington, near Haddington, fully seventeen miles off, and across hills and moors, for a supply of the necessary article. He returned with a bundle of spoons in time for dinner. Again—at Hume Castle in Berwickshire, the Earl of Home had one night given his footman a commission to proceed to Edinburgh (thirty-five miles off), in order to deliver a message of high political consequence. Next morning early, when his lordship entered the hall, he saw the man sleeping on a bench, and conceiving that he had neglected his duty, was about to commit some rash act, when the poor fellow awoke, and informed Lord Home that his commission had been executed, and that, having returned before his lordship was stirring, he had only taken leave to rest himself a little. The earl, equally astonished and gratified by the activity of his faithful vassal, rewarded him with a little piece of ground, which to this day bears the name of the *Post Rig*—a term equivalent to the postman's field, and an unquestionable proof, as all the villagers at Hume devoutly believe, of the truth of the anecdote. The custom of keeping a running footman did not cease amongst noble families in Scotland till towards the middle of the last century.

When the matter of communication was of particular importance, or required to be despatched to a considerable distance, horsemen were employed; and these, by means of relays of fresh animals, and great toil of body, would proceed journeys of some hundreds of miles to accomplish what would now be much better done by a post letter. Some journeys performed on horseback in former days would be considered wonderful even in modern times with good roads. Queen Elizabeth died at one o'clock of the morning of Thursday the 24th of March 1603. Between nine and ten, Sir Robert Carey left London (after having been up all night), for the purpose of conveying the intelligence to her successor James at Edinburgh. That night he rode to Doncaster, a hundred and fifty-five miles. Next night he reached Witherington, near Morpeth. Early on Saturday morning he proceeded by Norham across the Border; and that evening, at no late hour, kneeled beside the king's bed at Holyrood, and saluted him as king of England, France, and Ireland. He had thus travelled four hundred miles in three days, resting during the two intermediate nights. But it must not be supposed that speed like this was attained on all occasions. At the commencement of the religious troubles in the reign of Charles I., when matters of the utmost importance were debated between the king and his northern subjects, it uniformly appears that a communication from Edinburgh to London, however pressing might be the occasion, was not answered in less than a fortnight. The crowds of nobles, clergymen, gentlemen, and burghers, who at that time assembled in Edinburgh to concert measures for opposing the designs of the court, always dispersed back to their homes after despatching a message to King Charles, and assembled again a fortnight thereafter, in order to receive the reply and take such measures as it might call for. And even till the last century was pretty far advanced, the ordinary riding post between London and Edinburgh regularly took a week to the journey.

In consequence of the inattention of our ancestors to roads, and the wretched state in which these were usually kept, it was long before coaching of any kind came much into fashion. Though wheeled vehicles of various kinds were in use among the ancients, the close carriage or coach is of modern invention. The word *coach* is Hungarian, and the vehicle itself is supposed to have originated in Hungary. Germany certainly appears to have taken the precedence of the nations of Western Europe in using coaches. They were introduced thence into England some time in the sixteenth century, but were, after all, so little in vogue throughout the whole reign of Elizabeth, that there is no trace of her having ever used one. Lord Grey de Wilton, who died in 1593, introduced a coach into Ireland, the first ever used in that country. One was introduced into Scotland—we rather think from France—about the year 1571. It belonged to the famous Secretary Maitland of Lethington, who, during the horrid civil war between the adherents of Mary and those of her son James, made a journey in that vehicle from Edinburgh Castle, which he was holding out for the queen, to Niddry in West Lothian, for the purpose of holding a consultation with some others of her friends—the first time, it is believed, that a close carriage was ever used in Scotland. Fynes Morison, who wrote in the year 1617, speaks of coaches as recently introduced, and still rare in Scotland. For a long time these conveniences were only used by old people, who could not well bear riding. The young and active despised them, as tending to effeminacy, and as not being so quick of movement as the horse. The Duke of Buckingham, in 1619, first used a coach with six horses—a piece of pomp which the Duke of Northumberland thought proper to ridicule by setting up one with eight. Charles I. was the first British sovereign who had a state carriage. Although Henri IV. was killed in a coach—the only one, by the way, he possessed—his ordinary way of appearing in the streets of Paris was on horseback, with a large cloak strapped on behind, to be used in case of rain. In Scotland, previous to the civil war, coaches were only used by persons of high estate.

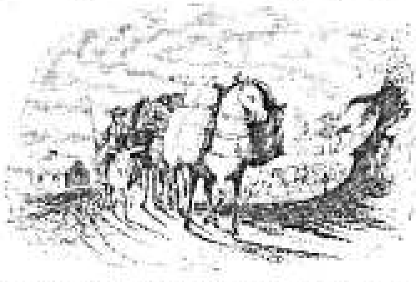
In a pamphlet called 'The Grand Concern of England Explained,' published in 1673, the writer very gravely attempts to make out that the introduction of coaches was ruining the trade of England. The following is an example of his mode of reasoning:—'Before the coaches were set up, travellers rode on horseback, and men had boots, spurs, saddles, bridles, saddle-cloths, and good riding-suits, coats and cloaks, stockings and hats, whereby the wool and leather of the kingdom were consumed. Besides, most gentlemen, when they travelled on horseback, used to ride with swords, belts, pistols, holsters, portmanteaus, and hat-cases, which in these coaches they have little or no occasion for. For when they rode on horseback, they rode in one suit, and carried another to wear when they came to their journey's end, or lay by the way; but in coaches, they ride in a silk suit, with an Indian gown, with a sash, silk stockings, and the beaver hats men ride in, and carry no other with them. This is because they escape the wet and dirt which on horseback they cannot avoid; whereas in two or three journeys on horseback, these clothes and hats were wont to be spoiled; which done, they were forced to have new very often, and that increased the consumption of manufacture. If they were women that travelled, they used to have safeguards and hoods, side-saddles and pillions, with strappings, saddle or pillion cloths, which, for the most part, were laced and embroidered; to the making of which there went many several trades, now ruined.' But the writer has other reasons to urge against coach travelling. 'Those who travel in this manner,' he observes, 'become weary and listless when they ride a few miles, unwilling to get on horseback, and unable to endure frost, snow, or rain, or to lodge in the fields.' Besides, he asks, 'what advantage it can be to a man's health to be called out of bed into these coaches an hour or two before day in the morning!—to be hurried in them from place to place till one, two, or three hours within night; insomuch that, after sitting all day, in the summer time, stifled with heat and choked with dust—or in the winter time, starving or freezing with cold, or choked with filthy fogs, they are often brought into their inns by torchlight, when it is too late to sit up to get supper, and next morning they are forced into the coach so early, that they can get no breakfast! What addition is it to men's health or business to ride all day with strangers, oftentimes sick, ancient, diseased persons, or young children crying; all whose humours he is obliged to put up with, and is often poisoned with their nasty scents, and crippled with boxes and bundles! Is it for a man's health *to be laid fast in the foul ways, and forced to wade up to the knees in mire; afterwards* sit in the cold till teams of horses can be sent to pull the coach out? Is it for their health to travel in rotten coaches, and to have their tackle, or perch, or axle-tree broken; and then to wait three or four hours (sometimes half the day), and afterwards to travel the whole of the night to make good their stage?'

These, however, do not exhaust the patriotic clamours of the writer against the odious innovation of stage-coaching. He says that the practice 'discourages the breed of horses,' an argument which, it is amusing to observe, has also been used in opposition to the introduction of railways in recent times. In certain very peculiar circumstances, he allows, stage-coaching might be tolerated, but in no other. 'If some few stage-coaches were continued—to wit, one to every shire-town in England, to go once a-week backward and forward, and to go through with the same horses they set forth with, and not travel above thirty miles a day in the summer, and twenty-five in the winter, and to shift inns every journey, that so trade might be diffused—these would be sufficient to carry the sick and the lame, that they pretend cannot travel on horseback; and being thus regulated, they would do little or no harm; especially if all be suppressed within fifty miles of London, where they are noway necessary, and yet so highly destructive.'

We have thought fit to introduce these extracts here, not so much for the purpose of amusing the reader with their absurdity, as to afford a caution to the general opponents of improvement. Arguments of a similar illogical nature are now used in reference to almost every proposed melioration in our social condition, and will doubtless, in a century hence, be quoted for their shortsighted folly, though at present meeting with countenance from a large class of the community.

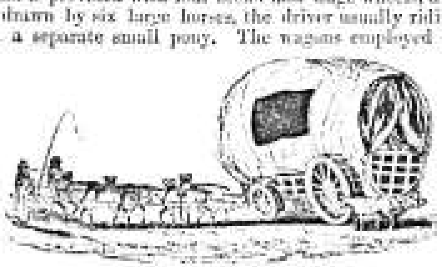
Notwithstanding the introduction of stage-coaches in the seventeenth century, they were placed only on the principal roads, and used almost exclusively by persons of refined taste and wealth. The popular mode of conveyance continued for at least a century afterwards to be by stage-wagons; these were very large and cumbersome machines, drawn by six or eight horses, and devoted chiefly to the carriage of goods to and from the metropolis. The only part of the vehicle which afforded accommodation to passengers was the tail of the wagon, as it was called, a reserved space with a hooped-up cover at the hinder part of the machine; and here, sitting upon straw as they best could, some half-dozen passengers were slowly conveyed—we should rather say jolted—on their journey.

The wagons thus employed in the double office of carrying both goods and passengers were, as we have said, confined chiefly to the great lines of road in England. On all the less important routes, and particularly in Scotland, the only means of conveyance for goods was by pack-horses. These animals were loaded



with sacks thrown across the back; and if not too heavy, piled to a considerable height. A number together were generally conducted in a line along the narrow and badly-constructed paths, that which went before carrying a bell, by the tinkling sound of which the cavalcade was kept from straggling after nightfall. This primitive mode of conveyance continued in operation in some parts of the country till the year 1780 or thereabouts, when one-horse carts came into use.

The old-fashioned wagons still remain in use in England, notwithstanding the numerous improvements in modes of conveyance and locomotion. They are chiefly employed for the carriage of goods between the metropolis and country towns which are at a distance from any line of canal or railway. A wagon of this kind is provided with four broad and huge wheels, and is drawn by six large horses, the driver usually riding on a separate small pony. The wagons employed in



London to convey coal from the wharfs to the houses of consumers, or beer from brewers, are of the same unwieldy form, and are drawn with a needless expenditure of power. Railway traffic, however, is now rapidly diminishing the number of these ponderous vehicles; and the desire for increased speed is as rapidly substituting on all the common roads light and elegant spring-vans.

The length of time consumed in journeys by even the best kind of carriages of past times is now matter for surprise. The stage-coach which went between London and Oxford in the reign of Charles II. required two days, though the space is only fifty-eight miles. That to Exeter (168½ miles) required four days. In 1703, when Prince George of Denmark went from Windsor to Petworth to meet Charles III. of Spain, the distance being about forty miles, he required fourteen hours for the journey, the last nine miles taking six. The person who records this fact says that the long time was the more surprising, as, *except when overturned*, or when stuck fast in the mire, his royal highness made no stop during the journey.

In 1742, stage-coaches must have been more numerous in England than in Charles II.'s time; but it does not appear that they moved any faster. The journey from London to Birmingham (116 miles) then occupied nearly three days, as appears from the following advertisement:—'The Lichfield and Birmingham stage-coach set out this morning (Monday, April 12, 1742) from the Rose Inn, Holborn Bridge, London, and will be at the Angel, and the Hen and Chickens, in the High Town, Birmingham, on Wednesday next to dinner; and goes the same afternoon to Lichfield. It returns to Birmingham on Thursday morning to breakfast, and gets to London on Saturday night; and so will continue every week regularly, with a good coach and able horses.' Thus the whole week was occupied in a journey to and from Lichfield by Birmingham, an entire space of probably not more than 240 miles—that is, at an average of forty miles a day.

Of the stage-coach journey to Bath about 1740, we learn some particulars from Smollett's celebrated novel. Mr Random enters the coach before daylight. It proceeds. A highwayman attacks it before breakfast, and is repulsed by the gallantry of the hero. Strap meanwhile accompanies the coach on horseback. A night is spent on the road, and the journey is finished next day, apparently towards evening—108 miles! At that time there was no regular stage-coach from London to Edinburgh; and the newspapers of the latter city occasionally present advertisements, stating that an individual about to proceed to the metropolis by a postchaise would be glad to hear of a fellow adventurer, or more, to lessen the expenses for mutual convenience. However, before 1754, there was a stage-coach between the two British capitals. In the 'Edinburgh Courant' for that year, it is advertised that—'The Edinburgh stage-coach, for the better accommodation of passengers, will be altered to a new genteel two-end glass coach machine, hung on steel springs, exceeding light and easy, to go in ten days in summer and twelve in winter; to set out the first Tuesday in March, and continue it, from Hosea Eastgate's, the Coach and Horses in Dean Street, Soho, London, and from John Somerville's in the Canongate, Edinburgh, every other Tuesday, and meet at Burrowbridge on Saturday night, and set out from thence on Monday morning, and get to London and Edinburgh on Friday. In winter, to set out from London and Edinburgh every other [alternate] Monday morning, and to go to Burrowbridge on Saturday night; and to set out from thence on Monday morning, and get to London and Edinburgh on Saturday night. Passengers to pay as usual. Performed, if God permits, by your dutiful servant, Hosea Eastgate.' Here the distance of 200 miles requires six days in winter, being at the rate of little more than thirty-three miles a day. So lately as the end of the last century, the journey by the stage between Edinburgh and Glasgow (forty-two miles) occupied a whole day, the passengers stopping to dine on the road. It was considered a great improvement when, in 1799, a coach was started with four horses, which performed the journey in six hours. It is not unworthy of being noticed, that when the mail-coaches were started by Mr Parker in 1788, six and a half miles an hour was the utmost speed attained.

ROADS.

It will appear, from the preceding notices respecting travelling and modes of carriage for goods, that little or no improvement could be expected in either case till a great change for the better was made on the state of the roads. In no branch of art do our ancestors seem to have been more deficient or heedless than in that of making roads, and keeping them in constant repair. In this respect, indeed, they were in a condition of greater ignorance than the ancient Romans, whose roads were on the most extensive and efficient scale, suitable to the necessities of the period, and may here be shortly described.

Ancient Roman Roads.

It is, we believe, generally allowed that the Romans gained a certain degree of knowledge on the subject of road-making from Greece and Carthage, and also perhaps from Egypt; but whatever they learned, they greatly improved upon, and therefore they are entitled to be called the first and best road-makers of whom history has preserved any account. One great leading principle actuated the Roman authorities in establishing roads: it was that of maintaining their military conquests. On vanquishing a barbarous country, their first efforts consisted in penetrating it with good roads, which were maintained with jealous care, and were connected as far as possible in unbroken and direct lines with the seat of government at Rome: this indeed formed one of their grandest engines of subjugation, and affords us a striking proof of their sagacious and active character.

Speaking of the subordinate Roman capitals in Asia Minor, Syria, and Egypt, Gibbon describes as follows the manner in which they were connected by roads:—'All these cities were connected with each other and with the capital by the public highways, which, issuing from the Forum at Rome, traversed Italy, pervaded the provinces, and were terminated only by the frontiers of the empire. If we carefully trace the distance from the wall of Antoninus [in Scotland] to Rome, and from thence to Jerusalem, it will be found that the great chain of communication, from the north-west to the south-east point of the empire, was drawn out to the length of 4080 Roman [or 3740 English] miles. The public roads were accurately divided by milestones, and ran in a direct line from one city to another, with very little respect for the obstacles either of nature or private property. Mountains were perforated, and bold arches thrown over the broadest and most rapid streams. The middle part of the road was raised into a terrace which commanded the adjacent country, consisting of several strata of sand, gravel, and cement, and was paved with large stones, or in some places near the capital with granite. Such was the solid construction of the Roman highways, whose firmness has not entirely yielded to the effect of fifteen centuries. They united the subjects of the most distant provinces by an easy and familiar intercourse; but their primary object had been to facilitate the marches of the legions: nor was any country considered as completely subdued, till it had been rendered in all its parts pervious to the arms and authority of the conqueror. The advantage of receiving the earliest intelligence, and of conveying their orders with celerity, induced the emperors to establish throughout their extensive dominions the regular institution of posts. Houses were everywhere erected, at the distance of only five or six miles; each of them was constantly provided with forty horses; and by the help of these relays, it was easy to travel a hundred miles in a day along the Roman roads. The use of the posts was allowed to those who claimed it by an imperial mandate; but though originally intended for the public service, it was sometimes indulged to the business or conveniency of private citizens.'

From other accounts, we learn that the Roman roads varied in importance and uses. The great lines were called *prætorian ways*, as being under the direction of the prætors; and these formed the roads for military intercourse. Other lines were exclusively adapted for commerce or civil intercourse, and were under the direction of consuls. Both kinds were formed in a similar manner. The plan on which they were made was more calculated for durability than ease to the traveller; and for our modern wheel carriages they would be found particularly objectionable. Whatever was their entire breadth, the centre constituted the beaten track, and was made of large ill-dressed stones, laid side by side, to form a compact mass of from twelve to twenty feet broad; and therefore in their external aspect they resembled the coarse stone causeways which are still in use in the towns and highways of France. Some of the roads had double lines of this solid pavement of this nature, with a smooth brick path for foot passengers; and at intervals along the sides, there were elevated stones on which travellers could rest, or from which cavalry could easily mount their horses. One important feature in the construction of all the Roman roads was the bottoming of them with solid materials. Their first operation seems to have been the removal of all loose earth or soft matter which might work upwards to the surface, and then they laid courses of small stones, or broken tiles and earthenware, with a course of cement above, and upon that were placed the heavy stones for the causeway. Thus a most substantial and durable pavement was formed, the expense being defrayed from the public treasury. Various remains of Roman roads of this kind still exist in France, and also in different parts of Britain. One of the chief Roman thoroughfares, in an oblique direction across the country from London to the west of Scotland, was long known by the name of Watling Street, which has been perpetuated in the appellation of one of the streets in the metropolis.

Modern Macadamised Roads.

We now proceed to offer some account of the introduction of a proper kind of road in modern times. Attempts to improve the roads forming the leading thoroughfares in England were made at the beginning of the eighteenth century; and for that purpose turnpike acts for various districts were passed by parliament. It is a very remarkable fact, that some of the counties in the neighbourhood of London petitioned parliament against the extension of turnpike roads into the remoter parts of the country. These remoter counties, it was pretended, from the cheapness of labour, would be able to sell their corn at a lower rate in the London market than themselves, and would thereby reduce their rents, and ruin their cultivation. In spite of these remonstrances, turnpike roads were extended into the remoter counties, and, as ought to have been expected, so far from injuring the neighbourhood of the metropolis, they greatly increased its value—for an easy interchange of commodities is always universally beneficial.

It is of little moment to ascertain the exact period when these improvements were effected on the roads of England; for, upon the whole, they were only partial, and as yet the proper mode of road-making was not understood. The plan consisted in making the paths somewhat more level than formerly, and of filling up the ruts and holes with stones gathered from the adjacent fields. By this means the holes, ruts, and sloughs were considerably limited in both breadth and depth; but as perfect levelings was not attained, carriages were dreadfully jolted over the rougher parts, and the wheels sunk jarringly into the softer ground beyond. As also no pains were taken to lay down stones of equal bulk, but small and large mixed, it happened that the larger ones in time wrought to the surface, and so created additional jolting to vehicles and damage to the roads. The defects in this species of improved roads were so conspicuous, that various engineers of eminence, and other individuals, turned their attention to the subject; and among these is to be numbered John Loudon M'Adam—a gentleman descended of an old and respectable landed family in the Stewartry of Kirkcudbright—whose plans surpassed all others, and, as is well known, are now generally adopted. M'Adam was the first to point out and prove, in practical operation, that a bed, of a few inches in depth, formed of fragments of hard rock—granite, greenstone, or basalt—small enough to pass through a ring not larger than two and a half inches in diameter, was the best material for ordinary roads. His system, in its leading features, is so conspicuously displayed to the public eye, that any minute account of it would be superfluous. It was not till 1815, when on the verge of sixty, that he began to devote his whole mind to the business of road-making. Being then appointed surveyor-general of the Bristol roads, he had at length full opportunities of exemplifying his system, which he forthwith proceeded to do in a manner that attracted general attention, and caused it to be quickly followed throughout the whole kingdom. In 1823, Mr M'Adam was examined before a committee of the House of Commons respecting the propriety of converting the rubble granite causeway of the principal thoroughfares into a smooth pavement resembling those which he had already formed on the principal roads. He expressed himself as decidedly of opinion that such a change should be made: 'I consider,' said he, 'that the expenses would be materially reduced; the convenience of passing over the surface would be generally facilitated, particularly in the leading streets; and the same weight of stone now put upon those streets as pavement, would be obtained at infinitely less expense, in a different form, for the purpose of road-making.' The consequence was, that in London, Edinburgh, and Dublin, some of the principal lines of street, which had previously been remarkable for solidity of pavement, as well as the large sums that pavement had cost, were—to use a phrase already familiar to every ear—*Macadamised*. A counter-revolution has, however, in many instances taken place, and the old mode of causewaying with squared blocks again resorted to. Macadamising, however excellent for post-roads, is by no means well adapted for busy streets and city thoroughfares. Rough and loose when newly laid down, rapidly ground into mud in winter, and raised into clouds of dust in summer, independent of the obstruction offered by its frequent repair, it may be considered as all but exploded as a system for streets, or at least as having nothing but its pleasant smoothness to recommend it.

According to the principles of road-making, as laid down and consistently acted upon by M'Adam, a road ought to be an artificial and hard flooring, placed on a level and dry surface. To make a good road, therefore, we must in the first place level and prepare the ground. If the ground be soft—as, for instance, have a covering of turf and earthy matter beneath—the top must be pared off, and as much earth removed as will produce a hardish base. In some instances it may be necessary to excavate, and fill up the gap with compact and substantial materials; but should this be the case, the materials used must on no account include any large stones, or be otherwise unequal in their nature. The principles on which the road should be made are thus alluded to by Mr M'Adam:—'Roads can never be rendered perfectly secure until the following principles be fully understood, admitted, and acted upon: namely, that it is the natural soil which really supports the weight of travel; that while it is preserved in a dry state, it will carry any weight without sinking, and it does in fact carry the road and* carriages also; that this native soil must previously be made quite dry, and a covering as much impenetrable to rain as possible must then be placed over it, to preserve it in that dry state; that the thickness of a road should only be regulated by the quantity of material necessary to form such impervious covering, and never by any reference to its own power of carrying weight.'

To put these principles in practice: after the base of the road has been prepared, it should be laid with a layer of small stones, made by breaking larger stones into pieces weighing about three ounces. No round pebbles or channel stones must be employed; all must be angular, or irregularly-shaped pieces. The covering of this kind of material, technically called *road metal*, should be spread to a depth of from six to ten inches, as may be found necessary, and raked level on the surface. The sides of the road must possess wet ditches or gutters, into which all water may be readily conveyed and run off. For this purpose, culverts, drains, and gratings may be necessary.

In certain cases it may be expedient to carry a line of road across a bog or peat morass; and this may be done with perfect security by laying a bottom of brushwood or furze on the soft under stratum, and covering it over with gravel, and the ordinary stone material above. The road so formed may perhaps yield or bend a little when travelled by a heavily-loaded vehicle, but will sustain as much tear and wear as any other portion of the highway.

The width of the road is a matter of taste and convenience, but it should not be less than thirty-three feet, to allow a free passage of vehicles in different directions. On all the good roads in Britain near towns, a side footpath protected by a curb-stone is added to the ordinary breadth. 'With respect to the shape of the surface of the road'—we quote Scientific Tracts—'when completed, there is also some difference of opinion; but all agree that it should be convex, the only difference being in the quantity. The degree of convexity should be governed in a great degree by the locality. A road formed of soft materials should have a greater convexity than one formed of hard materials; for the obvious reason, that water will injure a soft road quicker than a hard one. A road upon uneven ground should have a greater convexity than one upon level ground, to prevent the descent of rain-water along the face of the road, which is there caught by the slightest impressions of wheels, and thus wear channels, as may too often be seen, from the top to the bottom of the hill. A wide road also requires to be more crowning than a narrower one; which more readily frees itself from rain-water, inasmuch as the distance the water has to run is less. But it must be borne in mind that the freeing a road from rain-water is not the only object to be kept in view in making a road crowning. The ease and safety of carriages, and particularly those with heavy burdens, or with high loads, must be consulted. A carriage moves most freely, or with the least resistance, when the load lies evenly upon the wheels. Just in proportion as the weight or load is thrown on one side or the other, the resistance is increased. Hence the inconveniency of a very crowning road on a steep; and hence the utility of bars or breaks in long ascents. It is plain that a road should be equally and duly convex in every part of it, otherwise it sooner becomes partially worn; the more level parts being most used.

When a road is carried round a hill instead of going directly over it, or when a road is made on a hill-side, it should not be made convex from the middle, but it should be formed like half of a common road, with the highest part on the upper side, thus giving the water a tendency to run off on the lower side. Mr Walker recommends the least possible convexity consistent with a proper drainage of the road. In most localities this will rarely exceed four inches; that is, the middle should be four inches higher than the sides. An idea of a perfect road may be formed from a frozen canal, where flatness, smoothness, and hardness are combined: in imitation of such a surface, railways were invented, and fully illustrate the principles assumed. Roads cannot be made with all of these perfections, but they should always be kept in view; for the nearer we approach to this standard, the greater will be the draught. M'Adam says roads should be made as flat as possible. 'Where a road is made flat,' he says, 'people will not follow the middle of it, as they do when it is made quite convex, which is the only place where carriages can run upright, by which means three furrows are made by the horses and the wheels, and the water continually stands there; and I think that more water actually stands upon a very convex road, than on one which is reasonably flat.'

In laying out a new road, it is of some importance that the rises and falls be not too great. The most approved angles of ascents and descents are about one inch in a foot—from this to one inch in a yard. In order to obtain ascents not exceeding these, it is necessary in our uneven country to wind up a hill instead of going directly over it. In such cases the road is to be built upon the side of a hill, and this is considered

* The latest novelty in street-laying—namely, that of paving with wooden blocks—has also been abandoned, in consequence of its dangerous slipperiness; in fact the only materials at present in repute are legitimate stone blocks, and the asphaltic concrete noticed under FICTILE MANUFACTURES, p. 336.

the most advantageous ground upon which a road can be built, provided the hill has not too great an ascent; because what is taken from the upper side serves to form the embankment on the lower side. While we are speaking of embankments, we may mention the common method of forming them:—'The natural sod, which would be covered by the base of the embankment, having been cut off and set aside, the earth is then wheeled or carted on to form the two outsides, which are raised to the required height, leaving the middle open. The sods are then placed on one another, the grassy surface at right angles to the face of the outer slopes, forming as it were a battering wall of sods against the embankment.' This method is found effectual in preventing the banks from washing away and gullying. While the outsides are forming, the lumps of earth, stone, &c. run downward to the middle; and in this way the whole is finished. When the work settles, it is found to tend towards the centre, thus preventing the outside slopes from giving way.

The following judicious observations are made by the same authority on the subject of fences and junctions of different roads:—'Fences are necessary along the sides of a road in all enclosed countries; but they should never be allowed to rise higher than four feet on common roads. It is absolutely necessary that the air and sun have free admission to a road; besides, where the fences are high, it gives a sweeping power to the wind, which is not beneficial. Mr Telford thinks that fences should never be more than four feet high, and that all trees within twenty feet of the sides of the road should be removed. He also thinks that twenty per cent. of the expense of repairing or improving roads is incurred by the improper state of the fences and trees along the sides, particularly on the sunny side: this will be manifest to any person who will take the trouble to examine the condition of that part of a road which is much shaded, compared to the other parts which are exposed to the sun and air. The junction of one road with another requires a little attention: it should always be made at right angles, and on the same level if possible. All engineers agree that plantations of trees should not be made close to roads; but what the distance should be, depends on the elevation of the country, the soil, the breadth of the road, as well as its direction, &c. &c. An elevated situation is always more exposed to winds than a level or hollow. A broad winding road has chances of the direct influence of the sun and wind, according to the obliquity of its angles; a road running north and south, though planted closely on both sides, will enjoy the sun during a part of every day in the year; one running east and west, planted on the south side with trees forty feet high or more, will enjoy no sun during the winter months. The least injurious trees are single rows trained to high stems, properly pruned.'

For some time after a road has been laid with fresh materials, it presents a rough surface, unpleasant to the feelings of those who are conveyed over it: but this roughness is gradually abated; the small stones are crushed into a compact mass; and finally, the road is smooth, hard, and level. The length of time that may elapse before any new repair is required depends on the amount and kind of traffic, as well as the weather; but a smooth surface may be speedily acquired by using a heavy roller, and by *blinding* or strewing the metal with good sharp sand, which fills up the interstices, and renders the mass more readily compact. Rain is a great enemy to macadamised roads, and particularly so when accompanied with much traffic. The water lies on the surface, and softening the material, the action of the horses' feet and of the wheels causes a certain depth of thin liquid mud. This mud should by all means be scraped off to a side, for the longer it lies, the stratum beneath is the more liable to be cut up and damaged. The scraping of the roads—which is now performed by an ingenious hand machine—therefore, becomes an essential duty of all who are interested in preserving the highways economically in repair. When the mud and refuse which is scraped aside thickens by exposure, it should be carted off, and may be employed on certain soils as a manure.

Roads exposed to much traffic require to be renewed in surface at least once a year. The first indications of decay are observable in the form of slight hollows, and ruts next make their appearance. In some cases, where the decay is only partial, a small quantity of metal may be scattered in the hollows, bringing them up to a level with all around. However, this is not usually done on well-kept roads near large towns. There the road undergoes a thorough repair once a year, which is preferable to partial mendings. The best time for repairing roads is about November, or before the winter frost and snow set in. In commencing the repair, the road should be picked across, at intervals of twelve or fifteen inches. This is done by men, each having a pick by which he indents the hard bottom, or forms scores an inch deep in the road. The use of such a preliminary process is to cause a ready union between the new and old materials. If the fresh metal were scattered over the old road, without any preparation, it would with difficulty unite to the substratum, and at best form an upper crust, which would be too easily damaged.

With respect to the keeping of roads in efficient repair, the most advantageous plan consists in assigning the entire duty to a contractor. This person, by undertaking to keep all the roads in a county or district in constant and uniform repair, is able to execute his functions much more economically than the private gentlemen who act as trustees of the highways and turnpikes. The trustees appointed by local acts of parliament to superintend highways, now generally employ contractors to keep the roads in repair at a specified price per mile, the payment being made from funds collected by the lessees of the toll-bars or turnpikes.*

Law of the Road.—For general convenience and safety, drivers of vehicles and riders, in travelling along a road, are expected to take a particular side; and this practice is now so well understood, and is in itself so proper, as to have become a part of the common law. The law of the road is, that when drivers meet from different directions, each shall keep his left hand to the wall or footpath. Secondly, when one driver overtakes another, and wishes to pass him, he must keep his left hand to the vehicle which he passes. In the case of either meeting or passing, each party is entitled to the half of the road. The same rules apply to riders. If these regulations be neglected, and an accident occur, the law is always in favour of the party who kept his own proper side, and no excuse can shelter the aggressor. The trustees of the road are liable in an action of damages for any injury that may be sustained through the carelessness of themselves or servants in leaving the road grossly out of repair.

According to a well-known rule, foot passengers on pavements or side-paths are expected to walk with their right hand to the wall—that is, they keep their left hand to those whom they are meeting and passing. This custom prevents confusion in the streets of large towns, but is not a matter of law.

CANALS.

A canal is an artificial channel of water, and is usually constructed for inland navigation. Where rivers can be resorted to for purposes of this kind, they are preferable to canals, because little expense may be required to suit them for navigation, and they may be easily kept in repair. But few rivers, generally speaking, are sufficiently level, straight, or deep, to admit of being profitably navigated by barges, and therefore artificial channels require to be cut. Canals are ex-

* Turnpikes were so called from poles or bars, swung on a pivot, having been placed on them, and turned either way when dues were paid. Gates are now substituted for these poles in Great Britain. In Germany, the pole is still used, one end being depressed to raise the other, and so permit a free passage.

tremely suitable in level countries, possessing rivers or brooks which can afford a due supply of water. In China, from a very early age, certain large rivers have formed natural canals longitudinally through the country from west to east, while artificial canals have been made to proceed in a cross direction from north to south, thus effecting a universal water communication throughout the empire. Canals existed in ancient Egypt in connection with the Nile, on a similar plan to what now prevails in China. Notwithstanding that canals were known to have existed from a remote antiquity in the East, it was long before they were introduced into western Europe. In modern times, they were first used by the inhabitants of the Netherlands, in consequence of the extreme flatness of their country, and the numerous channels of water which intersect it in all directions, in connection with the lower branches of the Rhine and other rivers. In Holland and Belgium, therefore, canals in a great measure exist as an essential requisite in the general arrangements of the country, and are, in point of fact, so many ditches or drains to receive the superfluous waters.

In countries differently constituted, canals are constructed only with reference to the profit in the form of commercial speculation. The great question, accordingly, in forming the project of a canal, is, whether the anticipated amount of traffic will raise tolls sufficient to compensate the outlay of the undertaking and subsequent charges for repair and superintendence. It simplifies such an inquiry to know the following truths in reference to cost of conveyance:—The cheapest mode of conveyance is by coasting vessels, steamboats, &c. and these will at all times be employed for heavy and bulky goods, such as coal, barrels of liquids, iron, and other cumbrous materials proceeding coastwise. The next cheapest mode of conveyance is by barges on rivers; and the next is by means of canals. After this are ranked, in point of economy, conveyance by land on railways and roads, the last being the dearest, though often the only means of transport which can be obtained. According to this view, canals can never answer as profitable speculations when they have to compete with coasting vessels of any description, or with any species of conveyance by rivers. They cannot, even in certain circumstances, compete successfully with railways, on account of the slowness of speed at which barges or boats are drawn along them; and as speed is becoming daily a matter of greater moment in traffic, canals are gradually losing the conveyance of every kind of goods for which quickness of transit is desirable. For the sake of economy in national resources, it is very desirable that these truths in statistics should be generally understood and remembered.

When the undertaking appears warrantable from a careful consideration of circumstances, the next thing to be taken into account is the obtaining of an adequate supply of water, and the fixing on the best—that is, the most level and unexpensive—line of route. In some parts of England, where an enormous traffic could be reckoned upon, canals have been projected and executed on a stupendous scale; mountains have been perforated to admit channels of water through them, valleys raised by embankments, and bridges built in the form of aqueducts across rivers; in short, no expense has been spared to render the inland navigation complete. The principal operations in an engineering point of view are the *cuttings*, which are termed level when over plane ground, and side or oblique when along the face of a declivity; the *tunnellings* through heights where open cutting would be more expensive; the *embankments* across valleys and low grounds; the *aqueducts* over rivers and ravines; the *bridges* for carrying the common roads over the canal; and the *locks* or steps by which any acclivity is ascended by the canal, instead of attempting its reduction by cutting or passing through it by tunnel.

The supply of water necessary for a canal which is level throughout its course is small in comparison with that of one pursuing an uneven line. When there is a common level of surface, the only expenditure of water is by evaporation; but when the level is various, a large loss is incurred at the locks in raising or lowering vessels. A lock is a portion of the canal enclosed by folding-doors, and must at least measure the length of a vessel. If a vessel is to be raised from one level to another, it is drawn up to the doors of the lock, and these are opened to admit it. Having sailed into the lock, the doors are closed behind it, and it is now in a kind of prison, from which there is no apparent escape. While in this situation, the doors at the opposite end of the lock, which retain the water at the higher level, are slowly opened, and admit a rush of the liquid mass, which speedily buoys up the vessel, and allows it to sail off along the higher level. The lock is not immediately emptied, but remains full of water, and is therefore ready to be employed in letting a vessel down. When the vessel approaches, and is fairly within the lock, the upper doors are shut, and then the lower doors are opened: by this means the vessel is carried into the lower level along with the rush of liquid, and is drawn on its course. A lockful of water has now evidently been shot from a higher to a lower level on the canal, and is lost, unless required for lower locks. To prevent inundation of the banks from the issuing of water from the locks, waste outlets require to be provided at certain distances, particularly at the lower termination of the line of canal. The provision of water to supply the locks is ordinarily from an artificial lake or reservoir, which is established near the highest ground in the line; and the smallest possible quantity consistent with the purposes of navigation is admitted in order to keep down the height of the sluices, banks, and dikes, all of which are affected by the pressure of an increased body of water. (See HYDROSTATICS.)

The breadth of most canals varies from twenty to thirty feet, and the depth from four to six feet. If the depth of water be sufficient to keep the vessels from touching the bottom, no greater volume is necessary, for less power is required to pull a boat upon a shallow than a deep water, there being less liquid agitated or displaced. At one side of the canal a narrow road, called the *towing-path*, is constructed, and upon this the horses which drag the vessel proceed. There is a difference in the manner in which the dragging-rope is attached to the vessel. In Holland, it is the practice to attach the rope to near the bow of the boat, and to cause it to proceed over the outer extremity of a pole or species of mast, so as to keep it considerably above the water, and prevent its friction on the banks. This is not attended to in England, where the rope proceeds direct from the bow to the horse, and, except when in a state of great tension, it trails along the bank and surface of the water. In either case, the draught of the horse is exerted with a loss of power; for instead of being a fair draught behind, it is oblique, or in the direction of the rope slanting to the vessel. The tendency of the draught is to bring the boat to the shore, which is counteracted by the helm, and this again assists in diminishing the general amount of available power.

Throughout the canals of England and Scotland, only one horse is employed to drag a boat loaded to the extent of from fifty to seventy tons; and with this weight dragging after it in a manner most disadvantageous, it will travel at the rate of two and a half or three miles an hour. That one horse should be capable of drawing fifty tons of goods in this unexpensive manner, gives an apparently favourable view of canal conveyance; but laying all charges out of the question, the slowness of the motion, and consequently the detention of goods by the way, is a drawback of the most serious nature, and in reality renders canals almost useless for the transport of any but heavy and raw materials. Latterly, on a few canals, attempts have been successfully made to run 'swift boats' for passengers, drawn by two horses, at a rate of seven or eight miles per hour; but as these vessels are run at a great expense for horse power, and at the utmost speed are not quicker in their transit than stage-coaches, it may be expected that they will utterly fail in competing with railways.

It may not be generally known that the principal obstacle to the use of steam-engines on board canal-boats, is the injury done to the banks by the action of the water from the paddles. This obstacle has to a certain degree been overcome by the use of one-paddled boats—the paddle being placed in the line of the boat's keel; and also by the application of the Archimedean screw propeller. Still, steam-dragging is by no means general; and canals, as a superseded idea, do not now much occupy the attention of engineers and inventors. It has also been proposed to lay rails along the towing-path, and employ steam-drags; a notion somewhat superfluous in these days, when it would be quite as economical to convert the path into a railway at once, or even to lay dry the canal, and apply its course to a similar purpose.

One of the largest canals in Europe is that which extends from the German Ocean to the River Ai, at Amsterdam, by which vessels are enabled to reach that city by a direct channel, instead of sailing round by the Zuyder Zee. This ship canal was begun in 1819, and finished in 1825, at an expense of £850,000. Its length is nearly 52 English miles; its breadth 125 feet at the surface, and 30 feet at the bottom; and its depth 20 feet 9 inches. Traversing a perfectly flat country, it has no locks, except at its extremities, and is of such magnitude, that two frigates, or the largest merchant vessels, can pass each other. There is a towing-path for horses on each side; and about eighteen hours are required to perform the voyage from Amsterdam to the ocean. As a commercial speculation, the canal yields no profit, but its service to the shipping of Amsterdam is incalculable, and without it the town must have sunk into comparative insignificance.

France possesses about fifty different canals, some of which are of great importance for general traffic. The chief canal is allowed to be that of Briare, called also that of the Loire and Seine. It was completed in 1642, measures 34½ miles in length, and has 40 or 42 locks. The width is 25 feet at bottom. By this canal Paris receives large supplies of inland produce. The Canal du Midi, or Languedoc Canal, makes a communication between the Mediterranean at the city of Cette and the Atlantic Ocean at the mouth of the Garonne, passing through the province of Languedoc. Altogether, there are nearly 1000 miles of canals in France.

The United States of North America posses upwards of 2500 miles of canals, the whole of which have been constructed within the last thirty years. The principal undertaking of this kind is the Erie Canal, which unites the river Hudson at Albany with Lake Erie at Buffalo, a distance of 363 miles. The Miami Canal, from Cincinnati to Lake Erie, which extends 265 miles, is another great undertaking; and there are a number of other canals, scarcely less important, for the general traffic of the country. The Rideau Canal in Canada, extending a distance of 160 miles, from the Ottawa (a tributary of the St Lawrence) to Lake Superior, is a stupendous undertaking, and will ultimately be of great service to the trade of British America.

The canals of Great Britain are believed to extend to an aggregate length of 2400 miles. The greater part are in the midland districts of England, including Lancashire, and have for their object the connection of the large seats of manufacture with the sea on both sides of the island and with the Thames at London. The Grand Trunk Canal, connecting the Mersey with the Trent and Humber, extends 93½ miles. The Birmingham and Worcester connects the Grand Trunk Canal with the Severn. The Grand Junction connects the Grand Trunk with the Thames. Thus the four great ports of the kingdom—London, Bristol, Liverpool, and Hull—are connected by canals. So generally are these and other canals spread over England, that it is supposed there is not a place south of Durham more than fifteen miles from water communication. The trade on some of the lines of canal, since the introduction of railways, has sunk in an extraordinary degree, greatly to the loss of the proprietors. Ireland has about 300 miles of canals, mostly government undertakings, and in general possessed of little trade.

Scotland has a number of canals, but they are chiefly confined to the western and mid district of the country. That which possesses the largest traffic is the Forth and Clyde Canal, reaching from the Clyde, a short way above Dumbarton, to the Forth at Grangemouth. This canal, which was opened in 1790, and affords a ready communication for small vessels between the east and west coast, extends 39 miles in length; its highest level is 160 feet, with 20 locks on the eastern acclivity and 19 on the western. The canal is connected with Glasgow by a side cut; and it is now joined by the Union Canal, which extends from near its eastern extremity to Edinburgh. This latter canal has proved a poor commercial speculation, but has been of great service to Edinburgh, by introducing coal at a cheap rate to the city, and affording an exceedingly convenient means of conveyance for goods to and from Glasgow. The Caledonian Canal is formed in a great measure by a chain of lakes, stretching across the country from Inverness on the east to Loch Eil on the west coast, a distance of 59½ miles. The canal part is 20 feet deep, 50 feet wide at bottom, and 120 feet at top, which affords a passage to frigates of 32 guns, or merchant vessels of a similar size. This great canal was undertaken as a public work by government; and after a labour of eighteen years, was opened in 1822, having then cost £900,000. It possesses 13 locks on the east, and 12 locks on the west coast, the highest level being 94 feet. By this canal the dangers of rounding the northern extremity of the island by the Pentland Firth may be avoided; but, from the prejudices of seamen, it has never been much used. As a means of allowing steam-boats to run between the Clyde and Inverness, the canal has been of considerable public service.

RAILWAYS.

Before the practice of steam navigation had attained that degree of improvement which it now possesses, a not less wonderful mode of travelling by steam power on land had come into use; wherefore, during the first thirty years of the nineteenth century, infinitely greater improvements in the means of locomotion have been discovered and brought into practical operation for the benefit of mankind than had ever previously been known. To understand and value the application of steam power to land travelling, we must advert to the subject of draught on common roads.

There exist three obstacles to the rapid motion of carriages—terrestrial attraction, the atmosphere, and friction. By no human power can the two former be removed, but the latter can be so far modified as to form little or no opposition. On all common roads, no matter how well they may be constructed, there is a certain degree of roughness which it is impossible to remove, and this causes so great a friction, that to overcome it, much of the drawing power is consumed without advancing the carriage. On some roads, the plan of laying down continuous lines or *tramways* of smooth pavement for the wheels to roll over has been resorted to, but has never been found generally answerable, not only in consequence of the great expense of construction, but because drivers will not take the trouble to keep their vehicles upon it.

The draught of a horse upon a macadamised road may be estimated at fifteen hundredweight, walking at an ordinary pace, and for several hours continuously. Particularly strong horses may habitually draw twenty or twenty-two hundredweight, but to cause them to pull to that amount is not economical. Allowing, however, that all horses can draw a ton weight, that is a small amount of draught in relation to great purposes of commerce; and the speed at which the fleetest horse can travel, when drawing a weight after it, though perhaps ten miles an hour, is unsuitable for the rapid transit of passengers on long journeys. To drag a mail coach from London to Edinburgh, a distance of about 400 miles, in 43 hours, which was reckoned a good speed, it was necessary to employ four horses, and to change these every eight miles on an average; thus 200 horses were required for the performance of the whole journey. Having attained this rate of locomotion, by improvements on roads, carriages, and in the breed of horses, nothing more could be done. Something new required to be devised.

The idea of employing steam power to drag carriages over common roads, and thus save a large outlay for horses, besides accomplishing a greater speed, was suggested by various enterprising minds, but to its practical application there were, and are, many serious objections. Independently of the ordinary and unavoidable roughness of common roads, all highways are less or more uneven; because to construct them upon a perfect level throughout, would be attended with an expense which the tolls from any traffic could not sustain. The general unevenness of roads, therefore, causes a great loss of drawing power. In these circumstances, it is evident that, for the avoidance of friction and economising of forces, an entirely new species of road required to be contrived. This important desideratum is found in the invention of *railways*. The design of a railway is to furnish a hard, smooth, and unchanging surface for wheels to roll upon. No provision, as respects smoothness, is required for any part of the path, except the narrow lines which are immediately to come under the rim of the wheels. Accordingly, it is sufficient to provide two rows or lines of strong and straight iron rails; that is, long slips of iron, about two inches in thickness, and four or six inches deep. These rails, laid in two parallel lines, to suit the width of a carriage, are raised a little above the general level of the ground, being placed neatly end to end, and secured by bolts or trenails to blocks of wood or stone at short intervals. Such is the very simple contrivance of a railway, or *chemin de fer* (road of iron), as it is called by our French neighbours. By the establishment of railways, a way was opened for the adaptation of steam power to locomotion, and now, as is well known, that has come generally into use.

The earliest railway of which there is any account was one constructed near Newcastle-upon-Tyne. In Roger North's Life of Lord Keeper North, he says that at this place, in 1676, the coals were conveyed from the mines to the banks of the river, 'by laying rails of timber exactly straight and parallel; and bulky carts were made, with four rollers fitting those rails, whereby the carriage was made so easy, that one horse could draw four or five chaldrons of coal.' One hundred years afterwards, about 1776, Mr Curr constructed an iron railway at the Sheffield colliery. The rails were supported by wooden sleepers, to which they were nailed. In 1797, Mr Barnes adopted stone supports in a railway leading from the Lawson main colliery to the Tyne, near Newcastle; and in 1800, Mr Outram made use of them in a railway at Little Eaton, in Derbyshire. Twenty-five years afterwards, this species of road was successfully adopted on a public thoroughfare for the transportation of merchandise and passengers; namely, the Stockton and Darlington Railway, which was completed in 1825, and was the first on which this experiment was made with success. From that time, accordingly, a new and wondrous era commenced in the history of inland conveyance.

It is a remarkable circumstance, that the early practisers of railway conveyance could not imagine that a carriage, moved by steam power, could proceed along the rails without the aid of toothed wheels and a rack; and to overcome this imaginary difficulty, no small degree of expense and labour was fruitlessly incurred. About the year 1815, Mr Blackett of Wylam, near Newcastle, effectually proved, by repeated experiments, that the adhesive power of the wheels on the rails was at all times sufficient to cause a progressive motion in an engine, with a train of loaded carriages, upon a railway either level or with a small acclivity. Important as was this discovery, fifteen years elapsed before steam locomotives were established. This great triumph of art occurred in connection with the opening of the Liverpool and Manchester Railway on the 15th of September 1830, since which period railways have spread to all populous parts of the country.

Simple as is the idea of a railway, a prodigious expense is necessarily incurred in bringing it into practical operation. All inequalities of surface in the ground must be removed; low parts must be filled up by embankments, high parts must be reduced, eminences, which is would be impolitic to level, must be perforated by tunnels—the whole route being brought as nearly as possible to a level. Besides, the land over which it is to proceed must be purchased frequently at an exorbitant cost; and the preliminary expense of overcoming petty opposition, and procuring an act of parliament to establish the line, sometimes amounts to as much as £2000 per mile. An entire charge of £30,000 per mile has been considered a moderate outlay in the construction of railways in Britain.

No long line of railway that has yet been formed is perfectly level throughout, but the acclivity is seldom more than one foot per mile, and this does not produce any retardation, which it would be absolutely necessary to obviate by an excess of expenditure. Every line, also, is curved, or bent from a truly straight direction, at various places in its course; and this is another evil which it is necessary to tolerate to a certain extent, rather than avoid by uneconomical outlay. For the reasons now stated, nearly all railways are neither perfectly straight nor perfectly level; and so far as such is the case, there is a loss of power in drawing vehicles along them. Yet in the most disadvantageous known circumstances, the railways are so comparatively smooth, and suitable for transit, that they allow the nearest approach to a total absence of friction. It is deserving of notice that the absence of friction in railways is advantageous not only for the saving of power, but the saving of painful sensations to the traveller. The suffering usually endured in ordinary modes of land conveyance is that which chiefly arises from *friction*. Friction is the grand evil to be overcome. Practically, in locomotion upon railways, a certain amount of friction is required between the wheels and the rails, to cause adhesion, and this is accomplished by the ordinary roughness of the iron.

Rails.—The iron trackway on which the carriages run is formed of iron rails, made in lengths neatly fitted together at the ends, and secured to the ground by contrivances about to be described. Some time ago cast-iron rails were used, but now those of wrought-iron are almost always adopted; and the old fish-bellied rail is superseded by that whose depth or profile is the same throughout. The cross section of a rail appears somewhat in the form of the letter T, the broadest surface being that on which the carriage-wheels run. 'Sleepers,' made generally of larch or oak, are laid across the line at certain intervals; and on each end of these sleepers 'iron-chairs' are fixed, into a slit or opening in which the rail is inserted, and made fast by wood or iron wedges. The chairs are fastened to the sleepers by iron bolts or trenails, and in some instances by iron screws. Instead of wooden sleepers, stone blocks are sometimes used; but these produce a jolting motion, at once disagreeable to the traveller and injurious to the mechanism of the carriage, and are consequently falling into disuse. In one or two cases, the rails have been laid upon continuous beams of wood, which are held securely in their place by cross-beams, the whole forming a compact but expensive framework. The railway between Newcastle and North Shields is laid upon this principle, and is one of the smoothest and most agreeable lines in the kingdom—being remarkably free from noise and jolting.

In Britain, two gauges have been adopted for the distance between the rails—respectively known as the broad and *narrow gauges*. The broad gauge, first followed on the Great Western line, is seven feet between the rails; the narrow, most commonly preferred, is only four feet eight inches. Frequent and somewhat angry discussions between the supporters of the different gauges have taken place. It is here needless to enter upon the merits or demerits of either: each possesses its advantages; but it is desirable that all the lines in the island were of the same breadth, so that in the event of their being joined together, one breadth of locomotive and carriage could traverse the whole. Already the difference of gauge has been felt as an inconvenience, as the two species are now in junction, requiring, both for passengers and goods, a change of carriage, with all its trouble and delay. With a view to remedy the evil, engineers are now devising methods of transfer, but as yet with very partial success.

Sidings.—As on most railways the different trains run at different degrees of speed—such as the 'express' faster than the mail, the 'mail' faster than the common passenger train, and this, again, faster than the goods or luggage wagons—provision must be made to enable all the trains to traverse the line when necessary, yet to allow the fast to pass the slow at certain points of the journey. This is effected by turn-outs, or *sidings*, which are placed at certain convenient parts of the line, and are made by means of a movable or *switch-rail* at the angle where the turn-out track branches from the main one. This rail is two or three feet, more or less, in length, and one end may be moved over that angle, and laid so as to form a part of the main track, or the turn-out track. The switch-rail is usually moved by a hand-lever, and wherever it is placed, requires the constant duty of an attendant.

Carriages—Wheels.—The principal consideration in regard to the construction of carriages, relates to their bearings on the axle and the rim of the wheel. The rule given by Mr Wood as to the bearing on the axle is, that in order to produce the least friction, the breadth of the bearing should be equal to the diameter of the axle at the place of bearing. This diameter must be determined by the weight to be carried; and the breadth of the bearing will accordingly vary with it. In order to keep the wheels fairly on the rails, they are furnished with thin edges, which dip on the outside; these *flanges* are about an inch and a half in depth. The mid wheels of locomotives are now made without flanges, but the fore and hind pair require flanges of rather more than usual depth. Wheels of large diameter move with greater ease over the rails than those which are small, because the large ones, in this as in all similar cases, have more power in overcoming obstacles. Yet there is a proper medium in the dimensions of wheels. Large wheels are inconvenient in point of height, and are apt to produce a rocking motion. It would appear that the most suitable diameter for the wagon or carriage wheels is from two and a-half to three feet, which is the usual size. The wheels of locomotives vary in diameter, but are generally from four to six feet. In an excursion on one of the English railways, when the train was at its maximum speed, the tire of one of the locomotive wheels flew off, and caused much damage; and in consequence of this, means have been taken for securing the malleable iron tire round the wheels.

Carriages are usually divided into three classes—first, second, and third. The first are covered, and resemble three coach bodies united. Each compartment is double-seated, the seats being separated by cushioned arms or supporters, thus preventing the passengers crowding one another. The whole interior is lined, cushioned, carpeted, and lighted; presents as much elegance, and affords as much luxurious ease, as any nobleman's carriage. The second-class carriages—originally very uncomfortable concerns—are now covered, and provided with windows, and on some lines are furnished, like the first-class, with lamps, and soft cushions for seats. These are not divided into compartments, but are calculated to hold, without crowding, from four to six passengers on each side. The third-class carriages were originally quite open, and in some cases entirely unprovided with seats; but now the parliamentary third-class—so called from companies being obliged to run them by act of parliament—are very comfortable conveyances, infinitely superior to the outside seat of a mail or stage-coach. They are covered, and furnished with seats and windows.

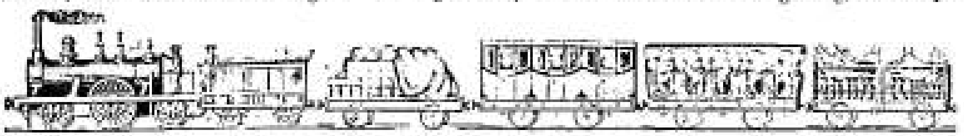
To lessen the amount of concussion between the carriages, each is provided at back and front with 'buffers'—that is, cushioned steel-rods which act upon springs, the springs in each case being made to resist a high degree of pressure. To diminish the noise arising from the wheels, it has been proposed to enclose them in cases of zinc, and fill the spaces between the spokes with sawdust: a mode which is said to be effectual, but seldom if ever adopted in practice. To prevent oscillation during high rates of speed, various plans have been proposed; but none, we believe, so efficient as well-balanced and well-constructed wheels and carriages. Another recent improvement is the sheltering of the guards from the inclemency of the weather, thereby enabling them to do their duty with greater efficiency; but means are still wanted by which the guards or the passengers may communicate readily with the engineer in cases of accident. There is great room, indeed, for improvement in the 'passenger transit department;' and we are happy to observe, from the introduction of 'pleasure,' 'invalid,' and other carriages, that some of the first-class lines seem alive to this subject.

Curvatures.—The curvatures in the line of railway present some obstructions, since the axles of the car and wagons being usually fixed firmly to the frames, every bend of the tracks must evidently cause some lateral rubbing or pressure of the wheels upon the rails, which will occasion an increased friction. If the wheels are fixed to the axles, so that both must revolve together, according to the mode of construction hitherto most usually adopted in passing a curve, the wheel that moves on the outside or longest rail must be slided over whatever distance it exceeds the length of the other rail, in case both wheels roll on rims of the same diameter. This is an obstruction presented by almost every railway, since it is rarely practicable to make such a road straight. The smallest curvature that is allowable should not be less than a radius of 300 feet. In going round a height, the radius should on no account be so small as this, in order that the engine-drivers may have a clear look-out a-head, and so prevent collisions and overtakings on the road. Another point to be observed is the proper elevating of the outer rail at any sudden curvature, in order to prevent as much as possible the centrifugal or tangential tendency of the train to escape from the line.

Inclined Planes.—Where the inclination of the road is greater than that for which the ordinary power is calculated, the ascent must be effected by means of an additional power, the amount of which can be readily computed, since in those parts no additional friction of the cars or wheels is to be provided for, and only the additional resistance arising from gravity is to be overcome. If, for instance, the additional inclination is one in ninety-six, or fifty-five feet in a mile, the additional power must be to the weight as one to ninety-six, or as fifty-five to the number of feet in a mile—namely, 5280. In descending planes so much inclined that the gravity would move the carriages too rapidly for safety, the velocity is checked by means of a break, which consists of a piece of wood of the same curvature as the rim of a set of the wheels, upon which the break is pressed by means of a lever, so adjusted, as to be within reach of the conductor in his position on the carriage. Very powerful breaks are occasionally applied (by wheel and screw) to separate trucks—these trucks being made of iron, very heavily loaded, and placed by way of drag in the rear of the train.

In some tunnels the incline is so great, that stationary engines are employed to drag up the trains, either by means of an endless chain, or by wire ropes of a peculiar formation. An invention, however, has recently been patented by an American engineer for enabling locomotives to ascend steep inclines with their usual load, and which bids fair to be of extensive utility. On the inclined plane *within* the usual line of rails a second line is laid down, and at regular distances in this enclosed line are laid small cross rollers. Beneath the locomotive employed to drag the train is placed a contrivance of a peculiar nature. This consists of what may be termed an 'Archimedean screw,' which is worked by the engine. On arriving at the incline, by a very ingenious arrangement, the wheels of the locomotive are completely lifted up from the outside rails, and at the same time the 'screw' is placed in contact with the line of rollers—the whole weight of the engine resting on this line. By putting the engine in motion, the screw revolves, and by working between these rollers, drags the train to the summit, on arriving at which, the screw is 'taken out of gear.' The engine rests on the outside rails, and once more proceeds on its journey. The whole operation is done in a remarkably short space of time, and is so efficient, that inclines so steep as to prevent the ascent of the most powerful engines by the ordinary way, are surmounted with apparent ease and facility.

Locomotives.—Within the last few years, very considerable improvements have been made in the construction of the locomotive engines by which the draught of the trains of carriages is effected. Originally, the locomotive was placed upon four wheels, the two front ones being smaller than those behind. Now six wheels are usually employed, the front and hind pair being smaller than those in the middle, these middle ones being the wheels upon which, by the action of cranks from the engine, the whole mass is propelled. As may be seen in the annexed engraving, which repre-



sents a railway train, the locomotive consists of a long iron barrel or cylinder supported by six wheels, with a chimney rising in front, and affording standing space behind for the engineer, who conducts and regulates the machine. It is unnecessary to give a minute account of this wonderful apparatus, which has been already explained under THE STEAM-ENGINE: suffice it to say, that the end of the barrel-like object next the engineer consists of a furnace or fire-box, and the heat generated in it by the consumption of coke is conducted thence through a great number of tubes in the cylinder, and finally escapes at the chimney. The cylinder, in which the water is boiled, and steam generated, is sheltered from the external air by a case; and by receiving the action of heat from so many tubes passing through it, the steam is rapidly generated for the use of the engine. The engine lies horizontally beneath the chimney, and in such a position, as to permit the working of the piston upon the crank of the axle of the middle set of wheels. By means of lever handles affecting the mechanism, the engineer can at pleasure produce or stop the motion as effectually, and much more readily, than a coach-driver could set off or arrest the progress of his horses.

Immediately behind the locomotive is a carriage called the *tender*, which is loaded with a supply of fuel, and a tank round its sides containing water. The weight of a locomotive, supplied with its proper quantity of water and fuel, is about twelve tons. The tender, when filled with water and fuel, weighs seven tons; it can carry 700 gallons of water, and eight hundredweight of coke forms a sufficient supply for a trip of from thirty to forty miles with an ordinary load. The average cost of a locomotive is about £1700 (though, during the late railway mania, it rose so high as £2100), and it seldom wears longer than two years without undergoing a very extensive repair. On the Great Western Railway, which is of unusual breadth of track (the broad gauge), the locomotives are much larger and more powerful. Ordinary locomotives evaporate seventy-seven cubic feet of water per hour, but those on the Great Western evaporate about 200 cubic feet. It is calculated that the evaporation of one cubic foot per hour, produces a gross mechanical force of nearly two horse power; consequently, to ascertain the power of a locomotive, we must multiply by two the number of cubic feet which it evaporates per hour. In common circumstances, an ordinary-sized locomotive exerts a power of 150 horses, and a larger one exerts a power of 400 horses. To estimate this degree of force, it is necessary to recollect that a horse upon a common road cannot draw for any length of time more than fifteen hundredweight, while on a railway it will pull with equal ease ten tons, being thirteen times the amount. We may now, therefore, compute that the power of a locomotive such as is usually employed, is equal to a draught of 1500 tons. With this weight to drag, however, only a slow motion is obtainable; and to procure the necessary speed of from twenty to twenty-five miles per hour, the load must be proportionally diminished. Something must also be allowed for the difficulty of ascending inclined planes. A weight of from 100 to 150 tons is considered a fair load for a locomotive to draw; but it is seldom more than sixty to seventy tons. The following experiments on the power of draught were made on the Liverpool and Manchester Railway in 1832:—

'On Saturday the 5th of May, the engine called the Victory took 20 wagons of merchandise, weighing gross 92 tons 19 cwt. 1 qr., together with the tender containing fuel and water, of the weight of which there is no account, from Liverpool to Manchester (30 miles), in 1 hour 34 minutes 45 seconds. The train stopped to take in water half-way for 10 minutes, not included in the above-mentioned time. On the inclined plane rising 1 in 96, and extending 1½ mile, the engine was assisted by another engine called the Samson, and the ascent was performed in 9 minutes. At starting, the fireplace was well filled with coke, and the coke supplied to the tender accurately weighed. On arriving at Manchester, the fireplace was again filled, and the coke remaining in the tender weighed. The consumption was found to amount to 929 lbs. net weight, being at the rate of one-third of a pound per ton per mile. Speed on the level was 18 miles an hour; on a fall of 4 feet in a mile, 21¼ miles an hour; fall of 6 feet in a mile, 25½ miles an hour; on the rise over Chatmoss, 8 feet in a mile, 17½ miles an hour; on level ground sheltered from the wind, 20 miles an hour. The wind was moderate, but direct ahead. The working wheels slipped three times on Chatmoss, and the train was retarded from two to three minutes.

On the 29th of May, the engine called the Samson (weighing 10 tons 2 cwt., with 14-inch cylinders and 16-inch stroke; wheels 4 feet 6 inches diameter, both pairs being worked by the engine; steam 50 lbs. pressure, 130 tubes) was attached to 50 wagons laden with merchandise; net weight about 150 tons; gross weight, including wagons, 223 tons 6 cwt. The tender weighed 7 tons, making a gross load (including the engine) of 240 tons 8 cwt. The engine with this load travelled from Liverpool to Manchester (30 miles) in 2 hours and 40 minutes, exclusive of delays upon the road for watering, &c.; being at the rate of nearly 12 miles an hour. The speed varied according to the inclinations of the road. Upon a level, it was 12 miles an hour; upon a descent of 6 feet in a mile, it was 16 miles an hour; upon a rise of 8 feet in a mile, it was about 9 miles an hour. The weather was calm, the rails very wet; but the wheels did not slip, even in the slowest speed, except at starting, the rails being at that place soiled and greasy with the slime and dirt to which they are always exposed at the stations. The coke consumed in this journey, exclusive of what was raised in getting up the steam, was 1762 lbs., being at the rate of a quarter of a pound per ton per mile.'

General Appearance and Management.—In America and Belgium, most lines consist of but one track; in Great Britain all possess two tracks, suitable for trains going in opposite directions, besides which there are turn-offs or sidings, at which quick-going trains may pass those of slower motion. At certain convenient points along the line there are station-houses, at which the trains stop to take up and set down passengers, and there is no stoppage at any other place. On most of the lines there are slow trains, taking goods and second-class, or an inferior kind of carriages; and fast trains, taking only first and second-class carriages: some lines also have mail trains, which proceed at more than usual speed, and taking only first-class carriages, stop at fewer places by the way. 'Express' trains are now daily seen on most of the lines: they carry only a limited number of passengers, and stop only for water—seldom taking up or setting down a passenger except at very important stations. These express trains run at a most astonishing speed, usually from fifty to sixty miles an hour. Generally, the fares charged for transmission are higher than they need be: a common charge is at the rate of 3d. per mile for each passenger in a first-class carriage; but it is understood that lower rates would create more than a compensatory amount of traffic. In the parliamentary carriage trains, the highest rate allowed is one penny per mile—a great boon indeed to the poorer classes of society.

There are certain excellences in the arrangements of all the railways which deserve to be mentioned. Each line, being the property of a private association, is secluded from one end to the other from the intrusion of the public; and therefore no jostling or confusion takes place either upon entering or leaving the carriages. The rails of one line, likewise, join those of another, by which means carriages generally proceed onwards, without changing passengers or luggage. A carriage in which passengers take their seats at London can go straight on to Edinburgh; and very shortly even to Aberdeen. The extraordinary magnitude of the railway undertakings has enabled the directors to organise rules which could never be enforced in the irregular scramble of stage-coaching. It is customary to dress the subordinate functionaries on all the lines in a uniform resembling that of the London police—each man having his number inscribed in figures on some part of his dress; so that if any one be guilty of incivility or inattention, he can be easily reported to his superiors. There is one pleasing peculiarity in the arrangements which is entitled to the highest commendation: it is the rule that no officer shall on any account take a fee from passengers, on pain of instant dismissal. Those who imagine that fees to guards, coachmen, or waiters, are requisite to insure civility, will be surprised to find that railway attendants are infinitely more polite and attentive than their brethren of the coach conveyances. This in itself gives travelling by railway a great superiority over all other modes of public conveyance. On all the lines there are waiting-rooms both for ladies and gentlemen at the different stations; and on some there are large and commodious houses of entertainment at the termini, where meals stand ready prepared for the passengers.

Passengers who make the journey for the first time by the mail train on the great lines of England, will be amused by observing a travelling post-office in the string of carriages. This 'Grand Northern Railway Post-office,' as the inscription on its side denotes, is a carriage consisting of two small apartments, one of which is appropriated to the guard, whose duty is to exchange the bags, and the other is fitted up with a table for sorting letters, and holes round the walls for their reception. The manner in which the duties of the clerk and guard are performed in this flying post-office, is strikingly significant of the new order of things introduced by the railway system. Outside the vehicle a species of net is extended by a hoop, and into this the letter bags are dropped as the train sweeps onward in its course, the bags which are to be left being at the same time tossed from the window by the guard. The fresh bag of letters being received, it is speedily opened, its contents rearranged, and a new bag for next town being made up, it is projected as before at the place of its destination. By this means a letter may be written, sent through the post-office, and delivered at the distance of twenty miles, in the space of a single hour.

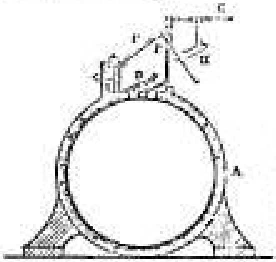
The speed at which railway trains usually proceed is from twenty to twenty-five miles per hour, though sometimes it is much more. At the ordinary rate of speed, a journey from London to Liverpool by the mail train is performed in about nine hours. Now that a continuous line of railway is made from London to Edinburgh, *via* Carlisle, journeys between these cities will soon be made by 'express' trains in eleven or twelve hours. Already an express train has traversed the distance (427 miles) between London and Edinburgh, *via* Berwick and Newcastle, in little more than ten hours, and this with the interruptions caused by the yet incompleted bridges over the Tweed and Tyne. Contrary to early predictions, travelling by railway at any of the common rates of speed is attended with less personal danger than stage-coaching, because the locomotives are perfectly under control. Any deaths or personal injuries which have occurred on railways are, with scarcely an exception, attributable to the carelessness of the engine-drivers; and by the employment of a superior class of men to direct the motions of the trains, this fruitful cause of mischief is in the course of being obviated. With this improvement, conveyance by railways will be ranked among the most useful and stupendous inventions of art.

Atmospheric Railways.

If a smooth and straight metal tube be provided at one end with an air-tight piston, and the contained air be extracted, the piston, on being let go, will traverse the tube from end to end, being, as it were, forcibly driven by some unseen agency. This agency is the weight or pressure of the atmosphere. It is well known that the atmosphere presses upon all substances exposed to its influence with a certain force; this, when the barometer stands at thirty inches, being about 15 lbs. on the square inch. Now, in the case supposed above, before the air is extracted from the tube, the same pressure exists on each side of the piston, consequently it remains at rest; but as a vacuum is formed, the atmosphere, pressing on each square inch of the piston with a force of 15 lbs., drives it along the tube, there being no atmospheric pressure on the other side to prevent its movement. This, then, is the principle of the atmospheric railway.

If the reader will suppose a small carriage to be fitted to the tube, and attached to the piston, he will have a good idea of the atmospheric railway, as first proposed to be established between London and Brighton. This mode of travelling not possessing many charms to ordinary travellers, excepting that of novelty, the scheme, as might be supposed, did not succeed; but the idea being a good one, many engineers and men of science directed their attention to the subject. The first evident improvement to be made was having the carriages *external*, and connected with the piston by some contrivance sliding along a slit or opening made in the upper side of the tube. Messrs Clegg and Samuda patented improvements, which were first tried experimentally at Wormwood Scrubbs, on a portion of the West London Railway; and these proving successful, were adopted by the Dublin and Kingstown Railway on that part of their line between Kingstown and Dalkey, a distance of about one mile and three-quarters. This line is much inclined; the carriages descend by their own gravity, and are propelled up the incline by the atmospheric agency. This first application of the atmospheric principle proving eminently successful, the example has been followed by the London and Croydon, and South Devon Companies. There are many conflicting opinions relative to the merits of the system; but some of the engineers of first celebrity having, within these last three years, directed their attention to its improvement, we doubt not that in a short time the difficulties which have beset the plan will be overcome by their ingenuity, and that in a few years it will meet with more extensive adoption. Numerous patents have been taken out for improvements in connection with it, but our space will not permit any detail; we must content ourselves with giving a brief account of the plan adopted on the Kingstown and Dalkey line.

The vacuum pipe (the distinguishing feature of the system) is fifteen inches diameter, and is laid in the ground between two lines of rail on which the carriages run. In the upper side of the tube is a slit or opening, closed with a valve, to render the tube air-tight when required. This valve is made of leather, on the sides of which are rivetted pieces of iron—the inner plate assuming the same curve as the pipe, so that when the valve is closed, the bottom side of the valve forms part of the pipe. The upper side of the plate and leather is longer than the lower, and extends a little over the edge of the opening. The valve is attached to one side of the pipe by a projecting rib, and the other edge lies in a groove among wax and tallow, which, when melted, forms an air-tight joint or seam. A piston, having a rod fourteen or fifteen feet in length, to which are attached rollers for opening the valve in the rear of the piston, is placed within the tube or vacuum pipe. This piston is connected with the first carriage, called the *driving-car*, by a contrivance called a *coulter;* to the driving-car is attached a copper vessel heated with coke, used for melting the wax lying in the hollow previously mentioned. The annexed sketch will show the operation; it is a transverse section of the vacuum tube: A, the tube; B, the air-tight valve; C, the weather valve, which prevents rain, snow, &c. from getting into the air-tight valve; F, the coulter; G, part of the driving-car; H, roller to open the weather valve. The rollers to open the air-tight valve are not shown, as it would confuse the sketch.



The operation is as follows:—The steam-engine placed at the extreme end of the line exhausts the air from the tube before the piston, and when the barometer shows a vacuum of proper degree, the driving-car moves forward, dragged by the piston; the sealed valve is opened behind the piston, and the air is thus admitted to the tube. The valve is now pressed into its seat again, the heated copper follows, melts the wax, and makes the joint air-tight. Meanwhile the engine works to maintain the partial vacuum, and on the train arriving at its destination, the pipe is ready sealed for another trip. As the tractent power of the atmospheric railway depends upon the sectional area of the vacuum tube, and the degree of rarefaction of the air before the piston, the larger the tube, and the faster the air can be withdrawn from it, the greater the power and velocity of the train. A speed of sixty miles an hour has been realised on the Dalkey line. It will be evident that no collision can possibly take place—indeed one train running into another in the atmospheric line is a physical impossibility; there is little or no danger of the train being turned off the rails, the connection with the piston preventing this; and there is little or no oscillation. A gentleman placed a half-crown on the step of a carriage on starting from London, and on his arrival at Croydon, the half-crown was still there; an ample proof of the smoothness of this mode of transit. Steep gradients, or inclines, can be ascended with ease by the atmospheric line, which are impracticable to locomotive engines. Much trouble has been encountered by the changing of the composition in extreme hot or cold weather. We believe this difficulty has now been obviated by the discovery of a very ingenious valve.

Such is the atmospheric principle. The most important objections yet given by the opponents of the system are in the words of Mr Barlow; namely, 'that the traffic is dependent upon keeping air-tight a great length of pipe, and upon the perfect order of a great number of engines. In fact it depends upon the perfect order of an extensive, delicate, and complicated machine, composed of an infinite number of parts, the failure of any one of which would render the whole machine useless; and it must be evident to any person practically connected with the maintenance of a railway, that the machinery of such an engine will be liable to frequent interruption from causes which it is impossible to control.'

Electric Telegraph.

Astonishing as the rapidity of railway transit may appear, it is not for an instant to be compared with that of the Electric Telegraph. This wonderful apparatus is now appended to every railway of importance, both for the purpose of conveying messages in connection with the working of the line, and as a means of correspondence for the public. Telegraphs so set in motion were invented by Cooke and Wheatstone about the year 1837, but have since undergone numerous modifications and improvements by Bain, Brett, Little, and others. As explained under ELECTRO-MAGNETISM, p. 272, the invention depends upon the principle, that an electric current can pass along a conducting wire to any distance, and be made to move magnetic needles at any part of its course—these needles indicating or signalling according to some predetermined arrangement. The essential features of the operation are the *conducting wire* or wires, the *battery* which generates the electric current, the *signalling apparatus*, and the *mechanism for making and breaking the metallic contact* that completes the circle. As the passage of the current is almost instantaneous, no matter what the distance, the chief endeavour has been to discover a mode of signalling a message with as great rapidity as it can be spoken or written. At present, there are two great modes—the *mechanical*, by which needles will signal at the rate of fifty or sixty letters per minute; and the *chemical* (involving the action of the voltaic current on chemically-prepared paper), by which a thousand symbolic characters or letters may be transmitted in the same space of time. These symbolic characters are in fact a species of electric printing; and though the trouble of transcribing them in ordinary writing is at present requisite, there is little doubt but we shall shortly have the electric telegraph printing correspondence in the common character as fast as the human voice can dictate, or at all events as rapidly as the hand can indicate the original. Thus the message-sender at London will scarcely have withdrawn his hand from the wires, when his friend at Edinburgh will have spread before him every word and letter of the intelligence! With such an extraordinary instrument as this, it is impossible to conjecture what may yet be accomplished in the way of rapid communication between the most distant and remote places. There is, indeed, no necessary limit, but the matter of expense, to its application; for the wires, under certain precautions, are equally fitted to convey the electric current through water as through the medium of the atmosphere. At present, this telegraphic network is being spread over the country under the superintendence of a Company, to whom the exclusive right has been patented for a period of fourteen years.

MARITIME CONVEYANCE.

The instruments of maritime conveyance are *ships*—a term which, though commonly applied to decked vessels only, may be made to include every species of craft, from the rude canoe of the savage to the three-decked man-of-war. Their construction and equipment, their navigation and management when afloat, the building of docks and harbours for their reception, the erection of lighthouses and beacons for their guidance; in fact, the whole science by which man is enabled to traverse the ocean, and bring the most distant regions as it were into local proximity, is one of superlative interest, and especially so to the inhabitants of an insular country like Britain. To a brief exposition of its leading features, as above indicated, we intend to devote the following pages.

SHIPS.

Of the early history of ship architecture little can be said of any importance. The buoyant property of water, particularly that of the sea, must have been soon observed by mankind; and therefore, beginning with rude skiffs and canoes, they would in time acquire sufficient experience and skill to form vessels of a larger size, and to guide them in the required direction by means of a rudder and sails. The cultivated nations of antiquity—Egyptians, Phœnicians, Carthaginians, and others—possessed ships for commerce and war, some of which were of large dimensions, and were moved either by oars or by the action of the wind on sails. But of these early vessels, as well as of those now employed by half-civilised nations, it is unnecessary here to speak; and we proceed to notice the construction and character of ships formed according to the principles of modern and improved science.

The nicest and most difficult operation in ship-building consists in first forming a draught or model of the proposed vessel, or, as we may call it, the *plan* which the mechanics are to adopt and follow out. In forming this plan, the designer is governed by a consideration of the precise object to be attained. There are two classes of vessels—ships of war and merchantmen—and each must possess certain qualifications. In a ship of war the great object is speed, with ease of movements, and capacity to accommodate her crew, and carry a sufficient weight of guns, stores, and provisions. One point, moreover, is especially to be looked to; this is, that the ship float high enough above water to run no risk of receiving waves or seas in her lower ports during action, when these holes must be necessarily open. In order to be secure of this, the constructor makes an estimate of the whole weight of the ship, including body, spars, armament, men, and munitions, and must so model the bottom that it will have displaced an equal weight of water when arrived at the desired depth. In the case of merchantmen, the primary consideration is to attain the greatest capacity to carry cargo, combined, as far as possible, with safe and easy movements and rapid sailing.

The English excel in ship-building, but in some respects they are outdone by the Americans, whose packet ships carry enormous weights, while they are noted for their speed. Among the admitted and well-established principles of construction is the leading one, that the greatest breadth must always be before the centre, and consequently the *bow* or front be more blunt than the *stern* or hinder part. Abstractly, it would seem most important that the bow should be the sharpest, so as to cleave the water with the least possible resistance; but experience has proved that it is far more essential to facilitate the escape of the displaced water along the side of the vessel; for when once a passage is opened for the ship, the fluid tends to reunite behind the point of greatest breadth, where, instead of offering resistance, it presses the ship forward, and fills up the space constantly opening behind her. The principle is evident in the form of the duck and other aquatic animals, which are uniformly broadest in front, and gradually diminish to the tail. As it is, then, less essential that a ship should be sharp forward than aft, there is a further advantage in having the bow full towards the edge, that it may check her in descending into the waves, not abruptly, but gently—pitching, or rising and falling endwise, being the most dangerous to hull and spars of all a vessel's movements. Though sharpness towards the stern-post is vitally essential to fast sailing, yet care must be taken to leave the buttock full towards the surface, in order to check the stern gently in descending, and when scudding before a gale, to lift it in timely season on the arrival of a sea. To hit the exact mean in these respects, so as not to retard the sailing on the one hand, nor to endanger the ship on the other, requires all the skill of the architect.

There must likewise be a due correspondence between the general bulk of the vessel and its length and breadth; the whole must be properly proportioned. If unduly long, speed may be gained, but there is a difficulty of turning, and also of rising to escape the breakings of the sea; long ships, therefore, are apt to roll and to cut through waves instead of breasting them, by which their safety is perilled. When a ship is unduly short for its general bulk, it is apt to pitch, which is equally dangerous; hence the greatest care is required to proportion the various dimensions.

All essential preliminaries being settled, the ship is begun to be constructed; and this is always done in the yard of a ship-builder, close by the water's edge. The wood considered to be best adapted for ship-building is oak, pine, teak, elm, or beech; and whichever is employed, it requires to be strong, well seasoned, and dry: the greater part, likewise, should be bent or crooked, to suit the curves and angularities in the structure; and for this end growing timber is often constrained to assume particular forms. The *keel*, which is the lowest part of the vessel, and corresponds to the backbone of an animal, from which the ribs or *timbers* spring, is formed and laid first on a slip and blocks set for the purpose. As the framework proceeds, all parts are firmly bolted and rivetted together, and the whole is finally covered with the planking in even lines from bow to stern. When it is necessary to bend a plank for either the bow or stern, it is heated by steam, and then forced into its place by screws and levers. The planks are fastened to the ribs by *treenails* or wooden pins, and the plan is followed of allowing a seam or space between each plank, which is filled up or *caulked* with oakum, and the whole is smeared with pitch. In some instances the bottom is further secured by sheathing it in sheets of copper. Meanwhile the interior beams and partitions have been placed; and when duly prepared, the vessel is *launched*, or shot, by an easy movement, down the inclined plane on which it rests into the water. After launching, the rudder or *helm* is shipped. The rudder is a wooden apparatus placed at the stern of the ship, a large portion being in the water; and by means of it the vessel is steered and turned about at pleasure. The steering part is on deck, and consists either of a simple lever, called the *tiller*, or of a wheel placed perpendicularly, and connected with the tiller by chains and pulleys. The principle on which the rudder acts is very simple: the object is to turn the vessel; and to whatever side the inclination is to be made, the rudder is caused to present an obstacle to the water in that direction.

The masts of the vessel are now set; and the *spars*, comprehending the bowsprit and yards, and also the rigging, are attached. The spars of a ship are not abandoned to their own unsupported strength, but are sustained by what is called the *standing rigging*, which consists of strong well-spun ropes, or in some recent instances, of iron wire twisted into strands of the requisite thickness. Besides this there is the *running rigging*, which consists of the tacks and sheets that serve to spread the sails, the halliards, traces, lifts, clewlines, and all other ropes used in making, taking in, or manœuvring the sails. In the construction of both hull and rigging there is a vast amount of bolting, nailing, splicing, and so forth, much of which is likely to be now superseded by the use of Jeffrey's marine glue—a substance of such tenacity that planks joined by it have been found to give way invariably in the solid wood, and not at the junction. Masts marine-glued, and without hoop or bolt, have been tried, and after the exposure of a tropical voyage, have returned sound and strong as on the day they were constructed. Indeed so invincible is the tenacity of this compound, that the possibility of constructing a hull without bolt or treenail has been soberly asserted.

The sails of a ship are sheets of canvas bent to the yards, and fore-and-aft sails traversing on stays or bent to gaffs. Let us proceed to describe an entire suite, beginning forward, and referring to the subsequent figures:—On the extremity of the bowsprit is the *flying-jib*, a three-cornered sail, which goes from the end of its boom upward along its stay, leading to the foretop-gallant-mast-head, and confined to the stay by rings of wood or iron, called the *hanks*. It is hoisted by means of the halliard; hauled down by a downhaul; and when up, is trimmed to hold the wind by a sheet or rope leading to the forecastle. The *jib*, which leads from its boom to the foretop-mast-head, is of similar form, and so is the *foretop-mast-stay-sail*, running from the bowsprit end towards the mast-head. On the foremast we have the *fore-sail*, bent to the fore-yard, and spread at the foot by means of tacks and sheets; above it, the *foretop-sail*, bent to the top-sail-yard, by means of which it is hoisted aloft, while its lower corners are spread to the extremities of the fore-yard; next the *top-gallant-sail*, bent to its yard, and sheeting home to the top-sail-yard; and so with the *royal* and *sky-sail*. All these sails are turned at pleasure, to be presented to the wind, by means of braces attached to their yard-arm, and leading to the mainmast. The mainmast is furnished with a similar suite of sails, somewhat larger; the mizen-mast also, though smaller than either, instead of a square-sail on the lower part of the mast, has a *gaff-sail*, hoisting up or down abaft the mast. Some ships have similar gaff-sails on the fore and mainmasts, which are found of great use in gales of wind, as a substitute for storm stay-sails. Most carry, also, light stay-sails between the masts; but they are very troublesome. *Studding-sails*, spread beyond the square-sails like wings, are found useful when going before the wind. The perfection of equipping a ship with spars, rigging, and sails, consists in so disposing them, that in a whole or full sail breeze the centre of effort of all the sails will be in the same line with the ship's centre of rotation; or that the effects of the forward and after-sails to turn the ship will be exactly balanced, as not to require any continued assistance from the rudder in either direction.

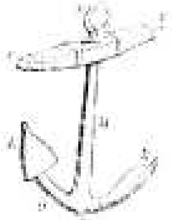
Such is a brief outline of the construction of a common decked vessel as regards hull and rigging. It must be remembered, however, that different modes are adopted according to the kind of service for which the craft is intended, and that general improvements are occasionally being made in naval architecture. Thus independently of a difference in material, some arrange the timbers or framework in such a manner that they shall form the main strength of the vessel; while others, following a cheaper and less scientific course, plant the timbers perpendicularly and sparsely, thereby throwing a great, if not the greater, portion of the strain on the outer planking. Again, much depends on the securing of the masts, which, when under press of canvas, act as powerful levers on the parts of the hull to which they are attached. Instead of resting these only upon steps, strong platforms, which diffuse the pressure on all sides, are now generally used, and by this means a fertile source of leakage extinguished. Round sterns, which can be constructed with all the strength of the bow, are now also preferred to the old square and massive but weak stern; and further, the breadth of beam, which adds stability to the whole fabric, has of late been considerably increased.

The principal ship-building ports in Britain—laying aside consideration of the government dock-yards—are London, Sunderland, Newcastle, Liverpool, Hull, Yarmouth, &c. 'The business'—we quote M'Culloch's Statistics—'has increased with extraordinary rapidity at Sunderland; so much so, that while only 60 ships, of the burden of 7560 tons, were built in that port in 1820, no fewer than 302 ships, of the burden of 87,023 tons, were built in it in 1840. Ships built at London, Liverpool, Bristol, and other western ports, are, however, in higher estimation than those built in the Tyne and the Wear, at least for those branches of trade in which the best ships are required. Within the last few years, a great many steam vessels have been built in the Clyde.' With respect to the classification of British vessels, the same authority remarks: 'Until very recently, ships, how much soever they might differ in other respects, were classified at Lloyd's (the office of the Society of Underwriters, and great centre of shipping affairs) with reference solely to their age and the place where they were built. Thus, supposing two ships were launched about the same time in the Thames, the Wear, or anywhere else, they were enrolled together in the *highest* class in Lloyd's Register, and stood there for a certain number of years, how different soever they might have originally been, or how different soever they might afterwards become! And underwriters thus seeing them standing together, and having no other test of goodness to which to refer, insured and employed the one on the same terms as the other! It is unnecessary to dwell on the preposterous absurdity of such a system. Practically it operated as a high bounty on the building of defective, or what is called *slop-built* ships; and there can be no doubt that it tended materially to depreciate the character of our mercantile marine, and to multiply shipwrecks to a frightful extent. We are therefore glad to state that a new system of classification has been adopted, by which the place of vessels on the register will be made to depend, not on their age, or the port where they were built, but upon their actual condition.' The several classes are marked by the letters A, Æ, E, and I, which have reference to the state of the hull; and by figures which indicate the condition of the stores and equipment. Thus 10A1 denotes a ten-years ship of the first description of the first-class, with stores well and sufficiently found. Steam-ships are similarly classified, but require to be surveyed *twice a year*.

Anchors—Buoys.

The retarding apparatus of the vessel consists of heavy iron instruments called anchors, of which each vessel has usually more than one. Large ships carry the following suite of anchors:—1. The *sheet* anchor, which is the largest, and only used in the case of violent storms; 2. Two bower anchors—namely, the *best bower* and *small bower*, so called from their situation at the bows; 3. The *stream* anchor, the *kedge*, and *grappling* or *grapnel*. The three last are often used for moving the ship from place to place in a harbour or river. Each anchor is let down by a strong cable of iron or rope, and is lifted by means of the windlass placed on deck. To the cable, when in the water, a *buoy* or floating object may be attached, to show where the anchor has been let down; and to save time, or in an emergency, the anchor and cable are sometimes left, while the vessel proceeds, the buoy serving to point out where the anchor may be recovered. The anchor is said to be *a-peak* when the cable is perpendicular between the hawse and the anchor; it is said to come *home* when it does not hold the ship; it is said to be *foul* when the cable gets hitched about the flukes. *Riding at anchor* is the state of the vessel when moored or fixed by the anchor. *Dropping* or *casting anchor* is letting it down into the sea. *Weighing anchor* is raising it from the bottom.

An anchor—whatever be its form—should be of sufficient weight to fix itself to the bottom; and for this purpose it is customary to allow one hundredweight of anchor for every fifteen or twenty tons of ship-burden or tonnage. In men-of-war, the weight is sometimes roughly estimated at one hundredweight for every gun. The weight of the anchor is not strictly proportional, however, to the size of the vessel, as large vessels are less affected by sudden or violent motions than smaller ones. The shape and proportion of the different parts must be also carefully attended to; so as at once to yield the greatest hold or gripe, and withstand the greatest amount of strain. Large anchors are made thicker in proportion to their length than smaller ones; and as the greatest strain takes place during the operation of weighing, the diameters of the shank are unequal—the longest being in the direction of the arms. The several parts of a common anchor, here represented, are technically designated as follows:—The straight bar B, to which the cable is attached, is called the



shank; r the *ring*; the cross bar s s, fixed at the free extremity of the shank, the *stock*; the upper end of the shank the *small round*; the extremity c, where the shank and arms unite, is called the *crown*; the angle formed by the arms and the shank is termed the *throat*, and generally stands about 50°. The arms consist of three parts—the *blade*, g; the *palm*, h; and the *bill*, k. The palm or fluke is made of a flat triangular shape, the apex of which is prolonged so as to form the bill or peak. However large and ponderous, anchors are all formed of bar-iron, welded and wrought together by hand-hammering. Their fabrication, which is extensively carried on in Britain, requires great skill and care.

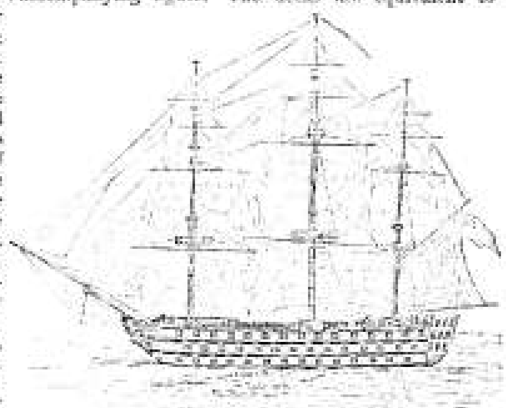
In addition to the common anchor represented above, there are various other forms in use, each laying claim to some peculiar superiority. Thus the grapnel has three or four arms instead of two; the mushroom anchor (so called from its shape), much used in the East Indies, has an entire holding edge, being shaped like a mushroom or bowl; and in the patent anchor of Lieutenant Rodger, R.N., the old broad flukes are entirely dispensed with, and the arms placed at an angle of 45° with the shank. Several forms of *floating anchor* have been proposed, for the purpose of retarding the progress of vessels during heavy gales in the open sea, where anchoring is not practicable. The principle of this species of anchor is simple:—A structure or framework is passed over the stern into the sea, so as to present a large amount of perpendicular or resisting surface to the forward motion of the vessel. Dr Franklin's device consisted of lashing two cross-bars firmly together, and stretching over these strong sailcloth—a simple apparatus, by which he thought sufficient retardation could in most cases be produced.

Buoys are vessels either formed of wood, cork, or some light substance, moored or anchored so as to float over a certain spot, in order to indicate the situation of a shoal or sandbank, and thus mark out the course which the ship ought to follow; or they may be constructed of large blocks of wood, clamped with iron, and furnished with rings, to which vessels may moor themselves in rivers or in harbours. When used for the former purpose, they are usually hollow vessels, barrel-built, in the form of a cone, of large dimensions, so that they may be seen at a distance; and generally painted of some particular colour, that they may be more readily distinguished from one another. Mooring buoys, on the other hand, are generally solid blocks, kept in their places by heavy anchors or sunken weights. As these are liable to be dragged, various methods of secure fixing have been proposed, but none with the same likelihood of success as the 'screw pile' of Mr Mitchell, to be hereafter described. Buoys for the above purposes are designated *public*, and are placed under the control of the Trinity House, who charge, as in the case of lighthouses, a small tonnage-due for their maintenance. *Private* buoys are those used by individual vessels for indicating the situation of their anchor, with a view both to prevent their running foul of the anchor, and also that the anchor and cable may be recovered when the latter may happen to be broken or cut.

Having thus treated of the general construction and outfit of ships, we shall now briefly advert to the peculiar characteristics which distinguish vessels of war from those of mercantile burden.

War Vessels.

At the head of the list stands the ship-proper, a vessel with three masts, called the fore, the main, and mizzen-masts, and which is square-rigged, or carrying large square sails. The largest ships are vessels of war, named line-of-battle ships, having three complete decks, and carrying 120 guns. A representation is given of such a magnificent floating apparatus in the accompanying figure. The decks are equivalent to



First-rate War Vessel.

different floors. On the first or uppermost, extending on each side of the foremast, is the *forecastle*, and next to it, between the foremast and the mainmast, are the *waist* and *gangway*; between the main and mizzen-masts is the *quarter-deck*; and next to it, towards the stern, is an elevated part called the *poop*. A narrow passage on each side of the vessel, communicating from the quarter-deck to the forecastle, are called *gangways*, and in nettings above these the seamen's hammocks are stowed as a protection during action.

The forecastle is appropriated to the best or able-bodied seamen, the quarter-deck is the proper situation for the officers, and in the poop are stationed the marines. The quarter-deck is a privileged spot, and as, by a fiction, the sovereign is supposed to be present, every one who enters this deck must salute it by touching his hat, and all present return the compliment by touching their hats likewise. Beneath the poop are the apartments of the captain, and some others. Descending from the upper range of decks, we arrive at the *main-deck*, at the fore-part of which is the sick-ward, and next to it the *galley* or cook's room; at the after-part, beneath the captain's cabin, is the admiral's cabin. The next, or third range of deck, is the *middle-deck*; at the fore-part of which is the ward-room, or general apartment for the officers. The fourth range is the *lower-deck*, where the sailors sleep and mess, and on which also is the *gun-room*, for inferior officers. On all the decks mentioned, cannon or large guns are ranged, each having its appropriate port-hole; and by these holes, on which temporary windows are fastened, light is admitted to the interior. We now descend to a floor beneath the surface of the water, which is called the *orlop-deck*, on which, between the main and mizen-masts, is the cockpit, or surgeon's room; the purser's, boatswain's, and carpenter's berths, and midshipman's messroom. Beneath the orlop-deck is the *hold*, a species of cellar in divisions, containing the boatswain's and carpenter's stores, the powder-magazine, shot, the water-casks, and provision stores.

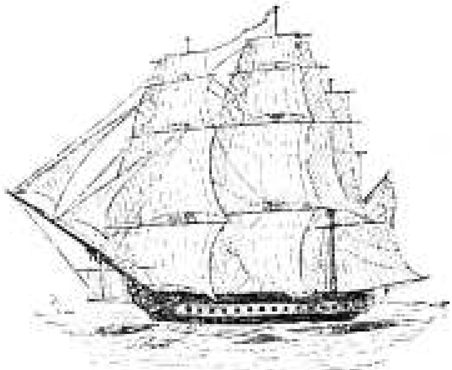
War vessels receive their designations from the number of their decks, or of the guns which they carry. Line-of-battle ships are of various *rates*. The *first*-rates include all carrying 100 guns and upwards, with a company of 850 men and upwards; *second*-rates carry 90 to 100 guns, and from 650 to 750 men; and *third*-rates carry from 60 to 80 guns, and from 600 to 650 men. The rates thus diminish in bulk and complement of men down to sixth-rates. A common rate is a 74 gun-ship, which carries 600 men. The following is a list of the titles and number of the crew of a first-rate war vessel, classed in the order of their amount of pay:—

Captain,	1	Brought forward,	106
Lieutenants,	8	Coxswain of Pinnace,	1
Master,	1	Sailmaker's Mate,	1
Chaplain,	1	Caulker's Mate,	1
Surgeon,	1	Armourer's Mates,	2
Purser,	1	Cooper,	1
Second Master,	1	Volunteers,	12
Assistant Surgeons,	3	Gunner's Crew,	25
Gunner,	1	Carpenter's ditto,	18
Boatswain,	1	Sailmaker's ditto,	2
Carpenter,	1	Cooper's ditto,	2
Mate,	1	Yeoman of Storeroom,	1
Midshipmen,	23	Able Seamen, } Ordinary ditto, }	470
Master's Assistants,	6		
Schoolmaster,	1	Cook's Mate,	1
Clerk,	1	Barber,	1
Master-at-Arms,	1	Purser's Steward,	1
Ship's Corporals,	2	Captain's ditto,	1
Captain's Coxswain,	1	Captain's Cook,	1
Launch ditto,	1	Wardroom ditto,	1
Quartermasters,	12	Wardroom Steward,	1
Gunner's Mates,	5	Steward's Mate,	1
Boatswain's Mates,	8	Lamleman,	1
Captains of Forecastle,	3	Boys,	32
Captain of Hold,	1		
Ship's Cook,	1	Total Seamen,	690
Sailmaker,	1		
Ropemaker,	1	Captain of Marines,	1
Carpenter's Mates,	2	Lieutenants,	3
Caulker,	1	Sergeants,	4
Armourer,	1	Corporals,	4
Captains of Maintop,	3	Drummers,	2
Captains of Foretop,	3	Privates,	146
Captains of Mast,	3		
Captains of After-Guard,	3	Total war complement of officers, seamen, and marines,	850
Yeoman of Signals,	1		
	106		

A number of the above officers and subalterns are not appointed to third or inferior rates. Latterly, engineers have been added to the list of men in the royal navy, intended for service in the steam marine; they take rank below carpenters.

The burden of a first-rate is from 2700 to 2800 tons; the length of the lower gun-deck is 205 feet 6 inches, and length of keel for tonnage 170 feet 6 inches, the upper decks being longer in proportion; the height from keel to midships from 50 to 60 feet. The guns are generally distributed as follows:—Forecastle, two 18-pounders and two 34 carronades; quarter-deck, two 18-pounders and fourteen 32 carronades; main-deck, thirty-four 32-pounders; middle-deck, thirty-four 32-pounders; and lower-deck, thirty 32-pounders and two 68 carronades. Total, 120 guns.

Ships of less than 44 guns are termed *frigates*. A frigate, of which the following engraving is a sketch, has only one gun-deck beneath the quarter-deck; and beneath that, lighted and ventilated partly by skylights, and partly by small holes in the sides, is a deck appropriated to the men, officers, &c.



Frigate.

The following account of the organisation and arrangements on board of war vessels is abridged from a work entitled 'Two Years and a Half in the American Navy,' by E. C. Wyne; 1833. Though strictly applying to an American frigate, it is generally applicable to a similar vessel in the British navy. 'Time on shipboard is divided into watches, and reckoned by bells. Hence you never hear the question, "What's o'clock?" but "How many bells is it?" The twenty-four hours are divided into six equal portions, called watches. At the end of the first half hour of one of these portions the bell is struck one; at the end of the second, two; and so on, till the series reaches eight, when it commences again. In the ship's journals, the dates are put down according to the common mode of reckoning time. The division of time into watches differs somewhat at sea and in port.

Order is the first great rule on board a man-of-war, and that to which all others must bend. From day to day, from week to week, from month to month, and from year to year, the same stroke of the bell is followed by the same whistle, the same call, and the recurrence of the same duties. Everything has its place, too, and must be kept in it. So true is this, that a person acquainted with the details of a ship, can lay his hand on a given object in any part of her as well in the dark as if a thousand suns were shining on it. To the same grand principle—ORDER—are to be attributed the numerous divisions and subdivisions of the officers and seamen.

At the head of the list of officers stands the captain, whose will is supreme; and from his decisions, for the time being, there is no appeal. He has a general superintendence over the affairs of the ship, and every order of a general nature must originate in him. No important alteration can be made without his knowledge and consent. It is his duty to take a general oversight of the officers' conduct; to see that they are guilty of no improprieties, and to punish such as are. He is responsible for the safety of the ship both at sea and in port. If any business of a public nature is to be transacted with a foreign power, it falls of course into his hands. These are his duties in time of peace; in war he has still higher responsibilities.

Next in rank come the wardroom officers, consisting, on board of a frigate, of six lieutenants, a purser, surgeon, chaplain, sailing-master, and lieutenant of marines. The first lieutenant is next in power to the captain; and though his station is less responsible, his duties are more laborious. He has a general supervision over the ship, and is to see that she is kept clean and in proper order. To this end he is obliged to inspect every part of her at least once a day, and report her condition to the captain. When the ship is put in commission, it devolves chiefly upon him to station the men;

a business of the most laborious and difficult nature, requiring great patience, a discriminating judgment, and deep insight into the human heart. It is his duty to have the men frequently exercised at the guns; to regulate the expenditures of certain public stores; to take care that the men keep themselves clean and decently clad; to superintend the watering and victualling of the ship; and, in short, to see that all her multifarious and complicated concerns move on regularly and harmoniously. In coming to an anchor, and getting under weigh, and when all hands are called to reef topsails, or for other purposes, he takes the trumpet. On him, more than on the captain himself, depends the comfort of the officers. In port, it belongs to him to grant or withhold permission to go ashore; and there are a thousand other ways in which, if he is a man of capricious or malignant disposition, he can gratify his whims or his spleen at the expense of the comfort and feelings of his fellow-officers.

The other lieutenants are divided into watches, and take turns in performing the duties belonging to their station. The lieutenant on duty is styled in writing the officer of the watch, but is familiarly called the officer of the deck. Some of his duties are common at sea and in port, and others are peculiar to each of these situations. In both he is responsible for the deck while he has charge of it, and has also to take a general oversight of the ship. He must see that the men's rations are properly cooked, and that they have their meals at proper hours. The serving of the grog is also under his control. At sea, his duty is to sail the ship, keeping her on the course given her by the captain, and reporting to him any change in the wind, the discovery of land or strange sails, and any extraordinary occurrences. At night he has the captain waked at stated periods, and the state of the weather reported to him. On receiving the trumpet, the first thing the officer of the deck does is to glance at the compass, the sails, the dog-vane, the sky, and the water, to discover the state of the ship, the wind, and the weather; and at the end of the watch, he must have a general account of the weather, and other matters which he may deem proper, inserted in the ship's log-book. The duty of the officer of the deck in port is to receive any supplies of water or provisions which may come alongside, to regulate the sending away of boats, to keep a look-out as to what is going on in the harbour, to report the arrival of ships and any important occurrences to the captain, &c. The lieutenants are also officers of divisions, and frequently have to exercise the men at the guns, besides superintending the monthly issues of slops to their respective divisions.

Next in rank to the lieutenants comes the sailing-master, whose duties are more comprehensive and arduous than those of any other officer. His supervision and responsibility extend to almost all the public stores in the ship, but particularly to the water, spirits, cables, and anchors. He reports the daily expenditures of water to the captain. It is his business to keep the ship's place, and report it at least twice a day to the commander, together with the bearings and distance of the port to which she is bound, or the nearest land desired to be made. Some commanders leave this entirely to their sailing-masters.

There is no berth on board a man-of-war more cozy than that of purser. He holds the keys of the strong-box; and though his regular salary is not much, his emoluments arising from other sources are considerable. All the provisions on board are committed to his charge, and the ship's accounts are all kept by him. His responsibilities are very great, and heavy bonds are therefore justly exacted from him.

The surgeon and his two assistants form the medical staff of a frigate. The assistant-surgeons form a distinct class of officers, ranking between the wardroom officers and midshipmen. In frigates and ships of the line they mess in the cockpit, but in all other public vessels in the steerage. The business of the staff is of course to take care of the sick, and perform such surgical operations as may be necessary. A daily journal is kept of the names, rank, diseases, and constitutional habits of all the sick on board, and also of the medicines administered to them. From the journal a report is made out and signed by the surgeon every morning, stating the names, rank, and diseases of the sick, and the number added to and taken from the list. This is handed to the captain. Another list, containing only the names, is placed in the binnacle for the use of the officer of the deck. Nothing will excuse either an officer or a man from duty, but the fact of his being registered on the sick list. A general review of the sick takes place every morning after breakfast. One of the assistant-surgeons inspects the ship's coppers every day, to see that no verdigris is allowed to collect upon them. It is the duty of the surgeon not only to attend to the sick, but also to recommend and enforce such precautionary measures as will have a tendency to prevent disease, and thus secure the general health of the officers and crew. On board of every war vessel there is a chaplain, who conducts the Sunday services, and administers spiritual consolation to the dying. Of late, a schoolmaster has been added to the list of functionaries.

The midshipmen may be called apprentice officers, and they require to learn certain duties of seamen. They are also useful by carrying messages from the officer of the deck to the captain, and in port one of them takes charge of every boat that leaves the ship. Towards noon, while at sea, they are obliged to go on deck with their quadrants, and take an observation. They have to work out the last day's run, and report the course, distance made good, and ship's place at noon each day, to the captain. They muster the crew when the watch is called at night. They are also required to keep a journal of the cruise, which is, however, only a copy of the ship's log. This is examined every few weeks by the commanding officer; and if it happens not to be written up when called for, the delinquent is generally punished by a curtailment of some of his indulgences. Five of the oldest midshipmen are master's mates; and their duties are more important and responsible than those of the others.

The boatswain, gunner, carpenter, and sailmaker, form a distinct class of officers, called warrant-officers. The boatswain is charged with the rigging of the ship, and in port attends to squaring the yards. You may know him by his silver whistle, rattan cane, and above all, by the ruddy hues of his countenance, and the odious vapours that issue from his mouth. The gunner has charge of the military stores, and when all hands are called, of the main rigging. The carpenter is responsible for the stores belonging to his department, and superintends the corking of the ship, and other work performed by his subalterns. The sailmaker is charged with the sails, hammocks, and generally all the canvas in the ship. At sea, he is obliged to go aloft on each of the three masts, examine the condition of the sails, and report it to the first lieutenant every morning before breakfast.

The grand divisions of the crew are into petty officers, seamen, ordinary seamen, landsmen, and boys. This division has reference to rank; but there are others into which considerations of this kind do not enter. Such are the military divisions, and the divisions into larboard and starboard watches, into forecastlemen, fore, main, and mizentopmen, afterguard, waisters, &c.

The petty or warrant-officers are appointed by the commander, and may be degraded by him without the formalities of a court-martial. They are selected from among the most experienced and trustworthy of the seamen. They consist, on board of a frigate, of a master-at-arms, eight quartermasters, four boatswain's mates, eight quarter-gunners, a boatswain's and gunner's yeomen, a carpenter and sailmaker's mate, an armourer, a cooper, cook, and cockswain.

The highest and most responsible of the petty officers is the master-at-arms, who may be called the principal police-officer of the ship. He has charge of all the prisoners, and every morning makes out and hands to the commander a list of their names, with a specification of the crime for which each is confined, and the time when he was put in confinement. He has charge also of the berth-deck, and it is his duty to see that it is kept in good order. All property that falls in his way for which he cannot find an owner, is thrown into the "lucky-bag," the contents of which, if not finally claimed, are sold at auction.

The office of quartermaster is one of some dignity and considerable importance. It is his duty to keep a look-out with his spyglass for signals from other ships, and to report them to the officer of the deck; and also to report to him all boats that come alongside, and all other movements and occurrences in the harbour, which he may deem of sufficient importance. One quartermaster is stationed at the wheel to steer the ship, and the others keep a look-out, as in port. When the log is thrown, they hold the minute-glass. All the colours and signals are under their charge.

Boatswain's mates are an indispensable class of men on board of a man-of-war, but their office is the most invidious and least desirable of all. They have to perform all the flogging, and the men accordingly hold them in some degree of detestation. Each of the boatswain's mates has a silver whistle suspended from his neck, with which he echoes the orders of his superiors. The armourer is the ship's blacksmith. The cooper opens the provision barrels when their contents are wanted, and performs other matters in his line of business when necessary. The duties of the cook are somewhat arduous, and it requires a good deal of patience and care to perform them acceptably to the crew. The meals must always be reported "ready" morning, noon, and night. At noon, when dinner is reported ready, the cook takes a specimen to the officer of the deck, who inspects it, to see that it is properly prepared.

The above are the principal petty officers; and we now come to the rest of the crew, or seamen, who are of different classes. The first class consist of seamen, or able-bodied men, who are expected to be finished sailors; the next class are ordinary seamen; and after these are boys, who perform various useful offices, but chiefly as servants. The boys, and all others on shipboard who do not keep watch, are called *idlers*.

On board of a frigate there are six military divisions; one on the quarter-deck, one on the forecastle, three on the gun-deck, and one on the berth-deck. The last is commanded by the purser, and each of the others by a lieutenant. It is the business of those who compose the purser's division to pass up powder to the combatants. Every officer and man is included in one or the other of these divisions, and is stationed in a particular part of the ship. These are the stations for action, and are called general quarters. The crew is mustered and inspected at quarters always once, and on board many of our ships twice a day. There are ten or twelve men to each of the guns in a broadside, called first and second captains, spungers, loaders, powder-boys, &c. On the intimation being given, the boarders run for their caps, and every man seizes a cutlass. At the first tap of the drum, there is a general rush throughout the ship, and before the music has ceased, you may hear the midshipmen of the divisions calling over the names, George Bell—first captain, sir; James Anderson—second captain, sir; William Stokes—powder-boy, sir; and so on. Having called the names, the midshipmen report to the officers of their divisions, the officers of the divisions to the first lieutenant, and he again to the captain. Should the order be given to retire, another rush takes place, the cutlasses and boarding-caps are returned to their places, and the men, as the case may be, proceed to their daily labours or their evening diversions. All this is but the work of a moment. Sometimes the call to quarters is beaten in the dead of night, and then the men are obliged to get up, lash their hammocks, take them on deck, and stow them in the nettings, and be ready to answer to their names in the space of about eight or ten minutes. The midshipmen have to do the same.

In addition to their general quarters, the men are also stationed for getting under weigh, and coming to an anchor for tacking and veering, and for other general evolutions. I have sometimes been astonished to see how quick, in the darkest night, it is discovered that a man is missing from his post, and how speedily he is searched out and brought to it. But not only does every man know his station; he has a specific duty to perform at every order, and a failure on his part might disconcert the whole operation. Thus it will be seen, that notwithstanding the complicated nature of naval evolutions, and the apparent confusion which must necessarily prevail when all hands are called, there is, in fact, the greatest possible order, efficiency, and harmony of action.'

The marines act as a body of soldiers, and do duty both as sentries at different parts of the vessel, and as marksmen, both below and aloft, during action. Being in some respects an armed police over the sailors, there is often, if not a feeling of jealousy between the marines and other members of the crew, at least a tendency to depreciate and jeer at each other.

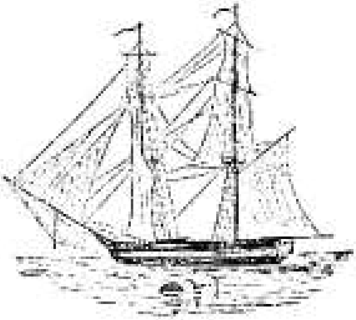
The following is the gradation of officers in connection with the royal navy:—Midshipman; lieutenant; master and commander (usually called captain); post-captain; rear-admiral (of which there are several gradations, styled red, white, and blue); and admiral. The senior captain of a squadron, which consists of a few vessels sent upon an expedition, is styled commodore, and he is the general commander for the time being. A fleet is a large number of vessels commanded by an admiral. The affairs of the royal navy are managed by a department of government called the Admiralty, whence the commissions of the officers are issued. Latterly, the condition of both officers and men in the royal navy has been greatly improved, and rendered much more comfortable than formerly.

Merchant Vessels.

Vessels employed in trade, or merchantmen, are of numerous sizes, shapes, and modes of rigging—these depending not merely on the peculiar trade for which they are destined, but on the taste and whims of the owners. The largest is of the ship-proper, as represented in the subjoined figure, with three masts

Merchant Ship.

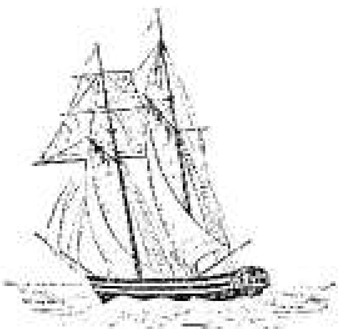
and square sails, but having only an upper deck, the sides of which are usually pierced to carry guns. Vessels of this kind possess holds of very large dimensions for stowing goods, and their burden is from 1000 to 1500 tons. When destined for long voyages, and in good service, as they generally are, order and discipline is maintained on board with almost as much severity as in the regular navy. The ships employed in the China and East India trade are the largest belonging to this country; those in the West India trade rank next; then the whale ships, those in the Baltic and Canada trade, the Mediterranean trade, the coal and general coasting trade, and so on in descending gradation.



Brig.

Next beneath the class of ships is that of *brigs*. A brig, of which we here present a sketch, has only two masts, but it possesses square rigging, like a ship. Brigs are handsome and roomy vessels, carrying from 400 to 800 tons burden.

With brigs, square rigging terminates, and we now come to classes of vessels in which the rigging is of a



Schooner.

different character. At the head of these stands the *schooner*, a vessel with two masts, and capable of carrying a large press of canvas. A schooner is in general sharp-built, with masts of considerable height and *rake* (that is, slant sternwards), and with small topmasts and fore-and-aft sails. The rigging, however, is various, though normally as above represented.

Vessels possessing only one mast are either *sloops* or *cutters*, both distinguished by their tall mast and extremely large main-sail, which projects towards the stern. Sloops are chiefly engaged as coasting traders, and are of all burdens, from 100 to 500 tons. The class of sloops employed to carry goods and passengers between distant ports are ordinarily styled *smacks*. There are schooners and sloops of war carrying from ten to twenty guns; they are generally employed in the custom-house service, and adapted for quick sailing.

Sloop.

A *lugger* is a small kind of vessel, but carrying three masts and a running bowsprit, with sails of the form called lug-sails. A *brigantine* is a brig which can be either sailed or rowed. A *xebec* is a light swift-sailing vessel, of three masts, and a long prow, peculiar to the ports of the Mediterranean. A *galley* is another vessel peculiar to the ports of the Mediterranean; it is low built, and carries two masts, but depends chiefly on being rowed with oars; condemned criminals are often sent as a punishment to row these galleys. A *yacht* is a small vessel designed either for state or pleasure. All the preceding classes of vessels possess decks. Small open vessels, not possessing the accommodation of a deck, are of the class of *boats*, of which there are many varieties—as the long-boat, pinnace, wherry, gig, barge; and so forth. Boats are mostly built with the side planks lapping over one another; and this, which is called being *clinker-built*, gives them greater buoyancy and strength than if built in the manner of ships.

In every class of merchant vessels the prime object is to accommodate as large a quantity of goods as possible, and therefore comparatively little space is occupied with accommodation for either the captain or his crew. If the cargo be light, such as cotton, *ballast* is required to be put on board; this consists of sand, shingle, or any other heavy material, which is placed lowest in the hold, in order to balance the vessel, and give it due hold of the water. In the royal navy iron ballast alone is used, in pigs of nearly three hundredweight. This has the advantage of lying in small compass; but in consequence of its great weight, it tends to give excess of stability, which renders the vessel uneasy from the suddenness of the motion. This defect is remedied by *winging* the ballast, whereby its centre of gravity is raised. For the like reason, in stowing the ballast, it is tapered to a point at the fore and after extremities. Iron ballast, from its greater cleanliness, is more healthy for the crew than that of other materials." When a ship has no other loading, she is said to be *in ballast*. In stowing cargo, care is taken to preserve the *trim* of the vessel—that is, to keep it upright, and also equally balanced fore and aft. The connection between the motions of a ship and her stowage (whether of ballast or cargo) has not, however, been sufficiently analysed to lead to the discovery of any direct rule on this very important point.

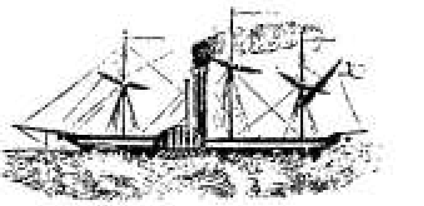
Within the present century, vessels propelled by steam power have been introduced and largely employed both in the commercial marine and in the royal navy; and to these we shall now advert.

Steam Ships.

Referring the reader for an account of the *mécanique* of steam power, as applicable to propulsion, to the article STEAM-ENGINE, p. 397, we shall here merely allude to the progress of the discovery, and to the extraordinary changes which have been effected upon maritime conveyance since its general adoption. For this purpose we transcribe, with some slight modifications, from the Cyclopædia of Commerce the following brief and perspicuous account:—

'Steam navigation was attempted by various individuals in the course of the eighteenth century; but the experiments which tended more than any other to develop this application of steam were the joint labours of three Scotsmen—Patrick Miller of Dalswinton, Dumfriesshire; James Taylor, his son's tutor; and William Symington, a mining engineer—Miller preparing the proper vessel and propelling apparatus, Taylor recommending the steam-engine as the moving power, and Symington effecting the modifications necessary in its structure. This took place between 1786 and 1789; and in 1802, a steam-tug made by Symington, with a single paddle-wheel in the stern, was placed on the Forth and Clyde Canal; but the project was abandoned, through fear that the undulation produced by it would prove injurious to the banks. Symington's apparatus, though then neglected in this country, had been seen and examined by many, and especially by Robert Fulton, an American, then studying under West, and who, with less merit as an inventor than Symington, but with more ample resources and greater energy, succeeded, in conjunction with Chancellor Livingstone, in introducing steam navigation into the United States in 1807, when the "Clermont" of 160 tons was launched at New York. Four years afterwards it was successfully established in this country by Mr Henry Bell, an enterprising house-carpenter of Glasgow, who in 1811 started the "Comet" of twenty-five tons burden and three horse-power, to ply to a bath hotel which he had set up at Helensburgh.

The progress of steam navigation was afterwards rapid, particularly in the United States, owing to the extent and number of its rivers, for which alone steamers were at first considered to be adapted. As improvement advanced, however, and confidence increased, they came gradually into use as marine vessels, for which purpose they were first fitted, in 1818, by David Napier, engineer, Glasgow, who, from that year till 1830, effected more for the improvement of steam navigation than any other man. He established regular steam communication between Britain and France and Ireland; by degrees, almost all parts of the shores of Europe were traversed in like manner; and in 1838, a line of steamers of gigantic size commenced running between England and the United States—a distance now generally performed in ten or twelve days. Steam vessels have since been adopted for many other parts of the ocean; and their increasing use in every civilised country has produced, and is daily producing, results which it is impossible fully to estimate.'



We refrain from entering into any details respecting the formation of steam vessels; but we may notice that, of late years, many have been wholly constructed of iron, and that the old paddle has been superseded in some instances by the Archimedean screw, and other kinds of propeller. By many iron is preferred, on account of its superior buoyancy, the facility of working it, its greater tenacity, and in the long-run, its greater cheapness. Vessels constructed of iron, either wholly or in part, are now divided into water-tight compartments, so that any one of these might be stove in and filled with water without destroying the buoyancy of the ship. As a proof of the value of the compartment system, we may instance the case of the Nemesis, which struck some time ago on the English Stones in the Bristol Channel, going nine or ten knots an hour: she slid off, after making such a slit as filled the forward compartment. She steamed several hours with the compartment full, until she obtained additional pumps in Mount's Bay, with which the space was pumped out, and the leak stopped. At Portsmouth she was examined, and drawings of the damage were made by an employé of the Great Western Company: she was repaired in a few hours, at an expense of about £30, and then started for China. An instance of the time a complete wreck takes to go down, so as to enable the crew to escape, was afforded by the Brigand, a large iron steamer, which had been trading between Liverpool and Bristol. She struck on sunken rocks off the Scilly Islands, filled a forward compartment, and had some part of her paddle-wheel forced so far into the engine-room as to damage the plates, and fill that part also. She remained afloat, in consequence of the remaining compartments, long enough to enable the crew to save themselves and their kits comfortably, and then went down in deep water.

We have already stated that steamers, at first timorously confined to rivers and estuaries, are now found traversing the whole line of coast, and holding communication with ports in the most distant parts of the globe. Many of these voyages, both coasting and by open sea, are performed with the utmost regularity and precision, without reference to wind or tide, or to the season of the year. For this purpose lines of large steamers are got up by companies as a speculation, and by the carriage of passengers, goods, and the government mails, have been enabled in most instances to realise very profitable returns. The vessels are despatched to an hour, a regular succession is maintained; and thus the public can calculate with certainty, almost to a day, when they shall receive news from China, India, the West Indies, the United States, Canada, or any other country between which such lines have been established. Several of the vessels so employed are of vast dimensions and substantial construction, and are fitted up with promenade saloons, state-rooms, dining-rooms, bedrooms, and other apartments, in a style of elegance not surpassed by the first-class hotels on land. Besides the ordinary transit vessels here spoken of, steam ships have been adopted in the royal navy to a considerable extent, and from their speed and certainty of passage, are likely to prove highly advantageous, should their services unhappily be ever required. There are no means at present of arriving at accurate statistics respecting the steam navy of Britain, war and mercantile; but excluding the small unregistered craft which ply on rivers, the number of steam vessels, home and colonial, must exceed 1000, with a horse-power of nearly 100,000, and a burden of about 200,000 tons.

Large as this force may appear, on the coasts and rivers of North America steam navigation has been carried on to a much greater extent than in Great Britain or any other country. Some of the American steam vessels are equally powerful with those of Britain, and are still more splendid in decoration; but they are much more liable to accidents, from the employment of steam at a very high pressure, and a general carelessness in the mode of management. Very few war steamers have as yet been constructed in the United States. France also possesses a respectable steam navy; but that of other countries is comparatively inconsiderable.

NAVIGATION.

Navigation is the art of conducting vessels at sea in the direction in which they are designed to proceed; the term is derived from the Latin word *navis*, a ship, and *ago*, to manage or govern. From *navis* also is derived the term *navy*, which signifies a collection of ships. The terms *marine*, *maritime*, and *mariner*, are likewise from a Latin root—namely, *mare*, the sea.

Laying aside the consideration of steam as a moving power, vessels may be said to advance in their course by means of tides, currents, and winds; the winds are in most instances the principal agent, and the art of the mariner consists in rendering almost every breath of wind which blows subservient to the purpose of the intended voyage. The winds most favourable for impelling the vessel are those which blow on the *quarter*, or slantingly on the ship's course. The reason for this is very obvious: when the wind blows directly astern, it can affect one, or perhaps two sails with commensurate force; but when it comes obliquely, every sail may be trimmed to meet it, and receive a share of the impulsive power. The variety in the rigging of vessels causes much difference in sailing powers: some will sail close to the wind, as it is called, or with a very small angle to the direction of the breeze, while others require winds much more fair. When the wind becomes too powerful, certain sails are taken in, and others are *reefed*, a portion being bound to their respective yards, so as to reduce the surface of canvas. Reefing and bracing the yards are among the nicest points of seamanship.

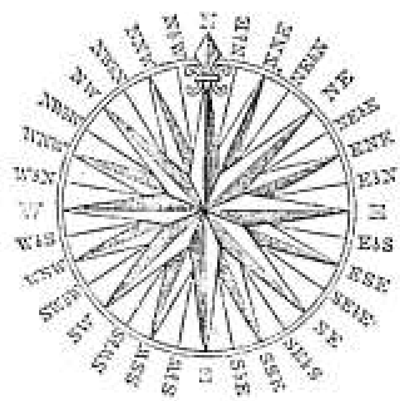
Ships are navigated, as nearly as possible, by the path which is the shortest distance between the port whence they depart and that for which they are destined; but from contrary winds and intervening land, it is generally necessary to sail in a track of a zig-zag form. When a vessel is obliged to sail to the right or left of the direction of the intended port, it is said to *tack*; when the ship is tacking towards the left, and the wind consequently on the right, it is said to be on the *starboard* tack; and when it is tacking towards the right, it is said to be on the *larboard* tack. A ship does not sail exactly in the direction of her keel, but deviates towards the side that is opposite to the wind; and the angle contained between the apparent and real direction is called *leeway*.

The tacking or changing of directions, in order to present the sails at a proper angle to the wind, is a process requiring considerable seamanship. The ship being already close to the wind, the helm is gradually eased down, so that the rudder may not exert its full force until she begins to turn, nor act suddenly to check the headway, so essential to the success of the evolution; at the same time the head sheets are flown, so as to cause the sails before the centre of rotation to shake, and lose their power of balancing the after ones. As the ship approaches the wind, the spanker is drawn gradually from the lee side towards the centre, that it may keep full, and by its action so near the stern, continue promoting the rotation. As soon as the sails reach the direction of the wind, and cease to draw, the corners of the courses are drawn up, and the tacks and sheets overhauled, ready to swing the yards. After a while the sails catch aback, and the foresails, soon masking the after ones, act with a powerful leverage in turning the bow. At length, having come head to wind, without loss of headway, and the evolution being certain, the after-yards are swung round, ready to receive the wind on the opposite side; which operation is then more easily performed, from the sails being becalmed by the fore ones. Lastly, when the after-sails are filled by the wind, the head-yards are also braced round to receive its impulse, and the ship at once recovers headway, and proceeds on her new tack.

Thus easily is a ship manœuvred in fine weather. Not unfrequently, however, a gale comes to disturb the peaceful course of the mariner, and call forth all his exertions. Let us suppose that, whilst our ship is contending against the head wind, the misfortune is augmented by its gradual increase. Shortening sail becomes necessary, and is determined by two leading considerations—the stability of the ship, and the strength of her masts: it is to diminish the careening of the one, and avoid endangering the other, that the surface spread to the wind is reduced. In shortening sail, we always begin with the highest and lightest sails, descending gradually, and keeping pace, in an inverse ratio, with the increase of wind. The sails do not, however, come in uniformly in the direction of the length; but the after-sails most rapidly; because, as the wind increases, the energy which it exerts in a forward direction upon the masts, tends, with a powerful lever, to depress the bow and raise the stern. Hence the latter drifts more easily to leeward, thereby bringing the bow towards the wind; this effort is also promoted by the action of the sails passing farther to leeward, and by the ship ceasing to sail on an even keel. From all those reasons, the more the wind increases, the more she tends to come to; so, to avoid a constant recurrence to the action of the rudder, it becomes necessary to shorten sail faster aft than forward, taking in the mizen-top-gallant-sail, and even the spanker, before the fore and maintop-gallant-sails: for the same reason, when it becomes necessary to reef, it is not unusual to begin with the mizen-top-sail. In the case of a heavy gale, it is sometimes necessary to reef or take in the whole from stem to stern; the helm being at the same time kept constantly hard down, the vessel is said to *lie to*. Should the gale abate, the reefs are shaken out, sail is added, and the vessel bounds actively on its course.

The Compass.

The most important instrument for the guidance of the mariner is the compass. There are different kinds of compasses to suit peculiar purposes; but that which is commonly in use on shipboard is of the following construction:—The most essential part is a magnetised bar of steel, called the needle, which is supported horizontally on a central pivot, round which it is free to move and to point in any direction. The pivot of the needle rises from a circular *card*, resembling the dial-plate of a timepiece, and round the circumference of which are marked thirty-two points. The following figure represents the card of a compass. North, South, East, and West, are the main or cardinal points, and are indicated by their initial letters respectively, while the subordinate points are also marked by letters, as N&E for north-by-east, NNE north-north-east; and so on. To be able to recite the various points is said to 'box the compass.' The north is usually indicated by an ornamented figure, or arrow head, as in the sketch here presented.



The card and needle are fixed in a round box, enclosed by a sheet of glass, to secure it both from the agitation of the atmosphere, as well as to exclude dust, moisture, and other things which might interfere with the correctness of the indications. The whole is enclosed in another box, suspended by two concentric brass circles or *gimbals*, as they are technically called, and in such a manner that the compass hangs as it were on points like a swivel, by which, during the lurching, or heaving up and down, or motion from side to side of the ship, the needle and its card remain in a horizontal position, and under all circumstances indicate the various points correctly. The compass, thus encased, is placed upon deck in a covered stand called the *binnacle*, in front of the man at the helm, so that the direction in which the needle points can be constantly seen in guiding the vessel. The point of the needle, which, for distinction, is some way ornamented, is understood to point towards the north, but properly it points a little to the west of due north; and this, as well as other variations to which it is subject in certain latitudes, must be thoroughly understood by the navigator. In the whole of the northern hemisphere of the globe, the point or northern pole of the needle is the active agent in pointing the direction of the compass. In the southern hemisphere, the southern pole of the needle assumes the active management of the instrument; and by pointing towards the south pole of the earth, keeps the point of the needle pointing towards the north as before. Practically, it is of no consequence to the mariner which point of the needle is most affected by the polarity of the earth, for in all places and conditions (slight variations excepted) the needle keeps its northern ornamented point towards the north pole of the globe.

The needle being liable to be affected by the proximity of iron, no piece of that metal is used in the construction of the binnacle, or is allowed to be near it. In the case of iron ships, or ships having much iron on board, means are adopted to counteract the tendency which the needle has to point in a wrong direction. From want of attention to this important point, serious disasters at sea have ensued.

The Log—Sextant.

Provided with a compass, the next object of importance is the *log*, an instrument for measuring the rate at which the vessel proceeds through the water in a given space of time. The log is a very simple contrivance. It consists of a long cord, having a piece of wood attached to one end, and called the *chip*. This is of a quadrantal form, and being slung at the corners with line, and loaded at the circumference, when thrown overboard it remains erect and stationary, and drags the line off as fast as the ship passes through the water. The line is divided into knots and half knots, representing miles and half miles, or minutes of a degree, to which they bear the same proportion as the log-glass does to an hour. Thus the log-glass being filled with sand to run through in 30", the length of a knot must be 51 feet, the first being the same proportion of an hour that the last is of a mile. As, however, the log is found to come home a little in the effort to draw the line out, it is customary to mark the knot a foot or two less than the true length. The mode of heaving the log to measure a ship's rate is as follows:—The log-reel, upon which the line is wound, being held by one of the sailors, the officer places himself on the rail to leeward, and a third person holding the glass, he proceeds to prepare the chip, so that the peg of one of the lines holding the chip in a perpendicular direction will draw out, by the force of the water, when the reel is stopped, and allow it to haul in easily. Then having gathered a sufficient quantity of line into his hand, he throws it far to leeward, that it may not be affected by the eddies which follow in the wake. The stray line, which allows the chip to get astern, now runs off, and the instant that the white rag, which marks its termination, passes through the hand of the officer, he cries 'Turn!' and continues to veer out line until the glass runs out, and the person holding it cries 'Stop!' Then the line is grasped, and the number of knots that have passed off mark the speed of the ship. When this exceeds five miles, it is usual to use a glass of 15" instead of 30", counting the knots double. The rate of sailing per hour multiplied by the hours sailed, thus gives the mariner the measure of his run.

In addition to these essential instruments for directing the course and ascertaining the distance, the navigator must be provided with *octants* of double reflection, to measure the altitude of the heavenly bodies, and a circle, or *sextant*, more nicely graduated, to measure distances between the moon and stars. He should also have with him a book containing the logarithms of numbers, sines, tangents, and secants, to facilitate trigonometrical calculations; tables for correcting altitudes for dip, parallax, and refraction; also lists of latitudes and longitudes for every part of the world; and of time of high water at every port, at the period of full and change of the moon, from which at all times to be able to find the tide; and a variety of tables to facilitate the various problems of navigation. He should also have with him the 'Nautical Almanac,' containing the places and declinations of the fixed stars and planets, and especially the distances of the moon from the sun and other stars, and all that relates to that body, with a view to calculate the longitude by observation. Finally, he must be provided with the general and local charts applicable to his contemplated voyage.

Thus furnished, the mariner may set sail with confidence; many do so with no other aids than their compass, log, quadrant, a single chart, and book of navigation, and arrive in safety. But it is less our business to show with how little care a ship may be navigated, than to show how she may be carried from port to port with the greatest possible certainty. Having taken leave of the port, and when the last land is about to disappear from view, either from the growing distance or the intervention of night, the mariner selects some conspicuous headland, of which the latitude and longitude are noted in his tables, and placing a compass in some elevated position, remote from any iron object to disturb its polarity, proceeds to determine its bearing, and estimate his distance from it, either by the progress made from it, or by the ready estimate of a practised eye. Or taking the simultaneous bearings of two distinct points of coast, he has still surer data for deducing his position. This is called *taking the departure*, and is carefully noted on the log-slate, with the time of making the observation. Thenceforth the log is thrown every hour, and the course and distance are entered upon the slate, to be copied into the log-book at the end of the day.

Working a Reckoning.

At the first noon succeeding the time of taking his departure, the mariner works up his reckoning. Noon is an epoch fixed by nature, being determined by the passage of the sun over the meridian, and is therefore well chosen as the beginning of the day. The log-slate being marked, he copies the courses and distances, if from head-winds or other causes they have been various; the departure from the land is also converted into a course; as is also the current, if there be any known one. He next proceeds to find the difference of latitude and departure from the meridian corresponding to each course, either by geometrical calculation, or, more expeditiously, by reference to tables; then he adds the several differences of latitude and departure, and if they be of different names, as some north and some south, some east and others west, deducts the less from the greater. With the remaining difference of latitude and departure, he not only finds the course and distance made good, but also the latitude and longitude in which he is; the difference of latitude being applied to the latitude left, by adding or subtracting, in sailing from or towards the equator, at once gives the latitude of the ship. But before the departure can be thus applied to find the longitude, it is necessary to reduce it for the converging of the meridians towards the poles; for though all degrees of longitude are divided, like those of latitude, into 60 minutes or miles, yet they decrease in length from being equal to a degree of latitude at the equator, until they become nothing at the poles. There are many ways, more or less accurate, of deducing the difference of longitude from the departure, the latitude being known; they are founded upon this principle: the circumference of the earth at the equator is to its circumference at any given parallel of latitude as the departure is to the difference of longitude. The most easy and correct way of obtaining the difference of longitude on an oblique course, is by the aid of a table of meridional parts; for having taken out the meridional difference of latitude, the mariner has this simple proportion: the proper difference of latitude is to the meridional difference of latitude as the departure to the difference of longitude. The difference of longitude thus obtained is applied to the longitude left, adding or subtracting, in sailing to or from the first meridian, and the result will be the ship's longitude; which, with the latitude previously ascertained, determines her position on the chart. The method of navigating thus described is called *dead reckoning*. It is far from infallible, and leaves much to desire. It will indeed do pretty well in short runs; but as errors daily creep in from many causes escaping calculation, such as bad steerage, leeway, heave of the sea, unknown currents; and as these accumulate, and become considerable at the end of a long voyage, it becomes necessary for the mariner, removed from all reference to terrestrial objects, to resort to the immovable guides in the heavens. All the heavenly bodies are, by the revolution of the earth, daily brought to the meridian, at which time, if their altitude is measured, their declination or distance from the equinox being known, the latitude is readily deduced; it may also be deduced from single or double altitudes of bodies not in the meridian, the times being accurately known. But the meridian altitude of the sun is what furnishes at once the easiest and most correct method of finding the latitude. So great, indeed, are the advantages offered by the meridian altitude of the sun, that no other means of finding the latitude are used, except when these have failed from a clouded atmosphere, or when the momentary expectation of making the land quickens the mariner's anxiety. We shall therefore now explain the method of deducing the latitude from the sun's meridian altitude.

Taking an Observation.

Furnished with a sextant, circle, or octant of reflection, the observer goes upon deck, and having examined the adjustment of his instrument, proceeds to bring down the image of the sun reflected by its mirror, until the lower limb just sweeps the horizon. He continues to follow and measure its ascent, until it ceases to rise; the moment that it begins to fall, and the lower limb dips in the horizon, the sun has passed the meridian. The altitude marked by the index being read off, it is next corrected. And first, the observer adds the semi-diameter, in order to make the altitude apply to the centre of the object; next he subtracts the dip, to meet the error caused by the extension of the horizon, in consequence of the rotundity of the earth, and the elevation of his eye above its surface; also the refraction of the atmosphere by which the object, when not vertical, is made to appear higher than its true place; lastly, he adds the parallax (a small correction, inconsiderable from the sun's distance), in order to reduce the calculation for the centre of the earth; from which point all calculations are made, and which is ever supposed to be the station of an observer. (See Astronomy.)

Having made all these corrections, which many mariners despatch summarily, by an addition of 12 minutes, he has the true meridian altitude of the sun. Taking this from a quadrant, or 90 degrees, gives its zenith distance, or distance from that point in the heavens which is immediately over the observer, and would be met by a straight line passing from the centre of the earth through his position. Now, if the sun were for ever on the equinoctial, the zenith distance would always be the latitude; for whilst the zenith is the observer's position, referred to the heavens, the equator is there, in like manner, represented by the equinoctial; and we have already seen that latitude is the distance from the equator. But as the sun is only twice a year upon the equinoctial, and as his distance from it at times increases to more than 23 degrees, it becomes necessary to take this distance (called his *declination*) into the estimate. The sun's declination is given in the Almanac for the noon of each day; by correcting it for the time anticipated or elapsed, according as the sun comes first to him or to the first meridian, by his position east or west of east of it, the observer obtains the declination for noon at his own position. This declination applied to the zenith distance, by adding when the sun is on the same side of the equator, by subtracting when on the opposite side, gives the true latitude.

A daily and accurate knowledge of his latitude is, then, to the mariner of modern times, a desideratum of comparatively easy attainment. By its aid nothing is easier than to sail clear of any rock or shoal that crosses his track, either by a watchful look-out at the moment of passing its latitude, or else by avoiding its parallel entirely, until it be surely passed. Moreover, this is his best and surest guide in aiming at his destined port; for he has but to attain the exact latitude it lies in, and then sail directly upon it, east or west, to be sure of success. And here nature is again his friend: by a singular coincidence, discoverable in glancing at the map of the world, most coasts and continents lie in a northern and southern direction. Hence the value attached by seamen to an accurate knowledge of the latitude; and hence the familiar saying of 'Latitude, lead, and look-out.'

To find the Longitude.

Various ways have been devised to find the longitude, in all of which the great element is time. The earth performs her diurnal revolution in 24 hours, or, in other words, each part of the circumference of the globe, which is divided into 360 degrees, is brought under the sun once a day. Hence each part of the circumference (reckoning from east to west) has its own peculiar time of day. When it is noon at one place, it is one o'clock afternoon at another place, two at another, and so on; the time differs all round the globe. Dividing the 360 degrees by 24, we find that 15 is the result; for every 15 degrees, therefore, along the circumference, going westwards, there is an hour of difference, in advance; and going eastwards, an hour behind. If it be noon at Greenwich, it will be one o'clock at a point 15 degrees east from it (that is, the sun has passed over it an hour ago), and eleven o'clock forenoon at a point 15 degrees west from it (that is, the sun will be an hour in getting up to it). Dividing the 60 minutes of an hour by 15, the result is 4; the earth, therefore, moves under the sun at the rate of a degree, or 60 geographical miles, in four minutes, or 15 miles in the minute, or one mile in the four seconds, or a quarter of a mile in the second. Here, then, the element of time is brought at once, and in the most satisfactory manner, to bear upon the distance of any given place, east or west from any other given place. The measuring of such a distance is called finding the longitude.

Different places on the globe have been established as starting points in making these measurements. The French reckon from Paris, and the English from Greenwich, near London, where an astronomical observatory has been long established, and supported at the public expense. In all English works of geography, the longitude is reckoned from Greenwich, although not expressly mentioned. Navigators determine their longitude by watches or chronometers, whose movements are as exact as can possibly be obtained from mechanism. (See Horology.) In setting out on a voyage, the chronometer is set to London time, and kept going at that time. At the hour of noon of each day, as determined by an observation with the sextant, the difference is estimated between that hour and the hour indicated by the chronometer, and that difference is the longitude east or west of Greenwich, as the case may be. Some mariners, for security, take several chronometers to sea with them, as one only is by no means a safe guide. In general, however, the masters of coasting traders, or those who pursue short voyages by regular lines of route, depend on books containing lists of longitudes as well as of latitudes.

Marine Barometers—Log-Book.

The last great requisite in navigation is a good barometer, to indicate the approach of foul weather. The most delicate instrument of this kind is the sympiesometer of Adie, by which the earliest and most certain indications are presented of coming storms. In treating of the nature and value of instruments of this nature, Dr Arnott makes the following observations:—'The watchful captain of the present day, trusting to this extraordinary monitor, is frequently enabled to take in sail, and to make ready for the storm, when in former times the dreadful visitation would have fallen upon him unprepared. The marine barometer has not been in general use for many years, and the author was one of a numerous crew who probably owed their preservation to its almost miraculous warning. It was in a southern latitude. The sun had just set with placid appearance, closing a beautiful afternoon; and the usual mirth of the evening watch was proceeding, when the captain's order came to prepare with all haste for a storm. The barometer had begun to fall with appalling rapidity. As yet, the oldest sailors had not perceived even a threatening in the sky, and were surprised at the extent and hurry of the preparations: but the required measures were not completed, when a more awful hurricane burst upon them than the most experienced had ever braved. Nothing could withstand it; the sails, already furled and closely bound to the yards, were riven away in tatters; even the bare yards and masts were in great part disabled; and at one time the whole rigging had nearly fallen by the board. Such, for a few hours, was the mingled roar of the hurricane above, of the waves around, and of the incessant peals of thunder, that no human voice could be heard, and amidst the general consternation even the trumpet sounded in vain. In that awful night, but for the little tube of mercury which had given the warning, neither the strength of the noble ship nor the skill of the commander could have saved one man to tell the tale.'

A journal of events and observations on board ship is usually kept in what is called the log-board, and transferred thence into the log-book. The log-board consists of two boards shutting together like a book, and divided into several columns, containing the hours of the day and night, the direction of the winds, and the course of the ship, with all the material occurrences that happen during the twenty-four hours, or from noon to noon, together with the latitude of observation. From this table, which is written in chalk, and daily effaced, the officers work the ship's way, and compile their journals. From it, also, entries are carried to the log-book, in an expanded form, with any observations and additional particulars supposed to be necessary. The log-book is thus the journal of the ship, and is preserved with great care for exhibition, if required, at the termination of the voyage.

Thus, then, by the use of various instruments and practical experience in navigation, a ship is conducted from port to port, dangers avoided, and difficulties overcome. Though they who traverse the vast ocean leave no track for the guidance of those who follow, it is thus converted into a plain and convenient highway, extending to the extremities of the earth.

LIGHTHOUSES—BEACONS.

Beacons, warning-bells, lighthouses, and the like, are among the most indispensable adjuncts of maritime conveyance; without them, indeed, it would be utterly impossible to conduct it with anything like regularity or safety. The most ancient structure of this description which we read of was the Tower of Pharos—regarded by our ancestors as one of the seven wonders. It was commenced by Ptolemy the Elder, and finished some years after by himself and his son Ptolemy Philadelphus, in the year of the world 3670, on the island of Pharos, in the Bay of Alexandria. 'It was built,' says an ancient authority, 'on the east end of this island, upon a rock of white marble, of a large square structure, on the top of which fires were kept constantly burning for the direction of vessels. It was a most magnificent tower, 450 feet high, consisting of several storeys and galleries, with a lantern at top, which could be seen many leagues at sea.' This wonderful work has been demolished for ages; as also the Colossus of Rhodes, another ancient erection of a similar nature. The Light-Tower of Corduan in France, situated upon a low rock about three miles from land, at the mouth of the Garonne, was for a long time regarded as one of the chief wonders of modern Europe. It was founded in 1584, and completed in 1610. Its lower part consists of a solid platform of masonry, 135 feet in diameter, above which, in succession, are a number of apartments, all narrowing in circumference till the upper storey is reached—being in all 145 feet high.

In our own day, the most celebrated lighthouse is that built on the Eddystone rocks—a low reef situated south-south-west from the middle of Plymouth Sound, nearly fourteen miles distant from that port, and about ten from the promontory of Ramhead. The reef, which stretches across the channel for upwards of 200 yards, slopes gradually towards the south to the distance of a mile, so that the swell sweeps up, as it were, an incline, till within a few fathoms of the exposed rock, where, striking against a sudden ledge, it breaks and dashes upwards to a height of forty or fifty feet. On this dangerous reef the necessity of a lighthouse was early felt; and accordingly, in 1696, a gentleman of the name of Winstanley was furnished with the necessary powers to carry such a design into execution. He entered upon his task in 1696, and completed it in four years. So certain was Winstanley of the stability of his wooden structure, that he declared it to be his wish to be in it 'during the greatest storm that ever blew under the face of heaven;' a wish that was but too soon and fatally gratified, for in November 1703, while there with some workmen and the light-keepers, a storm of unparalleled violence arose, and in one night the whole fabric was swept away. In 1709 another lighthouse was built of wood by a Mr Rudyerd; and this structure, after braving the elements for forty-six years, was burned down in 1755. On the destruction of this lighthouse, Mr Smeaton, the celebrated engineer, was next applied to, who at once fixed upon the more durable material, stone, and chose for his model the natural figure of the trunk or bole of a large spreading oak. With these views as to the proper form of the superstructure, Mr Smeaton began the work on the 2d of April 1757, and finished it on the 4th of August 1759. The rock, which slopes toward the south-west, is cut into horizontal steps, into which are dovetailed and united by a strong cement Portland stone and granite. The whole, to the height of thirty-five feet from the foundation, is a solid of stones, ingrafted into each other, and united by every means of additional strength. The building has four rooms, one over the other, and at the top a gallery and lantern. It is nearly 80 feet high; and since its completion, has been assaulted by the fury of the elements without suffering any appreciable injury.

Equally remarkable with the lighthouse of the Eddystone is that of the Bell-Rock—a sunken reef, lying at the distance of eleven miles from the promontory called the Red Head, in Forfarshire, and on the highway to the firths of Forth and Tay, two of the most frequented estuaries in the kingdom. The ledge is said to be about 850 yards in length, and 110 in breadth; at low water, some of its summits appear from four to eight feet above the level of the sea; but at high water, they are always covered to the depth of ten or twelve feet. Tradition says that the abbots of the monastery of Aberbrothock succeeded in fixing a bell, which was rung by the swell of the sea, so as to warn the mariner of his situation; but that this benevolent erection was destroyed by a Dutch pirate, who, to complete the story, was afterwards lost upon the rock with his vessel and crew. However this may have been, it was not till the beginning of the present century that a solid substantial lighthouse, after the model of the Eddystone, was determined upon and erected. This work was intrusted to Mr Stevenson, the Scottish engineer; was begun in 1808, and completed in 1810. Being lower in the water than any rock on which a similar building has been raised, the difficulties of the architect were greatly increased; but by preparing all the stones on shore, and conveying them in lighters to the reef, where a tender and other accommodation were provided for the workmen, his success was complete, and the revolv-

ing ruddy light of the Bell-Rock now ranks among the chief achievements of British engineering. 'The lighthouse,' we quote the Edinburgh Encyclopedia, 'is a circular building, measuring forty-two feet in diameter at the base, and thirteen feet in diameter at the top. The masonry is 100 feet in height, and including the light-room, it is 115 feet. The ascent from the rock to the top of the solid, or lowest thirty feet, is by means of a kind of trap ladder; the ascent from the level of the entrance door is by means of a circular stair to the first apartment, containing the water, fuel, &c.; and from thence to the several apartments the communication is by wooden steps. The windows have all double sash-frames, glazed with plate-glass, besides a storm-shutter of timber for the defence of the glass against the sprays of the sea; for although the light-room is about eighty-eight feet above the medium level of the tide, and is defended by a projecting cornice or balcony, with a cast-iron rail, formed like the meshes in network, yet the sprays of the sea occasionally lash or fall upon the glass of the light-room, so that it becomes necessary in gales of wind to shut the whole of the dead-lights to the windward.'

Not less bold and hazardous in point of erection is the recent structure on the Skerryvore—a cluster of rocks just appearing above high-water in the Atlantic, between the north of Ireland and the Hebrides, from the nearest point of which it is twelve miles distant. This lighthouse, commenced in 1835, and finished in 1844, by Mr Alan Stevenson, son of Mr Stevenson above-mentioned, consists of a tower 138 feet high, curving inwards from a basis of forty-two feet, and contains nine apartments over each other, for the accommodation of the establishment by which the light is to be maintained. The lantern consists of an apparatus of eight annular lenses revolving round a lamp of four concentric wicks, and producing a bright blaze every minute, visible to the distance of eighteen miles. The cost of the entire structure amounted, we understand, to £89,000. We particularise this and the preceding cases as illustrations of the magnitude of some of our lighthouses, and of the hazard and expense encountered in their erection—difficulties which could be surmounted only at a period of great material wealth and scientific skill, and when the importance of maritime conveyance is so vast as to compel such protection.

A number of improvements have recently been made and promulgated in the construction of lighthouses, chiefly with a view to the saving of time and expense in their erection. The first deserving of notice is the iron lighthouse of Captain Brown. This structure is composed solely of rings of cast-iron, joined or cased one upon another till the requisite height be attained. The advantages of this plan are cheapness, facility of erection, strength, and durability. Metal lighthouses —that is, composed either of cast-iron, wrought iron, or gun-metal—have been strenuously advocated by Mr Gordon, who, from pretty obvious data, maintains that the Skerryvore, for example, could have been erected on this principle with equal efficiency at little more than one-third of its actual cost. The 'screw-pile' of Mr Mitchell is another invention likely to come into use in the erection of lighthouses on shoals and sandbanks. As the name implies, the basis consists of a framework of piles screwed, instead of driven home, and on this an open fabric is erected for the support of the lighting apparatus—the open structure offering no resistance to the waves. Another set of inventors have directed their attention to the improvement of the lighting apparatus—its lamps, lenses, and reflectors. As this department involves mathematical and optical principles of high consideration, we shall merely remark, that at present the lights on our coasts generally consist of Argand burners, placed on the foci of parabolic reflectors made of silver strengthened with copper. The reflectors are arranged, and the lights exhibited, in such a manner that those on the same line of coast should have some essential distinction: thus some of them are revolving or intermittent, many are fixed, others are placed one above another, some flash every five seconds, and not a few alternately red and white. These movements are in general effected by clockwork of a very ingenious description.

The lighthouses on and about the British coasts are upwards of 200 in number, and are classed as 'harbour lights' and 'general lights.' Almost all of them are now vested in public boards, as are also the marine beacons and buoys of the kingdom. The chief board of supervision and control is the Trinity House, Deptford, incorporated so early as 1515 by Henry VIII. In Scotland, the lights are under the immediate management of the 'Commissioners for Northern Lights;' those of Ireland are under a similar trust; but both Scotch and Irish are subject to the control of the Trinity corporation, who regulate all new erections and alterations, and give notice to the public of any change which may be effected. For the erection and maintenance of lights, beacons, and buoys, a rate is levied on all vessels passing them within certain limits—this rate varying from one farthing to one penny per ton for each light so passed.

Beacons are generally placed on sandbanks, rocks, and shoals, and are either floating or stationary. When floating, they are termed buoys (already noticed); when fixed, they are either of solid masonry, or of an open framework of wood or iron. Of late, their number has been much increased along the British coasts; many of them being composed of cast-iron pillars, screwed and rivetted together into a substantial framework, which stands thirty or forty feet above water-level, and which no storm can possibly destroy. The most remarkable of our beacons are those erected by the Trinity House (under the superintendence of Captain Bullock) on the fatal and shifting sands of Goodwin. From the number of shipwrecks constantly occurring on these shoals, these beacons are intended to serve also as a place of refuge for shipwrecked sailors. The first and largest consists of a strong framework, sunk to a considerable depth in the sands, from which rises a vertical column; and on this, at a height of eighteen feet above high water, is placed an octagonal platform, capable of holding forty persons. The platform always contains a barrel of water, a flag ready to be hoisted, and is inscribed in eight different languages with the words 'Hoist the flag.' The second, which was erected in 1847, is of a different construction. The centre column is a tube of cast-iron two feet six inches in diameter, put together in ten and twenty-feet lengths; it is inserted thirty-two feet into the sand by means of Dr Potts's newly-invented process of atmospheric pressure (see No. 28); the four surrounding tubes are of fifteen inches diameter; the whole is bolted together, and surmounted by a cage of seven feet diameter, the top of which is fifty-six feet above sand-level. At present the mariner is warned off these fatal sands at night by a floating light; but means are about to be adopted for the erection of a fixed and permanent structure.

SHIPWRECK—LIFE-PRESERVERS.

Notwithstanding every precaution of lighthouse and beacon, shipwrecks are continually occurring at different parts of our coasts, and to save the lives of the seamen in such cases—without reference to the fate of the vessel—has ever been a subject of earnest consideration with the humane and ingenious. During last century, several *life-boats* were invented; among others, one by Mr Lukin in 1785. But an accident which occurred on the Herd Sands of South Shields in September 1789, led to material improvements in the art of constructing these vessels. The 'Adventure,' a merchant-ship of considerable bulk, was wrecked within three hundred yards of the shore, in presence of an immense number of spectators; and almost every man of the unhappy crew perished, without the possibility of receiving assistance from the shore. The consequence was, that the people of South Shields met soon afterwards and offered a reward to any one who should invent a boat capable of being launched from the shore to the aid of ships in distress. Mr Greathead gained the premium; and in 1790, a life-boat constructed upon the plan proposed by him was effectually used in saving the crew of a vessel stranded under circumstances similar to those of the Adventure. Several other trials of the life-boat proved its utility so fully, that in 1802 the Society of Arts presented the inventor with their gold medal and fifty guineas; and parliament also decreed to Mr Greathead a reward of £1200. The Trinity House followed the example; and the Committee of Lloyd's devoted £2000 to the purpose of building boats on the same principle.

The form of Mr Greathead's life-boat is one well adapted to give it buoyancy, and keep it afloat in any sea. It is usually 'made about thirty feet in length, ten in breadth, and three feet three inches deep at midships; both extremities are made precisely of the same form, so that it goes through the water with either end foremost; and its shape lengthwise is a curve, so formed that a line drawn from the top of one stem to that of the other would be two feet and a-half above the gunwale at midships. In this boat there are five thwarts, or seats for *rowers*, double-banked, so that it must be manned with ten oars. It is cased and lined with cork, which gives it such buoyancy, that it will float and be serviceable though so damaged by hard knocks as to be almost in pieces; and this the softness and elasticity of the cork is well calculated to prevent. The cork on the outside is four inches thick, and it reaches the whole length of the shear, or side of the boat; on the inside it is thicker; and the whole quantity is about seven hundredweight. It is firmly secured with slips or plates of copper, and fastened with copper nails. The advantages of this boat are stated to be, that its curvature gives it great facility in turning, a single stroke of the steering oars, of which there is one at each end, moving it as though on a centre; that the covering of cork, being immediately under the gunwale, gives great liveliness, or disposition to recover its balance, after being suddenly canted aside by a heavy wave; and that its capability of being propelled with either end forwards increases its manageability.'

The life-boat is kept in a boat-house, and placed on a frame furnished with wheels, in order that it may be moved at an instant's notice. Where the road to the sea is smooth, this simple mode of moving the boat does well enough; but it has been found better in many cases to suspend the boat under the axis of the wheels, so that the shaking may be less injurious. At most of the life-boat stations the boat is under the charge of a committee; and twenty or twenty-four men, composing two crews, are alternately employed in its navigation. A reward is given to these men in cases of shipwreck, and the vessel receiving aid is expected to contribute to this end. Of course the life-boat men are picked persons, of steady habits and active frames; and the individual in command requires to possess peculiar skill and knowledge of the coasts and currents. It has been observed that the occupation of the life-boat men gives a sort of dignity to their character, and elevates their tone of thought. Many noble actions have been performed by them, which no mere pecuniary reward could compensate.

Mr Greathead recommends the life-boat to be painted white on the outside, as a colour that most readily catches the eye. He also advises the steersman to keep the head of the boat to the sea, and to give her an accelerated velocity to meet the wave. The strong reflux of the waves renders it necessary to approach a wreck with great caution, and the lee-side is usually the safest of access. Of course the first object is to convey the wrecked crews on shore, which, if they are numerous, must be done by degrees.

Since Greathead's time, several improvements have been effected on his life-boat, chiefly with the view of increasing its buoyancy and strength. One of the latest is the application of vulcanised caoutchouc, a substance possessing at once lightness, strength, and elasticity, and which may be used either in sheets or tubes. We believe, indeed, that in one or two instances life-boats have been constructed wholly of caoutchouc and cork-planking upon a frame of hollow iron. A boat of this kind is only about half the weight of the common life-boat, and will consequently be rowed with greater swiftness; at the same time that, under ordinary circumstances, it will be impossible to sink it.

Captain Manby's Apparatus.—Next to the life-boat, the most important inventions for the humane end of saving lives at sea have been those of Captain Manby. This philanthropic gentleman was in the corps of engineers, and held the situation of barrack-master at Yarmouth, on the Norfolk coast, in the year 1807. That coast, it is well known, is full of shoals, and many vessels have gone to pieces within a hundred yards of the shore, in sight of multitudes of people, without any chance of giving relief. Life-boats could not be stationed at all points of an extensive coast, and perhaps could not be always used if they were present. The lamentable case of the 'Snipe,' where sixty persons lost their lives near Yarmouth, made so deep an impression on Captain Manby, that he resolved to devote his mind and his life to the discovery of some means of relieving similar cases of distress. It appeared to him that the desired end was the discovery *of some means of throwing a rope from the shore to the ship, or from the ship to the shore.* Boats with the crews could obviously be thus drawn ashore in almost any circumstances. A cannon shot affixed to a rope, and projected from a piece of ordnance over a stranded vessel, seemed a practicable mode of establishing the communication. But to reduce it to practice, was found to be attended with much greater difficulty than the simplicity of the object appeared at first sight to promise. In the first place, the folding or manner of laying the rope, so as to unfold itself with the rapidity equal to the flight of a shell from a mortar, without breaking by sudden jerks at each returning fold, and without entanglement from the effect of uneven ground and boisterous winds, was no easy task. But it was at length attained by adopting what is called a French faking, in folds of the length of two yards; and by laying the rope in a flat basket always kept ready, with the rope in order in a secure place, so that it could be transported at a moment's notice to the situation required, and laid upon rocks and uneven ground, even in the most boisterous weather, without fear of disarrangement.

The next difficulty consisted in the means of connecting the rope with a shot, so as to resist the inflammation of gunpowder in that part of it which must necessarily occupy the interior of the mortar. Chains in every variety of form and strength universally broke, from the sudden jerks or play to which they were liable, which proved that not only an elastic, but a more connected body was necessary. 'At length,' says Captain Manby, 'some stout plaited hide, woven extremely close to the eye of the shot, to prevent the slightest play, extending about two feet beyond the muzzle of the piece, and with a loop at the end to receive the rope, happily effected it.' This apparatus, projected from a small howitzer over a vessel stranded on a lee-shore, so light as to be easily conveyed from one part of the coast to another, affords a certain means of saving the lives of the crew in the daytime, and when, from cold and fatigue, they are not disabled from seizing the rope, and in other respects joining their own exertions to those of their friends on shore.

Such is the simple but efficacious nature of Captain Manby's first invention; and a few practical experiments soon ascertained the allowance to be made in pointing the mortar to windward of the object over which the rope is to fall, in order to obviate the effect of a strong wind, which would of course carry it considerably to leeward. Experience also proved that the mortar should be laid at a low elevation, to insure the certainty of the rope's falling on the weathermost part of the rigging.

This original invention, however, was obviously capable of many improvements. The first of these was to afford assistance to vessels whose crews, either from their being lashed to the rigging, or from extreme cold and fatigue, are incapable of assisting to secure the rope to the wreck when projected over it from the mortar. This was attained by adding a quadruple barb to the shot—that is, making four hooks project from the ball—by means of which, when the rope is hauled tight by the people on shore, one end is firmly secured on some part of the rigging or wreck, and a boat can of course be hauled to the relief of the crew without any assistance on their part.'

But in order to make this invention effective in the darkest night, as well as by the light of day, the ingenious philanthropist had yet much to do and discover. He attained his end, difficult as the task was. 'The requisite objects were—*First*, to devise the means of discovering precisely where the distressed vessel lies, when the crew are not able to make their exact situation known by luminous signals. *Secondly*, to discover a method of laying the mortar for the object with as much accuracy as in the light. *Thirdly*, to render the flight of the rope distinguishable to those who project it, and to the crew on board the vessel, so that they cannot fail of seeing on what part of the rigging it lodges.

To attain the first object a fire-ball is used, such as is often thrown up in the attack and defence of fortified places to discover the situation of an enemy by night. It consists of a hollow ball of pasteboard, having a hole at top containing a fusee, and filled with about fifty luminous balls of star composition, and a sufficient quantity of gunpowder to burst the ball and inflame the stars. The fusee is graduated so as to set fire to the bursting powder at the height of 300 yards. On the stars being released, they continue their splendour, while falling, for nearly one minute, and strongly illumine every surrounding object: ample time is therefore allowed to discover the situation of the vessel. During the period of the light, a board, with two upright sticks at each end (painted white, to render them more discernible in the dark), is pointed towards the vessel, so that the two white sticks shall meet in a direct line with it, the wreck being a fixed object. This will obviously afford an undeviating rule by which to lay the mortar, making an allowance for wind, &c. Thus the second object is attained. For the third, a shell (instead of a shot) is affixed to the rope, having four holes in it to receive fusees, and the body of the shell is filled with the fiercest and most glaring composition, which, when inflamed, displays so splendid an illumination of the rope, that its flight cannot be mistaken.'

Such are the most prominent features in the scheme of Captain Manby for the relief of ships in distress. The number of persons saved by these inventions has been very great. Almost immediately after turning his mind to the subject, Captain Manby had the gratification of rescuing ninety persons from a grave in the deep. The whole expense of his apparatus did not exceed £10. Captain Manby was deemed worthy of a parliamentary reward.

Floats and Buoys.—In addition to such a flat boat as that recommended by Captain Manby, with rods and ropes furnished with hooks for grappling, Humane Societies usually possess floaters, consisting of circular cork buoys, or of short bars of wood, with masses of cork at each end. One of these being thrown out with a rope, a party in danger may grasp the bar, and be readily borne up till pulled ashore. Another provision of late invention consists of hollow girdles of cloth, air and water-proof, which, being sustained by straps from the shoulders, can be filled with air from the mouth, and when the pipe is closed, will sustain the wearer perfectly in water. One of the best and most convenient of these is the safety-cape, which combines an article of dress with its principle of life-preservation. It is the invention of a member of the Skating Club of Edinburgh, and is furnished by the Albion Cloth Company of that city. The cape, which is suited to lie easily round the neck and shoulders, and hang as low as the elbows, is formed of Macintosh cloth, which may be partially inflated with air at pleasure, by means of a small mouth-piece hid from external observation. A tape from the inner part of the back, to be tied round the body, keeps the cape down, in the event of immersion in water. When blown up, the cape swells to about an inch in thickness, which presents nothing unsightly; however, it need not be inflated till the wearer goes into a condition of danger.

HARBOURS—BREAKWATERS—DOCKS.

These are essential adjuncts of navigation—affording shelter and protection to ships during stress of weather, accommodation for loading and unloading, and facilities for repair and equipment. *Harbours* may be classed as natural, artificial, and composite—that is, partly formed by nature, and partly by art. Any creek, sound, or estuary sufficiently deep and land-locked, constitutes a natural harbour for shelter; but for the purposes of commerce, quays, wharfs, and landings must be erected by man. When harbours wholly artificial are to be constructed, surveys and soundings are taken, plans drawn, and various modes of execution adopted. Excavations have sometimes to be made, but more frequently piers and jetties are built forward into deep water, a certain amount of space enclosed, and breakwaters erected for its protection. Occasionally, foundations have to be piled, diving-bells, caissons, and cofferdams employed in submarine building, and all the resources of the civil-engineer and architect called into action. (See 'Practice of Architecture,' No. 28.) Stone piers and quays form the most substantial structures; they consist in general of rough rubble, faced seaward with dressed blocks placed on edge, and built slopingly, so as to present a gradual resistance to the impact of the waves; and finished harbourwards with stone coursings, so as to offer a concave or bevelled wall to the convex sides of the vessels. Wooden piers are constructed of squared beams, mortised and jointed together, and so arranged as to endure the greatest amount of strain and pressure. They are built either upon a stone or pile foundation, present an open framework to the sea, and are finished above with a strong planking. A really good harbour—no matter how formed—should possess sufficient depth of water at all states of the tide, should have a fairway of easy entrance, and be so protected as thoroughly to exclude the influence of the waves and currents.

The prime objection to harbours enclosed by solid walls and breakwaters, is their liability to be obstructed by deposits of sand, shingle, and other marine silt. Rivers and sewers entering the harbour, the drifting action of the tides and waves, all tend to collect débris; and unless these natural forces be made to counteract each other, or extraneous sluicing and dredging operations be resorted to, both fairway and basin of the finest harbours will in time be rendered useless. The contrivance adopted by Smeaton at Ramsgate is efficient, and might be applied with advantage elsewhere. He constructed a dock which was filled at high tide; at low tide the sluice gates were opened, and the rush of water was found to be so great, as to scour away the deposit. The chief objection to this plan is, that the water always taking the same channel, is not so extensive in its operation as to clear away the silt from all parts of the harbour; for instance, at the sides and angles of the quays, where the deposit goes on accumulating till it prevents vessels from being drawn closely up for loading and discharging. In such cases the *dredging machine* is now generally had recourse to. This machine consists of a boat of peculiar construction, provided with a steam-engine, which works machinery so contrived, that an endless chain or series of iron buckets, continually revolving near the stern, scoop up the deposit, and deliver it into barges. The bottoms of these barges are provided with trap-doors or sluices, and when they are taken to sea, the traps are struck out, and the slimy burden dropped into the deep. These dredging machines are very efficient, but are expensive in construction and operation. A more scientific remedy than either of the above has been proposed—namely, to convert the action of the tides and waves into a sluicing power. This is to be effected by leaving arched openings at frequent intervals in the piers and quays, through which the waters would pass with a force sufficient to scour away every vestige of deposit. Whatever may be the result of this proposal, there is no doubt that it is within the scope of hydraulic engineering so to construct piers, breakwaters, and jetties, and so to give them a direction and arrangement, that tidal and other currents shall be made to carry off, rather than lay down, the materials which they hold in suspension.

In addition to the ordinary harbours of commerce, an efficient system of maritime conveyance requires *harbours of refuge*, to which vessels can run for safety in cases of emergency. Britain, as becomes a great maritime country, is about to adopt such a system, and one of large dimensions is already begun at Dover. The chief point to be attended to in the construction of harbours of refuge, is the placing of the fairway or entrance so that vessels may 'make' the passage from almost any point, and without risk of being driven against the extremities of the piers.

Breakwaters are contrivances by which the force of the waves rolling into a harbour or roadstead may be broken, and the water within rendered comparatively smooth and easy. As now constructed, they are formed either of wooden or stone piers projecting from the land into the sea, of isolated mounds thrown across the opening of the roadstead or harbour, or of floating structures of timber. The celebrated breakwater at Plymouth may be given as an example *par excellence*. This erection consists of an immense mole, stretching for a full mile across the middle of the Sound or opening, which forms the entrance to the harbours of Plymouth and Devonport. This Sound has been for many years the principal place of rendezvous for the fleets of the royal navy; but though possessing numerous advantages over every port in the south-west of England, it had one great fault—that of being open to the fury of gales from the south and west, to which this part of the country is much exposed. Some defence from the inroads of these gales had long been a subject of public discussion; and in 1812, the suggestion of Messrs Rennie and Whidbey, that an 'insulated pier should be constructed, extending 1700 yards across the middle of the Sound,' was adopted, and the work commenced. Twenty-five acres of limestone rock, on the east bank of Catwater, were purchased from the Duke of Bedford for its construction; and on the 12th of August, the foundation stone—a huge block of marble raised for the purpose—was laid, or rather thrown into the sea, with great ceremony. In March 1813, the first stone was observed above the surface of low water; and by the end of 1816, the work was considered as half completed, at an expense of £364,000. The blocks, weighing from one to eight tons each, were carried to the spot in vessels constructed for the purpose. In 1822, about two millions of tons of stones had been laid; and the principal object of the breakwater being attained, there was a great reduction in the number of men and vessels employed, and a consequent slowness in bringing the work to a conclusion. In February 1841, a lighthouse was begun at the western extremity, the western entrance to the Sound being the safest, and the only one used by large vessels at night. The height of this tower is about 60 feet, or more than 120 feet from the bottom of the sea. It is wholly built of granite, and is divided into five storeys—respectively serving for oil-room, store-room, dwelling-room, sleeping-room, and one above, over which is placed the lantern. The lighthouse, which may be said to have completed the breakwater, was finished in 1843; the whole structure having required upwards of four millions of tons of rough stones, besides more than eighty thousand tons of cut granite.

What are termed *floating breakwaters* have been proposed at different times; but as yet, we know of no instance of adoption on a large scale. The late Sir J. Bentham drew out a plan of such a breakwater for Plymouth, the distinguishing feature of which was, the construction of prismatic floats of timber, securely moored across the entrance to the Sound. The floating breakwater of Captain Taylor consists of timber caissons or frameworks, fastened together by chains of a peculiar construction; and is recommended by the inventor on grounds of economy, quickness of erection, and, from its open character, preventing the deposition of silt, which a solid erection is likely to assist.

Docks are excavations formed in connection with harbours for the reception of vessels, and are generally lined with stone, and provided with appropriate gates or sluices. They are usually distinguished as 'wet' and 'dry.' Wet docks are used for the purpose of loading and unloading; and as they can be completely isolated from other parts of the harbour, every facility is given for warehousing and for conducting the business of the Excise. The level of the water in the docks corresponds with high water in the harbour or roadstead with which they communicate; consequently, at high water ships can enter and leave them, and if necessary, at low water they can be sluiced out and cleaned. In tidal rivers, it would be impossible to conduct a shipping business to any extent without wet docks; and thus on the Mersey, for example, upwards of a hundred acres of dock, of unparalleled magnificence, have been constructed for the commerce of Liverpool and Birkenhead. Dry docks are intended for the building, repairing, or examination of vessels which are admitted into them at flood-tide, and are so called because they are either left *dry* by the ebbing of the sea, or are rendered so by using gates, and pumping out the water. After the vessel has been repaired, the gates are opened, the tide admitted, and the vessel floated out. What are termed *naval docks* are depôts fitted with all sorts of naval stores, and all the requisite machinery for ship-building. The principal naval docks of Great Britain are Portsmouth, Plymouth, Chatham, Sheerness, Woolwich, and Deptford. It is in these docks, and particularly in the three first, that ships of war are laid up in time of peace. Vessels can also be conveniently laid dry for repairs by Morton's patent slip, which consists of a cradle first floated or slipped under the vessel, and then dragged up an inclined plane by steam power.

MARITIME LAW.

It is a common law of nations that the ocean is a free and universal highway, which no state can appropriate to its own especial use. While this exists as a principle generally recognised by all civilised powers, Great Britain has for a considerable period of time claimed *the dominion of the seas*, as a right acquired by its extensive conquests, and the skill and valour of its seamen. By this claim it is not assumed that Great Britain possesses a legal right of property in the waters of the ocean, or the lands which they may cover: the claim resolves itself into what is termed in law 'a military sovereignty,' which it would be exceedingly difficult to define, and is practically an empty and vainglorious boast. Within the last thirty years, during which a large maritime force has grown up in France, Russia, and the United States of America, the claim of the British to the dominion of the seas has been little heard of, and is perhaps now a dead letter in maritime law, as it is in fact. Each nation retains a judicial control over its vessels and their crews, in whatever part of the ocean they may be: all crimes and misdemeanours committed on board of a ship are punishable by law as soon as the vessel reaches the country to which it belongs. The other points of maritime law are of a civil or commercial nature, and refer to chartering, lading, pilotage, signalling, insurance, quarantine, and the like—subjects of too special and professional a character to be of interest to the general reader.

ARCHITECTURE.

ARCHITECTURE, or the art of planning and raising edifices, appears to have been among the earliest of human inventions. The first habitations of men were such as nature afforded, with but little labour on the part of the occupant, yet sufficient to supply his simple wants—grottos, huts, and tents. In early times, the country of Judea, which is mountainous and rocky, offered cavernous retreats to the inhabitants, who accordingly used them instead of artificial places of shelter. From various passages in Scripture, it appears that these caves were often of great extent, for in the sides of the mountain of Engedi, David and 600 men concealed themselves. In the course of time art was employed to fashion the rude cavernous retreats, and to excavate blocks by which rude buildings were composed in more convenient situations. The progress of architecture, however, from its first dawn, differed in almost every different locality. Whatever rude structure the climate and materials of any country obliged its early inhabitants to adopt for their temporary shelter, the same structure, with all its prominent features, was afterwards kept up by their refined and opulent posterity.

From the cause now mentioned, the Egyptian style of building had its origin in the cavern and mound; the Chinese architecture, with its pavilion roofs and pointed minaret, is moulded from the Tartar tent; the Grecian is derived from the wooden cabin; and the Gothic from the bower of trees. It is evident that necessity as much as choice or chance led to the adoption of the different kinds of edifices. Among a roving and pastoral people, the tent, which could be easily struck and removed, was obviously more suitable than an immovable and laboriously erected structure; it is equally clear that lofty and substantial edifices would be out of place in a country subject to earthquakes, or low buildings in situations liable to periodic inundation. Thus local circumstances everywhere produced local styles of architecture, and these distinctions are now almost as observable as they were thousands of years ago.

After mankind had learned to build houses, they commenced the erection of temples to their gods, and these they made still more splendid than private dwellings. Thus architecture became a fine art, which was first displayed on the temples, afterwards on the habitations of princes and public buildings, and at last became a universal want in society.

Traces of these eras of advancement in the art of erecting buildings are found in various quarters of the globe, especially in eastern countries, where the remains of edifices are discovered of which fable and poetry can alone give any account. The most remarkable of these vestiges of a primitive architecture are certain pieces of masonry found in Greece, Asia Minor, and in the island of Sicily, called the works of the Cyclops, an ancient and fabulous race of giants, mentioned by Homer in his 'Odyssey.' By whom these gigantic walls were actually erected is unknown, though it is most probable that they were raised by the Pelasgians—the predecessors or ancestors of the later Greeks. A gradual progress, indeed, may be traced in them, from the extreme of rudeness, to a degree of symmetry that indicates an approach to the elegance of Grecian architecture. Mr Hamilton divides these so-called Cyclopean structures into four eras:—1. Those such as the walls at Tyrins and Mycenæ, in which the blocks are of various sizes, having smaller stones in their interstices. 2. Those at Julis and Delphi, formed of irregular stones, without courses, their sides fitting to each other. 3. Where the stones are in courses of the same height, but of unequal length, as in Bœotia, Argolis, and Phocis. 4. Where the blocks are of various heights, and always rectangular, as in Attica.

Of the progressive steps from comparative rudeness to elegance of design, history affords no certain account, and we are often left to gather facts from merely casual notices. The most ancient nations known to us, among whom architecture had made some progress, were the Babylonians, whose most celebrated buildings were the temple of Belus, the palace and the hanging gardens of Semiramis; the Assyrians, whose capital, Nineveh, was rich in splendid buildings; the Phœnicians, whose cities, Sidon, Tyre, Aradus, and Sarepta, were adorned with equal magnificence; the Israelites, whose temple was considered as a wonder of architecture; the Syrians; and the Philistines. No architectural monument of these nations has, however, been transmitted to us; but we find subterraneous temples of the Hindoos, hewn out of the solid rock, upon the islands of Elephanta and Salsette, and in the mountains of Eloru. These temples may be reckoned among the most stupendous ever executed by man. The circuit of the excavations is about six miles. The temples are 100 feet high, 145 feet long, and 62 feet wide. They contain thousands of figures, appearing, from the style of their sculpture, to be of ancient Hindoo origin. Everything about them, in fact, indicates the most persevering industry in executing one of the boldest plans. In the chief temple, the vault is supported by several rows of columns, which form three galleries, one above the other. Twenty-four colossal monoliths, representing Indian gods, are placed in separate divisions, the sculpture of which, though on the whole rude, shows in some parts an advanced period of art, and a certain development of taste. In many respects Hindoo architecture bears a striking resemblance to the Egyptian (hereafter described), more especially in the pyramidal character of its masses, in its excavations and cavern temples, as well as those which, though presenting the forms of constructed buildings, are yet hollowed out of the rock. The Egyptian, however, is more simple and severe, and less loaded with incongruous and often grotesque ornament.

Of late years, travellers have made known the remains of an architecture and sculpture not very dissimilar to that of the ancient Hindoos in certain districts of Central America, believed to be the execution of a people anterior to those Mexicans who existed at the period of the invasion of Cortes. Our limited space precludes any detail of these curious structures, which consist of temples, palaces, triumphal and religious monuments—all of which are covered with rude but elaborate sculptures, and mark the existence of a luxurious and wealthy, but semi-barbarous people.*

EGYPTIAN STYLE.

All the architectural remains of ancient times sink into insignificance when compared with those of Egypt. The pyramids, obelisks, temples, palaces, and other structures of this country, are on the grandest scale, and such as could only have been perfected by a people considerably advanced in refinement. The elementary features of Egyptian architecture were chiefly as follow:—1. Their walls were of great thickness, and sloping on the outside. This feature is supposed to have been derived from the mud walls, mounds, and caverns of their ancestors. 2. The roofs and covered ways were flat, or without pediments, and composed of blocks of stone, reaching from one wall or column to another. 3. Their columns were numerous, close, short, and very large, being sometimes ten or twelve feet in diameter. They were generally without bases, and had a great variety of

* Of these new-world antiquities, the reader will find an ample and most interesting account (accompanied by illustrations) in Stephen's 'Yucatan' and 'Central America'—published at New York respectively in 1841 and 1843.

capitals, from a simple square block, ornamented with hieroglyphics or faces, to an elaborate composition of palm-leaves, not unlike the Corinthian capital. 4. They used a sort of concave entablature or cornice, composed of vertical flutings or leaves, and a winged globe in the centre. 5. Pyramids well known for their prodigious size, and obelisks composed of a single stone often exceeding seventy feet in height, are structures peculiarly Egyptian. 6. Statues of enormous size, sphinxes carved in stone, and sculptures in outline of fabulous deities and animals, with innumerable hieroglyphics, are the decorative objects which belong to this style of architecture.

The main character of Egyptian architecture is that of great strength with irregularity of taste. This is observable in the pillars of the temples, the parts on which the greatest share of skill has been lavished. The following are examples:—

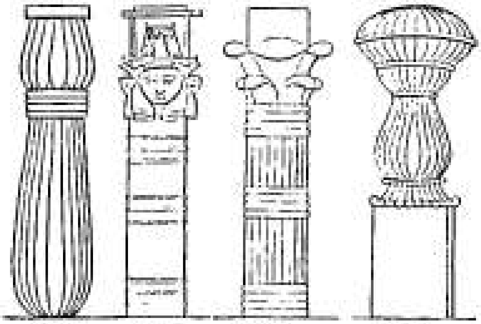


Fig. 1. Fig. 2. Fig. 3. Fig. 4.

In these columns we may notice that sturdiness is the prevailing characteristic. The design has been the support of a great weight, and that without any particular regard to proportion or elegance either as a whole or in parts. When assembled in rows or groups, the columns had an imposing effect, because, from their height and thickness, they filled the eye and induced the idea of placid and easy endurance. 'Compared with Greek architecture, the Egyptian,' says a recent writer, 'is deficient in beauty, grace, variety, and unity. Powerful and imposing as must have been its effect, combined with its sculptural and pictorial decorations, its avenues of sphinxes, obelisks, and gigantic statues, yet is there something so fixed, monotonous, and conventional, as to impress the mind with a conviction that it was unchangeable and incapable of improvement.' In fig. 5, which represents the exterior of a

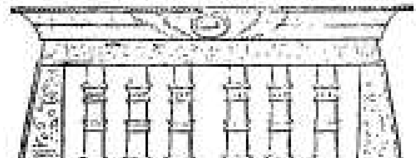


Fig. 5.

temple, this simple and imposing character is conspicuous. But while the Egyptians thus raised temples and monuments which in strength, solidity, and vastness of dimensions far outstrip those of all other nations; yet in street and domestic architecture they were all but utterly deficient. Their streets, if so worthy to be called, were narrow and irregular; the generality of their dwellings were mere huts built of sun-dried bricks formed of mud and chopped straw; and only among the higher classes was there anything like the enjoyment of a house possessing the elements of elegance or comfort. According to the delineations of Mr Wilkinson, their ordinary houses occupied three sides of a courtyard, which was separated from the street by a wall; while large mansions were detached, having entrances in their several sides, with doors very similar to those of their temples.

GRECIAN STYLE.

From Egypt the architectural art spread to Greece, where it passed from the gigantic to the chaste and elegant. The period during which it flourished in the greatest perfection was that of Pericles, about 440 years before Christ, when some of the finest temples at Athens were erected. After this it declined with other arts, and was carried to Rome, where, however, it never attained the same high character. The Grecian temples were built chiefly of marble, and surrounded or decorated with columns, and had a pleasing effect when situated amidst groves of trees or other kinds of natural scenery; and as they were lighted from the roof, the beauty of the structures was not deformed by formal rows of windows, such as are now common in modern edifices. Before describing the various orders of Grecian and Roman architecture, it will be advantageous to explain the terms ordinarily employed in reference to the component parts of buildings:—

Explanation of Terms.

The *front* or façade of a building, made after the ancient models, or any portion of it, may present three parts, occupying different heights (see fig. 7):—The *pedestal* is the lower part, usually supporting a column; the single pedestal is wanting in most antique structures, and its place supplied by a *stylobate;* the stylobate is either a platform with steps, or a continuous pedestal supporting a row of columns. The lower part of a finished pedestal is called the *plinth*, the middle part is the *die*, and the upper part the *cornice* of the pedestal or *surbase*. The *column* is the middle part, situated upon the pedestal or stylobate. It is commonly detached from the wall, but is sometimes buried in for one quarter of its diameter, and is then said to be 'engaged.' *Pilasters* are square or flat columns attached to walls. The lower part of a column, when distinct, is called the *base;* the middle or longest part is the *shaft;* and the upper or ornamented part is the *capital*. The swell of the column is called the *entasis*. The height of columns is measured in diameters of the column itself, taken always at the base. The *entablature* is the horizontal continuous portion which rests upon the top of a row of columns. The lower part of the entablature is called the *architrave* or *epistylium*. The middle part is the *frieze*, which, from its usually containing sculpture, was called *zophorus* by the ancients. The upper or projecting part is the *cornice*. A *pediment* is the triangular face produced by the extremity of a roof. The middle or flat portion enclosed by the cornice of the pediment is called the *tympanum*. Pedestals for statues, erected on the summit and extremities of a pediment, are called *acroteria*. An *attic* is an upper part of a building, terminated at top by a horizontal line instead of a pediment. The different mouldings in architecture are described from their sections, or from the profile which they present when cut across. Of these the *torus* is a convex moulding, the section of which is a semicircle, or nearly so; the *astragal* is like the torus, but smaller; the *ovolo* or *echinus* is convex, but its outline is only the quarter of a circle; the *scotia* is a deep concave moulding; the *cavetto* is also a concave, and occupying but a quarter of a circle; the *cymatium* is an undulated moulding, of which the upper part is concave and the lower convex; the *ogee* or *talon* is an inverted cymatium; the *fillet* is a small square or flat moulding. In architectural measurement, a diameter means the width of a column taken at the base; a module is half a diameter; and a minute the sixtieth part of a diameter.

In representing edifices by drawings, architects make use of the plan, elevation, section, and perspective. The plan is a map or design of a horizontal surface, showing the ichnographic projection or groundwork, with the relative position of walls, columns, doors,

&c. The elevation is the orthographic projection of a front, or vertical surface; this being represented, not as it is actually seen in perspective, but as it would appear if seen from an infinite distance (fig. 7). The section shows the interior of a building, supposing the part in front of an intersecting plane to be removed (fig. 17). The perspective shows the building as it actually appears to the eye, subject to the laws of scenographic perspective (fig. 23). The three former are used by architects for purposes of admeasurement; the latter is used also by painters, and is capable of bringing more than one side into the same view, as the eye actually perceives them. As the most approved features in modern architecture are derived from buildings which are more or less ancient, and as many of these buildings are now in too dilapidated a state to be easily copied, recourse is had to such imitative restorations, in drawings and models, as can be made out from the fragments and ruins which remain. In consequence of the known simplicity and regularity of most antique edifices, the task of restoration is less difficult than might be supposed. The groundwork, which is commonly extant, shows the length and breadth of the building, with the position of its walls, doors, and columns. A single column, whether standing or fallen, and a fragment of the entablature, furnish data from which the remainder of the colonnade and the height of the main body can be made out and restored.

Grecian temples are well known to have been constructed in the form of an oblong square, or parallelogram, having a *colonnade* or row of columns without, and a walled *cell* within. The part of the colonnade which formed the front portion was called the *pronaos*, and that which formed the back part the *posticus*. There were, however, various kinds of temples, the styles of which differed; thus the *prostyle* had a row of columns at one end only; the *amphiprostyle* had a row at each end; the *peripteral* had a row all round, with two inner ones at each end; and the *dipteral* had a double row all round, with two inner ones at each end, making the front three columns deep.

The theatre of the Greeks, which was afterwards copied by the Romans, was built in the form of a horse-shoe, being semicircular on one side and square on the other. The semicircular part, which contained the audience, was filled with concentric seats, ascending from the centre to the outside. In the middle or bottom was a semicircular floor, called the *orchestra*. The opposite or square part contained the actors. Within this was erected, in front of the audience, a wall, ornamented with columns and sculpture, called the *scena*. The stage or floor between this part and the orchestra was called the *proscenium*. Upon this floor was often erected a movable wooden stage, called by the Romans *pulpitum*. The ancient theatre was open to the sky, but a temporary awning was erected to shelter the audience from the sun and rain.

Orders.

Aided, doubtless, by the examples of Egyptian art, the Greeks gradually improved the style of architecture, and originated those distinctions which are now called the 'Orders of Architecture.' By this phrase is understood certain modes of proportioning and decorating the column and its entablature. They were in use during the best days of Greece and Rome for a period of six or seven centuries. They were lost sight of in the dark ages, and again revived by the Italians at the time of the restoration of letters. The Greeks had three orders—called the Doric, Ionic, and Corinthian. These were adopted and modified by the Romans, who added two others—the Tuscan and Composite.

Doric.—This is the earliest of the Greek orders, and we see in it a noble simplicity on which subsequent orders were founded. Compared with the best of the Egyptian models, it exhibits a great advance in purity of taste. From the remains of ancient art, it is found that the Doric varied in its proportions. The column, in its examples at Athens, is about six diameters in height; but in those of older date, as those at Pæstum, it is only four or five. One of the most correct examples is that given in fig. 6. The shaft of the Doric column had no base, ornamental or otherwise, but rose directly from the smooth pavement or stylobate. It had twenty flutings, which were superficial, and separated by angular edges. The perpendicular outline was nearly straight. The Doric capital was plain, being formed of a few annulets or rings, a large echinus, and a flat stone at top called the *abacus*. The architrave was plain; the frieze was intersected by oblong projections called triglyphs, divided into three parts by vertical furrows, and ornamented beneath by *guttæ* or drops. The spaces between the triglyphs were called *metopes*, and commonly contained sculptures. The sculptures, representing Centaurs and Lapithæ, carried by Lord Elgin to London, were metopes of the Parthenon, or temple of Minerva, at Athens. The cornice of the Doric order consisted of a few large mouldings, having on their under side a series of square sloping projections, resembling the ends of rafters, and called *mutules*. These were placed over both triglyphs and metopes, and were ornamented on their under side with circular guttæ. The Romans, in adopting the Doric, greatly spoiled its simplicity and grandeur by unduly lengthening the shaft, and making other tasteless alterations. To have a just idea of the Doric, therefore, we must go back to the pure Grecian era. The finest examples are those of the temple of Theseus, and the Parthenon (fig. 7) at Athens. The Parthenon, which is now a complete ruin, has formed a model in modern

Fig. 6.

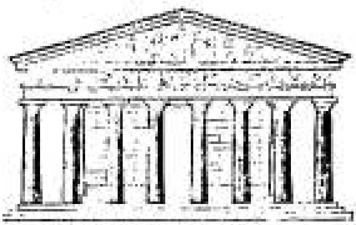


Fig. 7.—Façade of the Parthenon.

architecture. It was built by the architect Ictinus, during the administration of Pericles, and its decorative sculptures are supposed to have been executed under the direction of Phidias. The platform or stylobate consists of three steps, the uppermost of which is 227 feet in length and 101 in breadth. The number of columns is eight in the portico of each front, and seventeen in each flank, besides which there is an inner row of six columns at each end of the cell. The proportional height of the columns is five diameters and thirty-three minutes, and they diminish thirteen minutes in diameter from bottom to top. The sculpture of the frieze represented the combats of the Centaurs and Lapithæ; those of the eastern pediment represented the fabulous birth of Minerva; and those on the western the contests between the goddess and Neptune for the right of presiding over the city. The building was destroyed by the explosion of a bomb-shell during the siege by the Venetians in 1687.

Speaking of these splendid objects of art, a modern authority observes—'Of their effect it is impossible to form a competent idea without seeing one. And whence, it may be asked, does this interest arise? From their simplicity and harmony: simplicity, in the long unbroken lines which bound their forms, and the breadth and boldness of every part—such as the lines of the entablature and stylobate, the breadth of the corona, of the architrave, of the abaci, of the capitals, and of their ovalos also; in the defined form of the columns, and the breadth of the members of the stylobate: harmony, in the evident fitness of every part to all the rest. The entablature, though massive, is fully upborne by the columns, whose spreading abaci receive it, and transmit the weight downwards by the shafts, which rest on a horizontal and spreading basement; the magnitude of every part being determined by the capacity of the sustaining power. Besides graceful and elegant outline, and simple and harmonious forms, these structures possess a bewitching variety of light and shade, arising from the judicious contour and arrangement of mouldings, every one of which is rendered effective by the fluting of the columns, and the peculiar form of the columnar capital, whose broad square abacus projects a deep shadow on the bold ovalo, which mingles it with reflections, and produces on itself almost every variety. The play of light and shade, again, about the insulated columns, is strongly relieved and corrected by the deep shadows on the walls behind them; and in the fronts, where the inner columns appear, the effect is enchanting. For all the highest effects which architecture is capable of producing, a Greek peripteral temple of the Doric order is perhaps unrivalled.'

Ionic.—In this order the shaft begins to lengthen, and to possess a degree of ornament, but still preserving a great degree of simplicity of outline. In the best examples, as represented in fig. 8, the column was eight or nine diameters in height. It had a base often composed of a torus, a scotia, and a second torus, with intervening fillets. This is called the Attic base. Others were used in different parts of Greece. The capital of this order consisted of two parallel double scrolls, called *volutes*, occupying opposite sides, and supporting an abacus, which was nearly square, but moulded at its edges. These volutes have been considered as copied from ringlets of hair, or perhaps from the horns of Jupiter Ammon. When a column made the angle of an edifice, its volutes were placed, not upon opposite, but on contiguous sides, each fronting outwards. In this case the volutes interfered with each other at the corner, and were obliged to assume a diagonal direction. The Ionic entablature consisted of an architrave and frieze, which were continuous or unbroken, and a cornice of various successive mouldings, at the lower part of which was often a row of dentels, or square teeth. The examples at Athens of the Ionic order were the temple of Erectheus, and the temple on the Ilissus, both now destroyed. Modern imitations are common in public edifices.

Fig. 8.

Corinthian.—This was the lightest and most highly decorated of the Grecian orders (fig. 9). The base of the column resembled that of the Ionic, but was more complicated. The shaft was often ten diameters in height, and was fluted like the Ionic. The capital was shaped like an inverted bell, and covered on the outside with two rows of leaves of the plant acanthus, above which were eight pairs of small volutes. Its abacus was moulded and concave on its sides, and truncated at the corners, with a flower on the centre of each side. The entablature of the Corinthian order resembled that of the Ionic, but was more complicated and ornamented, and had, under the cornice, a row of large oblong projections, bearing a leaf or scroll on their under side, and called *modillions.* No vestiges of this order are now found in the remains of Corinth, and the most legitimate example at Athens is in the choragic monument of Lysicrates. The Corinthian order was much employed in the subsequent structures of Rome and its colonies. The finest Roman example of this order is that of three columns in the Campo Vaccino at Rome, which are commonly considered as the remains of the temple of Jupiter Stator. This example has received the commendation of all modern artists, yet has seldom been executed in its original form. This is probably owing to its excessive richness and delicacy, which renders its adoption very expensive; and perhaps the modification of it by Vignola is preferable to the original, possessing a sufficient enrichment without the excessive refinement of the other. In this order the base is one module in height; the shaft sixteen modules twenty minutes; and the capital two modules ten minutes; thus giving ten diameters to the whole column. The architrave and frieze are each one module fifteen minutes in height, and the cornice two modules. The cornice is distinguished by modillions interposing between the bead-mouldings and corona; the latter is formed by a square member surmounted by a cymatium, supported by a small ogee: the former is composed of dentels, supported by a cyma reversa, and covered by the ovalo. When the order is enriched, which is usually the case, these mouldings, excepting the cymatium and square of the corona, are all sculptured: the column is also fluted, and the channels are sometimes filled to about a third of their height with cablings, which are cylindrical pieces let into the channels. When the column is large, and near the eye, these are recommended as strengthening them, and rendering the fillets less liable to fracture; but when they are not approached, it is better to leave the flutes plain. They are sometimes sculptured, but this should only be in highly-enriched orders.

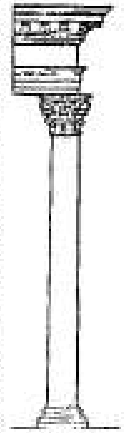


Fig. 9.

The flutes are twenty-four in number, and commonly semicircular in their plan. The Corinthian base is similar to that of the Composite order, excepting that two astragals are employed between the scotiæ instead of one; but the Attic is usually employed for the reasons before assigned.

'The Corinthian order,' says Sir William Chambers, 'is proper for all buildings where elegance, gaiety, and magnificence are required. The ancients employed it in temples dedicated to Venus, to Flora, Proserpine, and the nymphs of fountains, because the flowers, foliage, and volutes with which it is adorned, seemed well adapted to the delicacy and elegance of such deities. Being the most splendid of all the orders, it is extremely proper for the decoration of palaces, public squares, or galleries and arcades surrounding them; and on account of its rich, gay, and graceful appearance, it may with propriety be used in theatres, in ball or banqueting rooms, and in all places consecrated to festive mirth or convivial recreation.' 'The taste and perfect composition of the Corinthian capital,' says a more recent authority, 'sufficiently demonstrate that it could not have been of Egyptian origin, but the legitimate offspring of Grecian genius and Grecian art. Whatever hints the Greeks may have borrowed from Egyptian or Phœnician architecture, as regards the three orders of their decorative features, their superior taste, science, original genius, and fertile imagination so improved and remodelled, as to make them entirely their own. They breathed into them new grace and beauty, new life and vigour; in a word, they stamped them with the highest perfection of which they seem susceptible.'

Caryatides.—The Greeks sometimes departed so far from the strict use of the orders, as to introduce statues in the place of columns, to support the entablature. Statues of slaves, heroes, and gods appear to have been employed occasionally for this purpose. The principal specimen of this kind of architecture which remains is in a portico called Pandroseum, attached to the temple of Erectheus at Athens, in which statues of Carian females, called Caryatides, are substituted for columns. One of these statues has been carried to London.

ROMAN STYLE.

Strictly speaking, Roman architecture possessed little originality; it was founded on copies of the Greek models, and these were modified to suit circumstances and tastes. The number of orders was augmented by the addition of the Tuscan and Composite; the former being the Doric stripped of its distinctive ornaments; the latter, a combination of the Ionic and Corinthian. The distinguishing feature of the Roman style is boldness of execution and elaborate profusion of ornament—as by their adaptation of the principles of the arch, they were enabled to rear structures of greater extent and complexity of design. In the Colosseum, for example, columns and arches are piled upon columns and arches in the interior, and must have struck the beholder with wonder and astonishment; yet in the external plan the building has been pronounced 'a gigantic illustration of architectural blunders.'

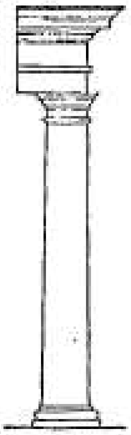


Fig. 10.

Tuscan.—This order is not unlike the Doric, and is chaste and elegant. As represented in fig. 10, the shaft had a simple base, ornamented with one torus, and an astragal below the capital. The proportions were seven diameters in height. Its entablature, somewhat like the Ionic, consisted of plain running surfaces. There is no vestige of this order among ancient ruins, and the modern examples of it are taken from the descriptions of Vitruvius.* The general effect is strength with simplicity, and the order is considered to be well adapted for such buildings as prisons, public halls, and inferior parts of edifices.

Composite.—This order, as the name imports, is a compound of other orders—namely, the Corinthian and Ionic (fig. 11). The proportion and distribution of its parts do not differ much from those of the Roman-Corinthian. It would appear from these efforts, as well as from all subsequent attempts, that the Greeks attained the highest state of improvement of which their style was susceptible, and that, consequently, all schemes to execute something better must prove abortive. The higher class of Roman architects were convinced of this fact, and very judiciously held to the Corinthian order in all their finest buildings, both in Rome and in the provinces. Thus the Corinthian prevails among the celebrated ruins of Palmyra and Balbec, and other great cities founded by Roman provincials.

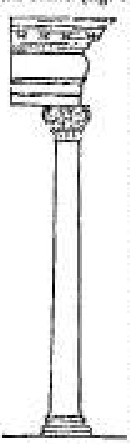


Fig. 11.

The temples of the Romans sometimes resembled those of the Greeks, but often differed from them. The Pantheon, which is the most perfectly preserved temple of the Augustan age, is a circular building, lighted only from an aperture in the dome, and having a Corinthian portico in front. Though stripped of its external ornaments, to furnish materials to decorate the modern cathedral of St Peter's, it is still incomparably the finest. It is a perfect circle, of 180 feet in diameter. 'Its beauty,' says Forsyth, 'consists in its admirable proportions; and its portico, 110 feet in length by 44 in depth, supported by sixteen Corinthian columns of white marble, has a most majestic appearance. Its portal is more than faultless: it is positively the most sublime result that was ever produced by so little architecture.'

The amphitheatre differed from the theatre, in being a completely circular or rather elliptical building, filled on all sides with ascending seats for spectators, and leaving only the central space, called the *arena*, for the combatants and public shows. The Colosseum is a stupendous structure of this kind. It consists of a vast ellipse, the length of the longest diameter being 620, and that of the shortest 513 feet, so that it covers about five and a quarter acres of ground! The longest diameter of the arena has been variously given at from 287 to 300, and the shortest at from 180 to 190 feet; the space between the arena and the outer wall (from 160 to 167 feet) being occupied by the walls, corridors, and seats, that rose, tier above tier, from the wall round the arena nearly to the top of the outer wall. The latter, which is about 179 feet in height, consists of three rows of vaulted arches, rising one above another, exclusive of which it had, when perfect, upper works of wood. This colossal amphitheatre is said to have had seats for 87,000 spectators, and standing room for 20,000 more! Belonging to the same class of buildings were the circuses, of which Rome had at one time no fewer than fifteen. Of these the chief was the Circus Maximus, of which there are now no remains; but of whose dimensions we may judge from the statement of Pliny, that it was capable of accommodating 200,000 spectators.

The aqueducts of Rome, both at home and in her provinces, were erections often of the boldest designs and most stupendous dimensions. They were essentially stone canals for conveying large streams of water for the supply of cities, and had frequently in their course to be supported on massive arcades, to which the largest of our modern railway viaducts are tame in comparison. Many of these arcades consisted of double and triple tiers of arches, and as they stretched their light and lofty structures across valleys of great width, must have had a sublime and imposing effect. For details as to their history and dimensions, the reader is referred to No. 30, in which he will find an account both of the ancient and modern methods of conducting supplies of water.

The triumphal arches were commonly solid oblong structures, ornamented with sculptures, and open with lofty arches for passengers below. The edifice of this kind most entire in the present day is the triumphal arch of Constantine at Rome, represented in fig. 12. This structure is ornamental, and far from inelegant, but it contains much that is tasteless, inasmuch as being without meaning; and there is also an undue overloading of embellishment, or at least frittering away in details. Carrying the eye up the columns, and dissecting their individual bearings,

Fig. 12.

we perceive that each may be resolved into the shafting represented on a larger scale in fig. 13, which is evidently anomalous in design, and inconsistent with the dignified simplicity of the pure Grecian models. The arch of Constantine has been copied at Paris, in the structure erected by Napoleon in front of the Tuileries.

The *basilica* of the Romans was a hall of justice, used also as an Exchange or place of meeting for merchants. It was lined on the inside with colonnades

* Vitruvius was a celebrated writer on architecture, who is supposed to have flourished in the time of Julius Cæsar and Augustus. His treatise on architecture was first printed at Venice in 1497. An English translation appeared in 1771. A new translation by Wilkins was published in 1812.

of two storeys, or with two tiers of columns, one over the other. The earliest Christian churches at Rome were sometimes called *basilicæ*, from their possessing an internal colonnade. The monumental pillars were towers in the shape of a column on a pedestal, bearing a statue on the summit, which was approached by a spiral staircase within. Sometimes, however, the column was solid. The *thermæ*, or baths, were vast structures, in which multitudes of people could bathe at once. As they now exist, they are an assemblage of naked, half-dilapidated brick walls, which surprise by their huge size and the extent of ground they cover—those of Caracalla, for example, occupying not less than twenty-eight acres! In the palmy days of Rome, these were fitted not only as hot and cold-water baths, but as gymnasia, reading and lecture rooms, gardens, theatres, and the like—being, as a whole, the most gigantic places of recreation ever built or known in any age or in any country.

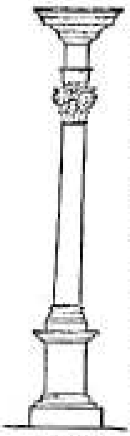


Fig. 13.

SAXON-NORMAN STYLE.

There are very few specimens of the Saxon style now in existence. It is distinguished by rounded arches over doors and windows, or in the entablature of turrets and walls. Sometimes the arch was composed of semicircles of different widths, swelling from a small to a larger compass, and thus affording a convenient entrance to porches in churches. An example is presented in fig. 14.

Fig. 14.

This style commenced at the establishment of Christianity among the Saxons in the sixth century, and takes its name from its having prevailed during the reigns of the Saxon and Norman kings in England. It continued to be used in England till about the year 1135, in the reign of King Stephen.

All ancient structures having semicircular arches belong to what is called the Anglo-Gothic or Norman-Gothic—a style the leading features of which are massive pillars supporting these half-circle arches, and arched doors and windows. The best specimens of this style are impressive, in spite of its inherent clumsiness; as in the Temple Church, London, and the chapel of the Tower of London. The peculiarities of the style may be met with in many of the English cathedrals—as, for instance, in those of Norwich, Canterbury, Gloucester, Worcester, &c.; and exemplifications of its external characteristics may also be seen in some of those edifices, and in the White Tower, Tower of London.

GOTHIC OR POINTED STYLE.

The term Gothic is a modern error, which, being now impossible to correct, is suffered to remain as the generally distinguishing appellation of the kind of architecture possessing pointed arches. This style, according to some, originated in Germany about the middle of the thirteenth century; according to others, it was introduced by the Crusaders from the East, where it is said to have been known long before that period. Be this as it may, for three centuries after its introduction it was zealously pursued as the leading fashion for ecclesiastical structures all over Europe. Executed by a class of skilled artisans, who wandered from country to country,* the finest specimens of the pointed style are the cathedrals of Strasburg, Cologne, and Antwerp, and the splendid abbeys of Melrose and Westminster (fig. 15).

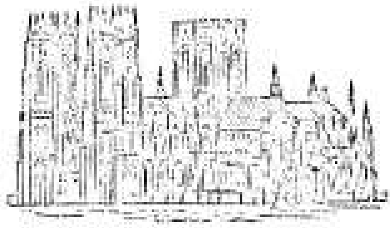


Fig. 15.

In this fanciful and picturesque style of architecture, the slender columns, always united in groups, rise to a lofty height, resembling the giants of the grove, in whose dark shade the ancient Teuton used to build his altar. 'No attentive observer,' says Bishop Warburton, 'ever viewed a regular avenue of well-grown trees intermixing their branches overhead, but it presently put him in mind of the long vista through the Gothic cathedral—or ever entered one of the larger or more elegant edifices of the kind, but it presented to his imagination an avenue of trees; and *this alone is what can truly be called the Gothic style of building.* Under this idea of so extraordinary a species of architecture, all the irregular transgressions against the art, all the monstrous offences against nature, disappear; everything has its reason; everything is in order; and a harmonious whole arises from the studious application of the means and proportions to the end. Nor could the arches be otherwise than pointed, when the workmen were to imitate the curve which branches of two opposite trees make by their insertion with one another; nor could the columns be otherwise than split into distinct shafts, when they were to represent the stems of clumps of trees growing together. On the same principles they formed the spreading ramifications of the stonework of the windows, and the stained glass in the interstices—the one to represent the branches, the other the leaves of an opening grove; and both concurred to preserve that gloomy light which inspires religious reverence and dread.' Some are even of opinion that the stained glass windows and oriels were constructed on purpose to imitate the harmonious and chastened gleams of sunshine passing through the branches and openings of the richly-variegated foliage. The decoration of the ancient Christian churches is therefore by no means an accidental ornament. They speak a figurative religious language; and at the tabernacle or ciborium, over the altar, where the pyx is kept, the whole temple is presented in miniature to the view of the beholder. In these edifices, every one must admire the accurate proportions, the bold yet regular construction, the unwearied industry, the grandeur of the bold masses on the exterior, and the severe dignity in the interior.

In England, the transition from the Saxon to the

* We here allude to the order or craft of Free-masons, the origin of whose associations may be dated from the ninth or tenth century, and who attained their greatest numerical strength and importance at the introduction of the Gothic or pointed style of architecture. Afterwards the order became a speculative society, unconnected with the practice of architecture, and finally has sunk before the spread of universal intelligence, and a common philanthropy which recognises all men as brothers.

pointed style of arch is observed on various old buildings. The accidental intersection of rounded Saxon arches with each other produces sharp points at the intersections, and this is believed by some to have been the origin of the pointed forms. The crossings of the boughs of trees in an avenue also afford a familiar illustration of the same fact. In the Temple Church the two arches may be found united, and other specimens may be seen in the church of St Cross near Winchester; and Fountains Abbey, Rivaulx Abbey, and Roche Abbey, in Yorkshire.

When the circular arch totally disappeared in 1220, the early English style commenced. The windows of this style were at first very narrow in comparison with their height; they were called lancet-shaped, and were considered very elegant: two or three were frequently seen together, connected by dripstones. In a short time, however, the windows became wider, and divisions and ornaments were introduced. Sometimes the same window was divided into several lights, and frequently finished at the top by a light in the form of a lozenge, circle, trefoil, or other ornament. A specimen of this kind may be seen in the beautiful church of St Saviour's, Southwark, which has lately been thrown open to view by the improvements connected with the erection of the New London Bridge; and another, and a very beautiful

Fig. 16.

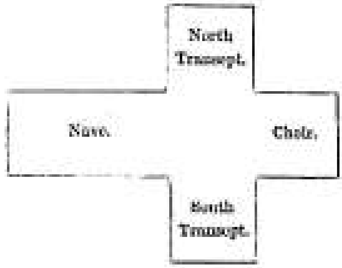
example, in the 'Lady Chapel,' near London Bridge, on the Surrey side of the Thames. A specimen of the pointed or Gothic doorway is offered in fig. 16.

About the year 1300, the architecture became more ornamental, and from this circumstance received the name of the decorated English style, which is considered the most beautiful for ecclesiastical buildings. The windows of this style are very easily distinguished: they are large and wide, and are divided into several lights by mullions, which are upright or perpendicular narrow columns, branching out at the top into tracery of various forms, such as trefoils, circles, and other figures. York Cathedral affords a fine specimen of this sort of architecture, and there is a beautiful window of the same style in the south transept of Chichester Cathedral. The west front of that of Exeter is another specimen, and the doorway of Lincoln Cathedral is in the same style.

The transition from the decorated to the florid or perpendicular style was very gradual. Ornament after ornament was added, till simplicity disappeared beneath the extravagant additions; and about the year 1380, the architecture became so overloaded and profuse, that it obtained the title of florid, which by some persons is called the perpendicular, because the lines of division run in upright or perpendicular lines from top to bottom, which is not the case in any other style. King's College Chapel, Cambridge, begun in the reign of Henry VI., though not finished till some time after; Gloucester Cathedral; Henry VII.'s Chapel at Westminster; St George's Chapel at Windsor; Wrexham Church, Denbighshire; and the chapel on the bridge at Wakefield, Yorkshire—are all of this character. Many small country churches are built in this style; and their size not admitting of much ornament, they are distinguished from structures of a later date by mouldings running round their arches, and generally by a square head over the obtuse-pointed arch of the door. A peculiar ornament of this style is a flower of four leaves, called, from the family reigning at that period, the Tudor flower.

Definitions of Parts.

Gothic architecture being for the most part displayed in ecclesiastical edifices, it may be of service to explain the usual plan and construction of these buildings. A church or cathedral is commonly built in the form of a cross, having a tower, lantern, or spire, erected over the place of intersection. The part of the cross situated towards the west is called the *nave*. The opposite or eastern part is called the *choir*, and within this is the *chancel*. The transverse portion, forming the arms of the cross, is called the *transept*, one limb being called the northern, and the other the southern transept:—



Generally, the nave is larger than the choir. If the nave, choir, and transepts be all of the same dimensions, the form is that of a Greek cross. When the nave is longer than the other parts, forming a cross of an ordinary shape, the edifice is said to be in the form of a Latin cross. The different open parts usually receive the name of *aisles* or *aisles*, from a word signifying a wing: the nave or largest open space is called the main aisle. Originally, the floors of all such edifices were unencumbered with fixed pews or seats, and as the floors were usually of mosaic or tesselated pavement (see No. 21, p. 327), the effect was exceedingly imposing.

The roofing of Gothic churches is of stone, in the form of *groins*, in which the arches are poised with intersecting points, and the whole skilfully adjusted so as to bear on the side rows of pillars (fig. 17). Any high building erected above the roof is called a *steeple*; if square topped, it is a *tower*; if long and acute, a *spire*; and if short and light, a *lantern*. Towers of great height in proportion to their diameter are called *turrets*.

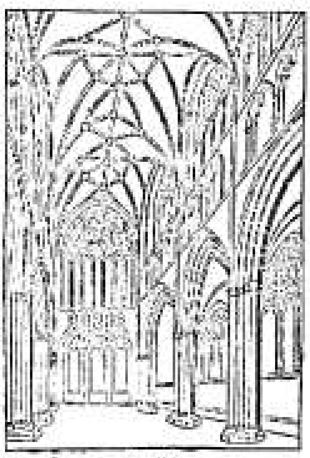


Fig. 17.

The walls of Gothic churches, on which the outer strain of the roof arches ultimately rests, require to be of great strength; and the imparting this necessary degree of resistance without clumsiness is the glory of this style of architecture. The plan adopted is to erect exterior *buttresses* (fig. 18). These rise by gradations from a broad basis to narrow-pointed *pinnacles*, and placed opposite the points of pressure, secure, without the slightest appearance of clumsiness, the general stability of the building. Slanting braces, which spring from the buttresses to the upper part of the roof, are called *flying* buttresses; such, however, are not always required in those modern edifices in which the roof is of wood and lead.

Fig. 18.

The summit or upper edge of a wall, if straight, is called a *parapet*; if indented, a *battlement*. Gothic windows were commonly crowned with an acute arch; they were long and narrow, or if wide, were divided into perpendicular lights by *mullions*. The lateral spaces on the upper and outer side of the arch are called *spandrils*; and the ornaments in the top, collectively taken, are the *tracery*. An *oriel*, or *bay window*, is a window which projects from the general surface of the wall; a *wheel*, or *rose window*, is large and circular; a *corbel* is a bracket or short projection from a wall, serving to sustain a statue, or the springing of an arch; the Gothic term *gable* indicates the erect end of a roof, and answers to the Grecian pediment, but is generally more acute.

The polished tastes of the architects employed in constructing Gothic edifices, led to numerous devices in the form of the pillars. Sometimes the column was single, round, and massive; at other times it was composed of seemingly a cluster of smaller pillars, and this had always the lightest effect; but occasionally the column was given the appearance of several shafts twisted, or of a single shaft with a festoon of flowers twined spirally around it. In the chapel at Roslin there are some highly ornamented pillars of this kind.

The Gothic style of building is more imposing, and more difficult to execute than the Grecian. This is because the weight of its vaults and roofs is upheld at a great height by supporters acting at single points, and apparently but barely sufficient to effect their object. Great mechanical skill is necessary in balancing and sustaining the pressures; and architects at the present day, hampered by principles of economy, find it difficult to accomplish what was achieved by the builders of the middle ages.

ITALIAN STYLE.

After the dismemberment of the Roman Empire, the arts degenerated so far that a custom became prevalent of erecting new buildings with the fragments of old ones, which were dilapidated and torn down for the purpose. This gave rise to an irregular style of building, which continued to be imitated, especially in Italy, during the dark ages. It consisted of Grecian and Roman details, combined under new forms, and piled up into structures wholly unlike the antique originals. Hence the names Græco-Gothic and Romanesque architecture have been given to it.

After this came the *Italian style*, which was professedly a revival of the classic styles of Greece and Rome, but adapted to new manners and wants—a kind of transition from ancient to modern times. Its great master was Andrea Palladio, a Venetian (born 1518—died 1580). This highly accomplished man expelled much of the Græco-Gothic taste, and established in the sixteenth century what may be called a new era in architecture. The majestic simplicity of the ancient orders was always present to the mind of Palladio, and he has left behind him many beautiful buildings which attest the purity of his taste. The writer in the Encyclopædia Britannica, already referred to, alludes to some peculiarities of the Italian style:—'Prostyles being almost unknown in Italian architecture, antæ are not often required. Pilasters, however, are very common—so common, indeed, that they may be called pro-columns, as they are often used as an apology for applying an entablature. They are described as differing from columns in their plan only, the latter being round, and the former square; for they are composed with bases and capitals; they are made to support entablatures according to the order to which they belong, and are fluted and diminished with or without entasis, just as columns of the same style would be. When they are fluted, the flutes are limited to seven in number on the face, which, it is said, makes them nearly correspond with the flutes of columns; and their projection must be one-eighth of their diameter or width when the returns are not fluted; but if they are, a fillet must come against the wall. Pedestals are not considered by the Italo-Vitruvian school as belonging to the orders, but they may be employed with them all, and have bases and surbases or cornices to correspond with the order with which they may be associated. Following Vitruvius, the Italian school makes the central intercolumniation of a portico wider than any of the others. Arched openings, in arcades or otherwise, are generally about twice their width in height; if, however, they are arranged with a columnar ordinance, having columns against the piers, they are made to partake of the order to which the columns belong, being lower in proportion to their width with the Tuscan than with the Doric, and so on; and the piers are allowed to vary in the same manner, from two-fifths to one-half of the opening. With columnar arrangements, moulded imposts and archivolts are used; the former being made rather more than a semi-diameter of the engaged columns in height, and the latter exactly that proportion (fig. 19).

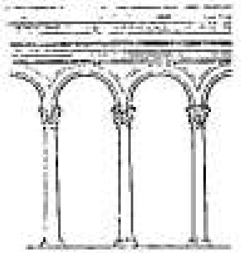


Fig. 19.

Variously moulded keystones are also used, projecting so that they give an appearance of support to the superimposed entablature. Smaller columns with their entablature are sometimes made to do the duty of imposts, and sometimes single columns are similarly applied; at others, columns in couples are allowed to stand for piers to carry arches. In plain arcades, the masonry is generally rusticated, without any other projection than a plain blocking course for an impost, and a blocking course or cornice crowning the ordinance. Niches and other recesses are at times introduced in the plain piers, which are in that case considerably wider than usual, or in the spandrels over wide piers. Very considerable variety is allowed in these combinations, which will be best understood by reference to the examples. Doors and windows, whether arched or square, follow nearly the same proportions, being made in rustic storeys generally rather less than twice their width in height, and in others either exactly of that proportion, or an eighth or a tenth more. If they have columned or pilastered frontispieces, these are sometimes pedimented; and, except in rustic storeys, whether with or without columns, a plain or moulded lining, called an architrave, is applied to the head and sides of a door or window. This architrave is made from one-sixth to one-eighth the width of the opening it bounds, and it rests on a blocking course or other sill, as the case may be.

The rule for the form, composition, and application of pediments in Italian architecture, if it may be gathered from the practice of the school, appears to be to set good taste at defiance in them all. We find pediments of every shape composed of cornices, busts, scrolls, festoons, and what not, and applied in every situation, and even one with another, to the number of three or four, and each of these of different form and various composition. The proportion laid down for the height of a pediment is from one-fourth to one-fifth the length of its base, or the cornice on which it is to rest. Balustrades are used in various situations, but their most common application is in attics, or as parapets, on the summits of buildings, before windows, in otherwise close continued stereobates, to flank flights of steps, to front terraces, or flank bridges. Their shapes and proportions are even more diversified than their application; that of most frequent use is shaped like an Italian Doric column, compressed to a dwarfish stature, and consequently swollen in the shaft to an inordinate bulk in the lower part, and having its capital, to the hypotrachelium, reversed to form a base to receive its grotesque form. The base and coping cornice of a balustrade are those of an ordinary attic, or of a pedestal whose dado may be pierced into balusters. The general external proportions of an edifice, when they are not determined by single columnar ordinances, appear to be unsettled.

There is considerable variety and beauty in the foliate and other enrichments of an architectural character in many structures in Italy, but very little ornament enters into the columnar composition of Italian architecture. Friezes, instead of being sculptured, are swollen; the shafts of columns are very seldom fluted, and their capitals are generally poor in the extreme; mouldings are indeed sometimes carved, but not often; rustic masonry, ill-formed festoons, and gouty balustrades, for the most part supply the place of chaste and classic ornaments.

SARACENIC, MOORISH, AND BYZANTINE STYLES.

The Arabs, or Saracens, as they are more usually called, and the Moors, introduced into Spain certain forms of architecture which differed considerably from the Grecian in appearance, though founded on its remains in Asia and Africa. The chief peculiarity of this architecture was the form of the arch: the Saracens are understood to have made it of greater depth than width, thus constituting more than half a circle, and therefore unphilosophical and comparatively insecure (fig. 20); while the Moorish style was principally distinguished by arches in the form of a horse-shoe, or a crescent. The Saracens and Moors, however, were so much one people that the works of each are not easily pointed out in the present day; both styles were highly ornamented with flowery tracery, called *arabesque*, and the pillars supporting the arches were generally slender and elegant. The crescent-like or bulging dome of the Oriental mosque was likewise introduced by the Moorish architects into Europe. It is common, for example, in the church spires of the Netherlands, having been brought thither by the Spaniards when in possession of the country.

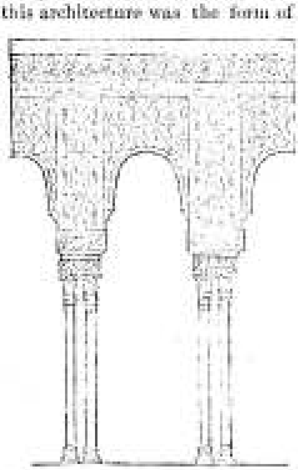


Fig. 20.

We associate with these styles another, which arose at Constantinople, called the Byzantine, likewise formed on the remains of Grecian art, and partaking of a slightly Eastern character. It became known in western Europe along with the Lombard, another degenerate Grecian style, about the ninth and tenth centuries. The two united received the name of the Lombard-Byzantine, and were employed upon the cathedrals of Worms and Mayence, and several other ecclesiastical structures in Germany. This style is distinguished by small arches resting on connecting central pillars, like the Saracenic, and sometimes there are rows of such arches one above another. Either pure or mixed, the Byzantine style remained in vogue till it was superseded by the Gothic, about the middle of the thirteenth century (p. 450).

CHINESE STYLE.

Of the date and origin of Chinese architecture we know nothing, except that it is evidently founded on the type of the Oriental tent—the primitive habitation of their Tartar ancestors of nomadic origin. So close, indeed, is the resemblance to the tent, that, from the accounts of travellers, a Chinese city looks like a large permanent encampment. Chinese roofs are concave on the upper side, as if made of canvas instead of wood. A Chinese portico is not unlike the awnings spread over shop windows in summer time. The verandah, sometimes copied in dwelling-houses, is a structure of this sort. The Chinese towers and pagodas have concave roofs, like awnings, projecting over their several storeys. A representation of this barbaric style of erection is given in fig. 21. Such structures are built with wood or brick; stone is seldom employed. Composed chiefly of timber, the houses of the Chinese are light and gay in appearance—the roofs, porticos, and verandas being generally variegated with different colours and varnishes. 'The law,' says Mr Cleghorn, 'has from time immemorial laid down strict regulations, rigidly enforced, for the plans, dimensions, and materials of the houses of all ranks and casts—from the palaces of the emperor and the princes of the first, second, and third degree, to the habitations of the nobles of the imperial family, the grades of the empire, the citizens, and all classes.' Hence the extraordinary uniformity remarked by all travellers.

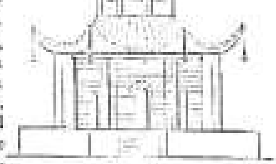


Fig. 21.

Without the gates of several cities in China lofty towers or pagodas are erected, which, according to Davis, are of a religious nature, and, like the steeples of churches, were at first attached to temples. The most remarkable of these—and which may be taken as an illustration of the whole—is that of Nankin, called the Porcelain Tower (fig. 22), from the roofs of its different storeys or stages being covered with porcelain tiles beautifully painted. It is of an octangular figure, contains nine storeys, and is about 200 feet high, raised on a very solid basis of brickwork. The wall at the bottom is at least 12 feet thick; and the building gradually tapers to the top, which forms a sort of spire. It is surrounded by a balustrade of rough marble, and has an ascent of twelve steps to the first floor, from whence one may ascend to the

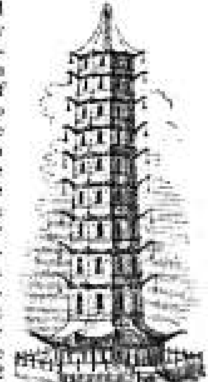


Fig. 22.

ninth storey by very narrow and incommodious stairs. Between every storey there is a kind of pent-house on the outside of the tower, from the eaves of which are suspended little brass bells, diminishing in size as they approach the top, and set in motion by the wind. Each storey is formed of strong beams of timber well boarded; the ceilings of the rooms are adorned with paintings; and the light is admitted through lattices of wire. There are likewise niches in the walls filled with idols; and the variety of ornaments that embellish the whole render it one of the most unique, as it is undoubtedly one of the most beautiful structures in China.

TUDOR—ELIZABETHAN—MODERN GOTHIC.

Throughout England may be seen many aged castles, some still in a state of good preservation, but the greater number in ruins, and occupying, with their picturesque remains, the summit of a rising ground or rocky precipice. These castles are of a style which prevailed during the feudal ages in Europe, and was brought to this country by the Normans, who erected them as fastnesses into which they might retire and oppress the country at pleasure. The same kind of buildings are also frequent in Scotland, where the barons ruled with the same feudal power as in the southern parts of the island.

The feudal castles in England, like those on the Rhine, consisted for the most part of a single strong tower or keep, the walls of which were from six to ten feet thick, and the windows only holes of one or two feet square, placed at irregular intervals. The several floors were built on arches, and the roof was flat or battlemented, with notches in the parapet, from which the inhabitants or retainers of the chieftain might defend themselves with instruments of war. The accommodations for living were generally mean, and what would now be called uncomfortable. Around, or in front of the main tower, there was usually a courtyard, protected by a high wall, and the arched entrance was carefully secured by a falling gate or portcullis. Outside, there was in many cases a regular wet ditch or fosse. Castles of greater magnitude consisted of two or more towers and inner buildings, including a chapel and offices for domestics, and horses and other animals. Some of them were on a great scale, and possessed considerable grandeur of design.

As society advanced, and civil tranquillity was established, these military strengths gradually assumed a character of greater elegance, and less the appearance of defence. The wet ditch disappeared, and was superseded by a lawn or shrubbery. Instead of the drawbridge and portcullis, there was a regular approach and gate of ordinary construction. The windows became larger, and were fitted with glass frames, and stone was abandoned for the greater comfort of wooden floors. Instead also of a bare region around, in which no foe might lurk, gardens were established, and a long avenue of trees led to the front of the modernised mansion. In some instances, the pepper-box turrets at the upper corners of the buildings remained. Of the class of structures that sprung up in this period of transition, which we may refer in England to the fifteenth and sixteenth, and in Scotland to the seventeenth centuries, there are several highly interesting remains. These edifices of the nobility and gentry were no longer called castles: they took the name of *halls*; and such had attained so great a pitch of magnificence in the reigns of Henry VIII. and Elizabeth, as to have subsequently given a name to a new style—namely, the *Elizabethan*. Latterly, and with no very distinct reference to any particular period, this remarkable fashion of building has been pretty generally called the *old English* style of architecture. One of the best existing specimens of this species of architecture is Haddon Hall in Derbyshire, the property of the Duke of Rutland.

A writer in the Quarterly Review, speaking of this species of architecture, takes occasion to notice that 'in a few of the houses built during the reign of Henry VIII., we may observe some slight traces of the Italian architecture, which in the next reign was more liberally introduced, and mixed up with the original Tudor, or early English, into an irregular, certainly, but in most instances an exceedingly rich and effective composition.' This was traceable to the influence of the Italian architects in England, whose 'fame was a subject of deep interest in this country, where the rage for building was no less strong and general than in Italy. In the brilliant reign of Elizabeth, the English nobles and princely proprietors vied more than ever with each other in the magnificence of their mansions. It might have been supposed that the noble Tudor houses, with their panelled walls, buttresses, and battlements, traceried windows, sculptured dripstones, florid pinnacles, and embossed chimney-shafts, were sufficiently rich and gorgeous to satisfy the prevailing taste for splendour; but in their anxiety to strike and surprise the admiration of their countrymen, many deserted the native styles, and sought for designs, and even artists, from abroad. Italian architecture became by degrees the mode; and even where the indigenous style was adhered to in the general design, many of the enrichments and ornamental features were borrowed from the Italian. First of all, the porch or gateway, as the most conspicuous points on which to exhibit these exotic novelties, were decorated on each side of the entrance, and perhaps a second or third storey above, with pilasters belonging to the different Greek orders; the doorway itself exchanged the low-pointed or Tudor for the circular arch; the deep, elegant, and sweeping Gothic mouldings for the Vitruvian architecture, cut across by the awkward projecting imposts. Next was introduced the cupola, whose invention in Italy had made so much noise, that it appears our country squires were anxious to have miniature specimens of it at home. It was applied as a covering to the high turrets, round, square, or polygonal, which flanked the entrance or terminated the angles of the building, and surmounted with gilded vanes, certainly produced a rich and imposing effect. Then followed the removal of the panelled battlements, and the substitution of a parapet, carved into fantastic notches or scrolls, or perforated with oval openings, and ornamented with obelisks, balls, busts, statues, and other singular decorations. These ran up the gables, which were often twisted into strange shapes, and sometimes wholly replaced by the level balustrade; and thus the most characteristic features of the old style—its numerous steep gables and spiry pinnacles—were succeeded by the uniform horizontal straight lines of the new. At length the whole building was surrounded by columns or pilasters, rising tier above tier, to the exhaustion sometimes of the five orders; open arcades took the place of the entrance porch; and nothing remained of the Tudor style but the mullioned window, which, however, was of itself sufficient to give a peculiarly picturesque and old-fashioned aspect to the whole building.'

'It has always appeared to us,' continues our authority, 'that this architecture of the Elizabethan age constitutes a style of its own—a compound of two extremely different modes, the Italian and the Tudor Gothic. It is evident that the Italian design was always greatly altered to suit the climate and the taste of England. Indeed, were we not afraid that the comparison might be considered profane, we should say there is something in the rich irregularity of the Elizabethan architecture, its imposing dignity, gorgeous magnificence, and quaint and occasionally fantastic decoration, reminding us of the glorious visions that flitted across the imagination of Shakspeare, the immortal bard of the same age. He, like the architects of his day, borrowed largely from the foreigner, but made his importations appear exclusively his own. The architectural garden, which always accompanied this style of mansion, is not the least pleasing part of it. We delight in its wide and level terraces, decorated with rich stone balustrades, and these again with vases and statues, and connected by broad flights of stone steps—its clipped evergreen hedges—its embowered alleys—its formal yet intricate parterres, full of curious knots of flowers—its lively and musical fountains—its steep slopes of velvet turf—its trim bowling-green—and the labyrinth and wildness which form its appropriate termination, and connect it with the ruder scenery without. This kind of ornamental garden came from Italy, with the change we have been discussing in domestic architecture.

The quadrangular embattled mansion of the last Henries affords scope for the display of much grandeur and magnificence, and adapts itself more conveniently to the plan of a modern house. The carved oriel, and deep many-lighted bay window, often projecting in a multitude of capricious angles and curves, besides the regular octagon, the panelled angled turrets, with richly-embossed finials, and the wreathed chimney-shafts, are characteristic beauties of this class of building. The gabled manor-house, together with these ornamental features, admits at the same time of a much greater irregularity of form and outline, so as to accommodate itself to every variety of disposition, and to buildings of every size, from the baronial residence to the parsonage and grange. All the forms which particularly mark the Elizabethan style, may be wrought in the cheapest materials with comparatively little labour; and a small portion of ornamental work, tastefully disposed, is capable of producing very considerable effect. Lastly, the Elizabethan house is distinguished by the number and size of its rectangular and many-mullioned windows, which gave a peculiar lightness and elegance to its several parts. The roof-line may be either horizontal or broken with gables, turrets, and cupolas. In either case it is enriched with perforated parapets, balustrades, or other architectural devices, while similar embellishments ornament the entrance, and the terraces which connect the building with the garden.'

Fortunately, this light and elegant style of domestic architecture is gradually superseding the bald Græco-Italian style of the eighteenth century. A better taste is evidently extending itself, particularly as regards the erection of villas, cottages, hunting-seats, gate-lodges, and other rural residences. To these the old English style is peculiarly well adapted. The leading feature of this style applied to cottages is the dispensing with unbroken lines. The house is composed of different parts, projecting at right angles from each other, with also a projecting porch, and the outshot octagonal windows commanding views in three different directions. It also sometimes exhibits an open rustic arcade along a portion of the front or back, which will be found useful and agreeable both in sultry and cold broken weather. It is not uncommon for a

Fig. 23.

cottage of this kind to have on the ground-floor two parlours, communicating by folding-doors, 14 feet by 12 each, and 10 feet in height; a kitchen and scullery, with a porch 7 feet by 5 feet 6 inches, opening to a staircase 17 feet 6 inches by 8 feet, with three rooms above. The gables are enriched with pendants and ornamental dressings to the doorways and windows, and handsome octagonal chimney-stacks. We offer a representation of a cottage in this elegant style in fig. 23.

In erecting ornamental cottages of this kind, there ought to be a lightness in the pointing of the upper projecting windows, with a sharp angularity in the roof; and the chimney-stacks ought to stand well out, in order to create effect in different points of view. When the little gardens adjacent are well trimmed and blooming, and the woodbine and ivy trained round the porch or mullioned window, the prospect exhibited is such as it would be impossible to surpass in rural elegance. We have not here room to enlarge on this interesting topic, and must conclude by recommending that, in applying cottage architecture to a residence, much care ought to be taken to preserve the simplicity of the component parts, or the idea of the cottage will be lost in the magnitude of the dwelling. Loudon's Encyclopædia of Cottage and Villa Architecture should certainly be consulted by gentlemen and others in the country, before fixing on the style or mode of construction of their residences—that is to say, when skilful architects are not employed.

Improvement is also shown in the style of church-building, particularly in the northern part of the United Kingdom, where there was most room for it. Since the Reformation, churches have been built in Scotland with very little regard to elegance; and in the last century particularly, there flourished a style, the products of which are scarcely to be distinguished from barns and granaries. Within the last twenty years, very few ecclesiastical structures have been erected without an effort being made to unite some degree of taste with a regard for conveniency. A modest Gothic style has become very prevalent, which, though not always free of faults, is a surprising advance upon the homely edifices of the last century.

Fig. 24.

In fig. 24, a representation is given of one of these improved ecclesiastical structures, suitable for a rural scene, or any other situation in which economy of means requires to be consulted. In general, these handsome Gothic churches are calculated to accommodate from a thousand to twelve or fourteen hundred sitters, are neatly fitted up with pews and galleries, and cost from three to four thousand pounds.

MODERN BRITISH ARCHITECTURE.

During the sixteenth century, as has been mentioned, an extraordinary effort was made in Italy to restore the purity of Grecian architecture; and in this attempt Palladio was followed by the not less eminent Michael Angelo Buonarotti, who, at an advanced age, in 1546, undertook the continuation of the building of St Peter's at Rome, a work on which the greatest splendours of the Italian style are lavished. Into England, this revived taste for the Grecian was introduced at the beginning of the seventeenth century by Inigo Jones, to whose contemptuous observations on the German or pointed style the term *Gothic* has been traced; and after his decease, the Grecian, or more properly the Italianised Grecian, was perpetuated on a scale still more extensive by Sir Christopher Wren. The edifices erected by this great master are characterised by the finest taste, and his spires in particular are models of elegance. The greatest work of Wren was St Paul's cathedral in London, in which the Italian is seen in all its glory.

The eighteenth century was an era of decline in architectural taste. Every other style merged in that of a spiritless and often mean Græco-Italian, out of which the architects of the nineteenth century have apparently had a difficulty to emerge. Latterly, there has been a revival in England of a purer kind of Grecian, and also, as we have already said, of old English, and the Gothic or pointed style, and in most instances with good effect. It is only to be lamented that, by the manner in which state patronage is distributed in this branch of the fine arts, some of the largest and most expensive structures—Buckingham Palace and the National Gallery, for example—have been erected on the poorest conceptions of the Grecian style, and with a general effect far from pleasing. In Paris there now exist some modern structures after correct Grecian models, which cannot be too highly praised; we would, in particular, instance the building called the Madeleine, the Bourse, and the interior of the church of St Genevieve, which are exceedingly worthy of being visited by young and aspiring architects from Britain.

Houses and Streets.

Till about the year 1820, the street architecture of Britain was on a poor scale; the houses ranging evenly with each other, being plain stone or brick edifices, of generally three storeys in height, overtopped by a slanting and tasteless roof of slate or tile; in London and some other places, the ugly tile roof was hid by a portion of the front wall carried upwards as a parapet. At the above period, a new era may be said to have begun in town architecture, whereby the houses were built more in a bold continental style, in which the Græco-Italian was aimed at with more or less success; and latterly, this improved taste has altogether superseded the barren architecture prevalent during the reign of George III. According to this revived taste, the houses are now constructed of polished sandstone, or covered with a plaster to resemble that material; the doors and windows are enlarged and ornamented,

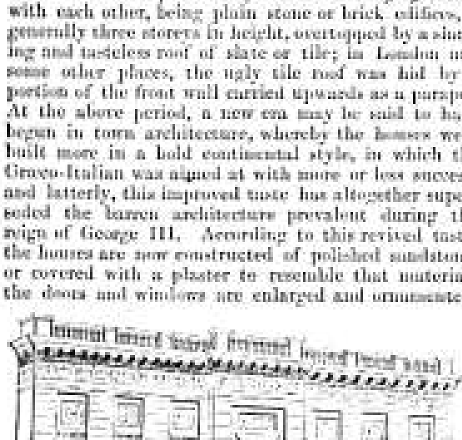


Fig. 25.

the floors more spacious and lofty, and the roof is invariably secluded from the eye by a balustrade or elevated coping. Some of the edifices erected at the west end of London, to accommodate clubs of gentlemen, are reckoned among the finest examples of the revived Italian style, and worthy of the best days of Palladio. The preceding cut (fig. 25), represents the front of the Oxford and Cambridge University Club-House, in Pall Mall, erected from a design of Mr Sydney Smirke and his brother Sir Robert, and which is distinguished for the richness of its cornice and entablature, as well as its generally imposing effect.

The various changes effected in recent times in general street architecture, are not more remarkable than those on the construction of shop-fronts, some of which now vie with the greatest efforts of the old Italian masters. A century ago, shop-fronts were little else than open booths, with an overhanging canopy. They afterwards were closed, and, as is well known, attempts were finally made to Grecianise them with pillars and pediments. The increasing rivalry and taste of shopkeepers, however, did not stop here; and in the present day, very extraordinary efforts are making to place shop-fronts among the works of classic architecture. The design, generally, is to supersede plain Grecian or Roman models by highly ornamental designs after the Italian style. The most favourable specimen we can present of this elaborate and splendid style of

Fig. 26.

shop-frontage is that observable at the corner of the Quadrant, Regent Street, London (fig. 26). As an architectural composition, it possesses considerable merit, presenting, with the lightness of the plate-glass windows, the appearance of sufficient solidity and strength, and not looking as if likely to be crushed by the upper part of the edifice.

Notwithstanding this appearance of revival, there is too much ground for the complaint that the majority of our architects and builders are merely parcel-Greek. 'Their attention,' says the author of Ancient and Modern Art, 'seems exclusively directed to the orders themselves and their details, as if in that consisted the secret and excellence of Grecian architecture. The Doric is their favourite order. *Every* master-mason, every plasterer, every carpenter who knows how to work a Grecian Doric column and entablature, piques himself on his knowledge of Grecian architecture, and looks with ineffable contempt on the Roman and Italian styles, and the ignorance of his predecessors. Every dwelling-house and shop-front must have its tiny, fluted, baseless, Pæstum Doric columns. Every public building, be it a church or meeting-house, a palace or hospital, a college or club-house, a theatre or jail, has its Grecian, Doric, or Ionic portico. Whatever may be the style or character of the building, it becomes henceforth a genuine Grecian structure.' To this may be added the authority of the Quarterly Review:—'That the porticos themselves are admired, we need no other evidence than the universal fashion, we had almost called it *mania*, for their application. In our suburban streets we have salmon and mackerel lying in stately funeral under Doric pillars, and tripe surmounted with metopes, triglyphs, and guttæ, of the most classic proportions. In some of our fashionable club-houses, after every accommodation has been provided for the members, a portico is superadded, apparently commensurate, not so much with the building itself, as with the unexpended residue of the subscription, and adorned, like the family picture of Dr Primrose, with as many columns as the artist could afford for the money: while undecorated windows are left, like Tilburina's maid, in primitive simplicity, a portico, the indispensable necessary of architectural life, is patched on to any visible wall of our pseudo-palaces.'

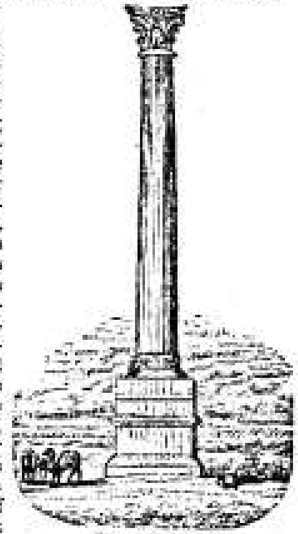
A pediment or portico, unless the termination of a real roof, and an integral part of the building, is a meaningless ornament, and is no indication whatever of the Grecian style; and in like manner, if the columns do not support the roof, they are nothing more than the ornaments into which they were degraded by Roman taste. But in point of fact, the term Grecian among us merely means *something not Gothic*. 'It would be of essential advantage to the progress and purity of the art, and be the means of preventing much error and misconception, were the three styles carefully distinguished from each other both in theory and practice. Our common street elevations, shop-fronts, and dwelling-houses, mimic, in mock majesty and tawdry plaster enrichment, the style and decoration of palaces; while our public buildings are meagre without simplicity, ornate without magnificence, and costly without grandeur or durability. In the metropolis, stone is rarely used for private houses, and not always for public buildings. Everything is sacrificed for present effect—for the caprice, novelty, and excitement of the moment. We are perfectly contented with that tawdry glitter and brilliancy, that vicious and overcharged ornament, which strikes the vulgar and ignorant. We have no classical taste, no extended views, no perseverance, no ambition to hand down lasting and national monuments to future ages.'

But the invention of window-glass in the sixth century rendered a purely Greek building practically obsolete. The few windows of the ancients were placed high in the walls, and many chambers were lighted exclusively by torches. In some temples the colonnade supporting the roof was open. Windows are now a grand feature in the building, for cupola light is not always attainable or always desirable; and windows, therefore, instead of being merely 'poked out,' should exhibit some distinctive characteristic of the order. The glass windows are not incongruous in themselves, being a modification of absolute necessity in the present age; but unluckily they are mere holes in the wall, with no more reference to the Doric than to the Gothic style of architecture. But this is a solitary grievance. The prevailing fault is the abuse of the classical forms as mere nicknacks, while the prevailing folly is the Grecian name we give to the anomalous result.

The Gothic, in like manner, becomes in our hands merely ridiculous. Baby-house towers and turrets—battlements where no battle can be waged—mock machicolations—niches in the walls for dolls instead of statues—what can be in more pitiful taste! 'The Gothic,' says Mr Macculloch, 'is not fit for dwelling-houses. Its dwelling-houses were its abbeys and castles, and were on a large scale. When we attempt to reduce them to a small scale, they become mean. The turrets of the castle, which were meant to contain men, will scarcely hold a cat; the towers will hardly admit of staircases, much less of chambers; the battlements are like the ornaments of an escutcheon; and instead of the machicolations, we have a paltry pretence.'

MONUMENTAL COLUMNS.

The erection of triumphal or monumental columns was a favourite idea of the Romans. Augustus erected a column of white marble near the Temple of Saturn, in the Forum at Rome, as a centre whence the account of the miles began in the calculation of distances from the city. This celebrated column, which is still in existence, is, however, not of great altitude. Among the principal triumphal columns of antiquity now remaining, is what is called the column of Pompey, constructed of red granite, and situated on a rock, about a mile without the walls of Alexandria in Egypt. The total height of this column is variously mentioned as being 92 feet and 114 feet. The spectator can never be tired with admiring the beauty of its Corinthian capital, the length of the shaft, or the extraordinary simplicity of the pedestal. To whom this famous pillar was erected is not now known with any degree of certainty. Notwithstanding its common appellation, it is agreed that it could not have been raised to the memory of Pompey, as neither Strabo nor Diodorus Siculus has spoken of it. Abulfeda, in his history of the country, calls it the Pillar of Severus; but an inscription on the west side, now nearly effaced, seems to prove that it was erected in honour of the Emperor Diocletian by the then prefect of Egypt.



Pompey's Pillar.

The Trajan Column, which falls next to be mentioned, is one of the most celebrated monuments of antiquity. Its height, including the pedestal and statue, is 132 feet. This monumental column was erected in the centre of the Forum Trajani, and dedicated to the Emperor Trajan for his decisive victory over the Dacians, as is testified by the inscription on the pedestal. It is of the Doric order, and its shaft is constructed of thirty-four pieces of Greek marble, joined with cramps of bronze, and so curiously cemented as to appear but one entire stone. Within, there is a spiral staircase leading to the summit, to which the light is admitted by a number of loop-holes; and the outside is adorned with bas-reliefs, representing the principal actions of the emperor. It is now inappropriately surmounted by a statue of St Peter, instead of the golden urn in which the ashes of Trajan were deposited. For elegance of proportion, beauty of style, and for simplicity and dexterity of sculpture, it is the finest in the world. The figures on the pedestal are masterpieces of Roman art. There are other columnar erections in Rome; one of which is the column of the Emperor Phocas, near the Temple of Concord; it is of Greek marble, fluted, and of the Corinthian order, 4 feet diameter, and 54 feet high, including the pedestal.

Trajan's Pillar.

The column which ornaments the British metropolis, better known as the Monument, was designed by Sir Christopher Wren, and erected by order of parliament, in memory of the burning of the city of London, anno 1666, in the very place where the fire began. This pillar was begun in 1671, and finished in 1677. It is of the Doric order, fluted, 202 feet high from the ground, and 15 feet in diameter, of solid Portland stone, with a staircase in the middle, of black marble, containing 345 steps. The lowest part of the pedestal is 28 feet square, and its altitude 40 feet; the front being enriched with curious bas-reliefs. It has a balcony within thirty-two feet of the top, on which is placed a blazing urn of gilt brass.

The column in Phœnix Park, Dublin, differs from any other work of this description. It was erected in 1745. It stands in the centre of an area where four great avenues meet, and from which there are entrances to the vice-regal lodge, and that of the chief secretary. The trees which shade the avenues form vistas, through which the perspective view of the column forms a picturesque object. The pillar is formed of Portland stone, and is of the Corinthian order, fluted, and highly ornamented. The base and pedestal are 5 feet in height, the shaft and capital 20 feet, and the phœnix which surmounts the column 5 feet, so that the whole presents an object 30 feet high.

The Napoleon Column has justly been considered as the greatest ornament of the French capital. It stands in the Place Vendôme, and was erected to commemorate the successful result of Bonaparte's arms in the German campaign of 1805. Its total elevation is 135 feet, and the diameter of its shaft is 12 feet. It is in imitation of the Pillar of Trajan, and is built of stone, covered with bas-reliefs (representing the various victories of the French army), composed of 1200 pieces of cannon taken from the Russian and Austrian armies. The bronze employed in this monument was about 360,000 lbs. weight. The column is of the Doric order. The bas-reliefs of the pedestal represent the uniforms and weapons of the conquered legions. Above the pedestal are festoons of oak, supported at the four angles by eagles, in bronze, each weighing 500 lbs. The bas-reliefs of the shaft pursue a spiral direction from the base to the capital, and display in chronological order the principal actions of the campaign, from the departure of the troops from Boulogne to the battle of Austerlitz. The figures are three feet high; their number is said to be 2000; and the length of the spiral band 840 feet. Above the capital is a gallery, which is approached by a winding staircase within, of 176 steps. The capital of the column is surmounted by an acroterium, upon which stands the statue of Napoleon, measuring 11 feet in height, and weighing 5012 lbs. The total expense of this sumptuous monument was 1,500,000 livres.

There are also several smaller columns, but of beautiful proportions, in various parts of England, in imitation of the above, but mostly of the Grecian or pure Doric order—as the Anglesea Column, erected in commemoration of the battle of Waterloo, and the noble earl of that name, in the island of Anglesea; the column at Shrewsbury, erected in commemoration of the same event, and of another noble general, Lord Hill; the Nelson Columns at Yarmouth and in Dublin; the Wellington Column at Trim, in the county of Meath, Ireland; the monument commemorative of Lord Melville at Edinburgh; and a similar one at St James's Park of the Duke of York, &c. A very common error is committed in the erection of monumental columns, by loading their summit with a clumsy mass of masonry, on which the statue is placed, and technically called an *acroterium*. The Melville monument at Edinburgh presents a notable instance of this kind of defect. If there must be an acroterium, it cannot be too modest in its proportions, or too little seen by the spectator.

BRIDGES.

The art of bridge-building is traced to the Romans, to whom must be ascribed the honour, if not of the discovery, at least of having first put in practice the principle of the arch. In the brightest days of the Grecians, when their fine style of architecture was complete, when their porticos were crowded with paintings and their streets with statues, the people of Athens waded or ferried over the Cephisus for want of a bridge. We cannot, therefore, imagine a people otherwise so ingenious, to have been sufficiently, if at all, acquainted with the value of the arch. After the construction of the Roman sewers, the aqueducts, and the cupola over the Pantheon of M. Agrippa, a bridge over the Tiber was of easy execution; and the invention of the architecture of stone bridges, as practised in its best and most effectual manner, must be conceded to this great and indefatigable people. The most celebrated bridges of ancient Rome were not distinguished by the extraordinary size of their arches nor the peculiar lightness of their piers, but, like the rest of the magnificent works of this city, as far as construction is concerned, they are worthy of study from their excellence and durability. The span or chord of their arches seldom exceeded 70 or 80 feet, and the versed sine or height was nearly half of the chord, so that they were mostly semicircular, or constituted a segment nearly of that form. Martellinis speaks of one near Narni, built by Augustus, consisting of four arches, whose spans were respectively 75, 114, 135, and 142 feet, and whose height was 102 feet. The latter appears to be the most magnificent bridge the Romans constructed in Italy, though in the provinces there were several of much more extensive dimensions. Thus that of Merida, upon the Guadiana, in Spain, consists of sixty-five arches, its total length being about 1300 paces; and that of Alcantara, upon the Tagus, of six arches, its length being 670 Spanish feet, and its height from the bottom of the river to the roadway not less than 205 feet.

After the revival of the arts in Europe, though power and wealth were directed chiefly to the erection of religious edifices, yet we are not without examples of such utilitarian structures as bridges, and these often of very superb dimensions. Thus the bridge of Avignon, on the Rhone, built between 1176 and 1188, consisted of eighteen arches; that of Lyons, of twenty; and that of St Esprit, of twenty-six. Perronet mentions an arch at Verona of 160 feet span, and another at Ville-Brioude, on the Allier, of not less than 183½ feet. Venice, from her peculiar situation, early boasted of more bridges than any other city—these at one time numbering between three and four hundred. The finest is the Rialto, a single arch of 98½ feet span, and only 23 feet of a rise. It was designed by Michael Angelo, and erected between 1588 and 1591. Within the last two centuries, several superb bridges have been erected in France, among which we may mention the following:—The Pont Royal, which was thrown across the Seine at Paris in 1685, consists of five arches, the central one of which has a span of 82¼ feet. The bridge at Blois has eleven arches, the central one being about 92 feet in span, with a breadth over the parapets of 53¾ feet. The new bridge upon the Loire at Orleans, erected in place of an old structure of nineteen arches, was completed in 1760, and consists of nine elegant arches, the largest of which has a span of 98½ feet. The bridge of Nantes, on the Seine, which was completed in 1756, consists of three arches, the middle one having a span of 120 feet; and that of Neuilly, consisting of five arches, each having a span of 128 feet, with a rise of 32 feet.

In England, the art of bridge-building seems to have taken its rise about the middle of the ninth century; but the structures of that early period are not to be compared with those of the same era on the continent. The most ancient bridge in England is the Gothic triangular bridge at Croyland, in Lincolnshire, said to have been built in 860. The ascent is so steep, that none but foot passengers can go over it—a common peculiarity of old bridges. The earliest of any importance, however, were London Bridge, finished in 1209; that of Newcastle-on-Tyne, built in 1281; and that of Rochester, much about the same time. The former originally consisted of nineteen arches; but in 1758 the middle pier was removed, and the two adjacent arches converted into one of 72 feet span. Since then, a number of bridges have been built across the Thames—all of which may be justly regarded with interest, seeing that an artificial foundation has to be prepared for the piers, and this in a river where the tide rises twice every day from thirteen to eighteen feet. That of Westminster, begun in 1738, and opened to the public in 1750, is universally allowed to be one of the finest in the world. It consists of thirteen large arches and two small ones, making a total length of 1223 feet, with a breadth of 44 feet. The arches are semicircular in form, and spring from about two feet above low-water mark; the centre one is 76 feet in span, and the rest decrease on each side equally by 4 feet. That of Blackfriars, begun in 1760, and completed in 1770, is another imposing structure, consisting of nine elliptical arches, the middle one of which has a span of not less than 100 feet, with a breadth of 43½. The arches are low in proportion to their span; but as the bridge is built to accommodate the navigation of the river, the upper surface of the whole forms a portion of a very large circle, and appears a gentle swelling ground under foot all the way. Waterloo Bridge, begun in 1811, and completed in 1817, is another of those costly erections which modern enterprise has thrown across the Thames. It consists of nine arches, all of one span and height, so as to form a level roadway; and this road is continued on either side the river, and supported on a number of brick arches. The length of the stonework or bridge is 1242 feet, the brickwork of forty arches on the Surrey side is 1250 feet, and of that on the Strand side 400 feet. Each stone arch has a span of 120 feet, and the height of the road above the river is 50 feet. The New London Bridge, begun in 1825, and opened in 1831, is the last of the stone structures over the Thames which we shall notice. It consists of five arches—the centre one having a span of 152 feet, the two on each side a span of 140 feet, and the abutment arches a span of 130 feet. The rise of the middle arch is 32 feet, that of the abutment arch falls to 25 feet. The extreme length of the structure is 950, and its breadth 55 feet. With the exception of the packings, it is constructed of granite of the finest description and workmanship; and including the approaches, is said to have cost about £2,000,000 sterling.

But it is not in the neighbourhood of the metropolis alone that we find structures of this class evincing both boldness and ingenuity of design. The Severn, the Ouse, the Tees, the Tyne, and other English rivers, are spanned by stone arches, some of which are of surprising dimensions. The centre arch of the bridge in Blenheim Park is 101½ feet span; a single arch across the Tees at Winstone is 109 feet; and one across the Taaf, in Wales, is not less than 140 feet. The architect of this bridge was a poor uneducated man; and the persevering courage with which he pursued his object till the completion of the edifice is worthy of record. His first attempts failed, in consequence of the enormous pressure of the haunches or sides of the bridge, which forced up the keystone; and to obviate this, he pierced the stonework with cylindrical apertures, which remedied the defect. All these, however, are inferior to some which recent railway requirements have called into existence. Thus Victoria Bridge, over the Wear, at a place called Penchar, and on the line of the Durham Junction Railway, consists of four main arches, and of six smaller ones to support the roadway. Of the main arches, that beneath which the river flows is 160 feet span; the north arch 144 feet; and each of the end ones 100 feet. The total height of the structure, from the foundation to the top of the parapet, is 156 feet; the clear width of roadway 21 feet; and the length 820 feet.

Scotland can also boast of some very handsome bridges; chiefly, however, of modern erection. The Tay at Perth, for example, is crossed by one of nine arches, the largest of which has a span of 77 feet; the Tweed, at Coldstream, by one of five arches; the North Esk, near Montrose, by one of seven; the Tweed, at Kelso, by one of five arches, each with a span of 73 feet; the Spey, near Gordon Castle, by one of four arches, the largest having a span of 95 feet; and the Tay, at Dunkeld, by one of seven arches, the largest having a span of 90 feet—which is perhaps the finest structure of the kind in Scotland. Of Scottish bridges having a large span and height, we may mention that over the Dee Burn, near Aberdeen, whose span is 130 feet; that over the Dee, near Kirkcudbright, having a span of 118 feet; the North Bridge of Edinburgh, consisting of three large and two small arches—the large ones having each a span of 72 feet, and a height of 65; the Pease Bridge, thrown across a deep dingle on the Edinburgh and Berwick road, consists of four arches, each 55 feet span, and 124 feet in height; and the Dean Bridge, near Edinburgh, the main body of which is composed of four arches, each 90 feet span, and from the river to the level of the roadway 106 feet high.

Iron Bridges.

Within the last half century, iron has been frequently substituted for stone in the construction of large arches; so that, instead of a solid vault of masonry, we have now a light but substantial framework of metal. The first iron bridge of any importance constructed in Britain was one near Coalbrookdale, on the Severn—the invention of Mr Obiah Darby. It was completed in 1779, and consists of a single arch 101½ feet span, with a rise of 45. In 1796, another was erected at Buildwas, near Coalbrookdale, under the direction of Mr Telford, the span of which is 130 feet, and its rise only 17. In the same year, Mr Burdon completed the celebrated iron arch across the Wear at Sunderland, the span of which is 240 feet, and its elevation above low-water fully 105 feet. This elevation consists of 75 feet of stone pier, and 30 of a rise in the arch—thus allowing large vessels to pass under without striking their masts! In 1803, an elegant iron bridge, somewhat resembling that of Sunderland, was erected at Staines, having a span of 180 feet, and a rise of only 16½. Since then, a number of others have been constructed, of 80, 90, and 100 feet span, some rising so little in their curve as 5 feet. But all these works have been far exceeded in extent and importance by those built over the Thames. Vauxhall Bridge, which was completed in 1816, consists of nine arches of cast-iron, each having a span of 78 feet, and 11 and 12 feet rise; and that of Southwark of three arches, each 240 feet span, and only 24 feet rise! In most of these structures the iron arch rests on stone piers and abutments; but in some the piers are also of iron, thus giving to the whole a lightness and elegance which it is impossible to equal in stone erections.

Suspension-bridges are such as are hung on chains, these chains being supported on piers or pillars, and stretched across the chasm or water-course over which it is designed to form a passage. From the chains a platform for the roadway is suspended, by means of a series of equidistant vertical rods. In Peru, China, and other remote regions, bridges on this principle, though of an extremely rude and perishable construction, and forming a most unstable and oscillating path, seem to have existed anterior to anything which is at present known of the history of those countries; but the introduction of suspension-bridges into civilised states, at least on a large scale, and of a substantial fabric, is of very recent date. By far the most stupendous in Britain, and indeed in the world, at the date of its erection (1826), is that constructed by Mr Telford across the Menai Strait, to connect the island of Anglesea with the mainland of Wales. The span of the suspended or central arch, between the highest points of the chains on the top of the piers, and 153 feet above high water, is 560 feet. Seven stone arches, of 52½ feet span, make up the rest of the bridge; four of those being next the island, and three on the Welsh coast. The chains, of which there are sixteen, reach over the whole structure, and, besides, descend 60 feet in sloping pits or shafts, to where they are secured by means of cast-iron frames ingrafted in the rocks; the entire length of each chain being 1714 feet, or almost the third of a mile. The two suspension piers of the great arch rise 52 feet above the roadway, and are surmounted by cast-iron blocks and saddles, movable upon friction rollers, for the purpose of allowing the chains which pass over them to move freely when expanding or contracting under change of temperature. The suspension platform, elevated 100 feet above high water, is occupied by two carriage-roads, each 12 feet wide, with a footpath of 4 feet between them. These pass through arches in the suspension piers; and each is separated, and strongly railed in, by lattice iron-work, both for protection and for stiffening the roadway, to prevent vibration. Each of the chains is fivefold, and of such complexity in design, that any part of the chain may with safety be removed at any time for repair, or be replaced by a new one.

The Menai Bridge, however—we quote the *Encyclopedia Britannica*—has been greatly surpassed, both in length and in height, by a far lighter and much less expensive one, though of great strength, which has since been constructed by M. Chaley of Lyons, over the Saane at Friburg, in Switzerland. This was completed in 1834. The span is 870 feet, and the roadway is elevated 167 feet above the river. The lightness of this bridge is in a great measure owing to its neither being suspended by chains nor solid iron rods, but by four cables of iron wire, each containing about 1200 wires, the united strength of which could support three times the weight of two rows of loaded wagons extending over its whole length. The wires are simply laid together, and bound in a cylindrical form by means of annealed wire wound round them at distances of two or three feet; and the whole is painted white, both for preservation, and that the least tendency to rust might be detected at once. But iron, even in its most approved form of wire cable, has been surpassed by the employment of steel; for we learn from the 'Register of Arts,' that in 1832 a bridge of this material was erected over the Danube, near Vienna. The span of this structure is 234 feet, with a rise of only 15. A saving of one-half in the total weight is calculated to have been effected by the use of steel instead of iron; and the strength is also said to be much greater.

PRACTICE OF ARCHITECTURE.

Architecture is practically conducted by two distinct classes of men—*architects*, whose profession consists in planning designs of buildings according to the wish of an employer; and *builders*, who, assisted by operative masons and other artisans, work out the plans in all their various parts. Some architects derive celebrity for designs for churches and public edifices, others for domestic structures, and a third class, who are sometimes styled *civil engineers*, are eminent for their plans of piers, quays, bridges, docks, aqueducts, and other great public works.

In representing proposed edifices by drawings, architects make use of the plan, elevation, section, and perspective. The *plan* is a map or design, of a horizontal surface, showing the ground-work, with the relative position of walls, columns, doors, and other details. The *elevation* is a drawing of the front, without any perspective effect. The *section* shows the interior of the building, as if the outer wall were removed. The *perspective* shows the building as it appears to the eye at a little distance, and is generally executed so as to give the effect of a picture. Along with the different designs, *specifications* of the work to be executed are put into the hands of the builder; these specifications are minute definitions of what must be done in the departments of the stone-mason, bricklayer, joiner, slater, plumber, glazier, and plasterer, as well as of the nature of the materials to be employed. [For an account of stones, bricks, tiles, mortars, cements, and other materials employed in building, roofing, and paving, the reader is referred to the sheets devoted to MINERALS and FICTILE MANUFACTURES.]

The rules of building require, that in a whole fabric judiciously and elegantly erected, there should be solidity, convenience, and beauty, along with simplicity and harmony of design. The structure, whatever it is, must be in character, or look like that for which it is intended. If a church, it should have the appearance of a church; if a house, a house; and if a castle, a castle. Some tastes would construct a cottage in the shape of a Norman fortress, with battlements and loop-holes; but all such oddities are essentially vulgar. It is an important principle in architecture to preserve character, and to make a building expressive yet simple in its outlines, and all of a piece. If there is ornament, it must be duly distributed, not overloaded at one part, and meagre at another. The design, to be striking, must also be of a height and breadth sufficient to fill the eye of the spectator. To aid in this desirable object, the buildings should be well placed, and, if possible, at the summit of slightly rising grounds, where they will stand clear of ungraceful objects. Unfortunately, this principle has not always guided our architects. Magnificent temples which crowned the summits of rising grounds in Greece, we find imitated in hollows; and the eye of the spectator, instead of taking in a bold and lofty outline of pillars relieved against the clear blue sky, is offended by looking down upon clusters of chimney pots. Thus innumerable public buildings in England and Scotland, possessing, intrinsically, good architecture, are greatly spoiled by the want of taste in those who have placed them in unseemly awkward situations.

It appears to us, likewise, that far too little attention is paid by architects to the nature of our climate. We cannot recall to remembrance one public edifice in the Grecian style in this country which does not exhibit a dingy damp look. At every projecting point, and particularly over the pediments, pillars, and flat cornices of doorways, there is generally an ugly spot covered with moisture, and exhibiting the early rudiments of vegetation on the walls. All this offends the eye of the spectator, and excites universal notice, except among those who can see nothing but beauty in Grecian architecture, however clumsy it may be, and however much out of place. Architects likewise require to guard against introducing forms which will revive recollections of unpleasing or mean objects. Fine buildings have been rendered ridiculous by inattention to this point. One structure is defaced by a dome the exact model of an inverted punch-bowl; the pinnacles of another resemble the upturned legs of a footstool; the front of a third is like a grenadier's cap; and the corners of a fourth are defaced by turrets the shape of pepper-castors.

Another point requires consideration. In cases where ornament is not introduced on a large scale, masses of wall will be greatly improved by being thrown into different projections; and this leads us to notice that the effect of interiors, when ornamented with pillars, is vastly enhanced by causing some to project and others to recede, thus gratifying the eye with what is seen, and raising hopes of beauties in those parts which are partially hid from observation. This breaking into seen and unseen parts is well exemplified in the church of St Genevieve at Paris.

Certain practical matters equally require attention in the erection of buildings. The foundation must be laid on a solid basis of rock, clay, or concrete; and if the situation be soft, or of doubtful stability, the ground should be fixed by piles of timber driven to a considerable depth. It is likewise a point of first importance to have the stool or lower part of the house free of damp; and this is only attainable by excavating the loose earth, by digging drains, and paving the surface with a material impervious to moisture. In general, in the construction of cottages and villas, far too little attention is paid to this particular.

In designing windows, the approved rule is to make each twice its width in height; those in the upper floor storey are generally made nearly square, but it is preferable to make them a third higher than broad. The stairs should be of easy access; the rise of each step to be 6 or 7 inches, and the breadth at least 10 inches,

HEATING—LIGHTING—VENTILATION.

Upon judicious means of heating, lighting, and ventilating apartments, manufactories, and several classes of public buildings, very important consequences depend, including not only the ordinary comfort, but the health of human beings. We propose here to treat the three subjects—confining our attention chiefly to plans involving scientific principles, as well as ingenious mechanical contrivance.

HEATING.

It is scarcely necessary to remark, that the mode of heating apartments most prevalent in Britain is by a fire of coal placed in a grate, having a chimney above, through which the vaporised products of the fuel are carried off. Of one class of results from this mode there can be no doubt. The fire glowing in its appropriate receptacle, has an air of cheerfulness and comfort which strikes every beholder, causing the domestic group to cluster around it with that feeling of satisfaction which makes an Englishman regard his fireside as amongst the most precious things connected with his existence. But while the common open fire is almost an object of worship amongst us, on account of its pleasant look and power of concentrating the whole family in one social circle, it is not unattended with certain drawbacks, difficulties, and disadvantages; nor can it be applied well in any place save an ordinary apartment. The greatest drawback is the uneconomical use which it makes of fuel. About one-half of the heat produced by a common fire ascends with the smoke; the smoke itself being an unconsumed part of the fuel. Finally, about a fourth of the heat which is radiated into the apartment is, in ordinary circumstances, carried into the chimney between the fire and the mantel-piece, and thus lost. It is calculated by Dr Arnott, that only about one-eighth part of the heat-producing power of the fuel used in common fires is realised, all the rest being dissipated into the surrounding atmosphere. Count Rumford gave even a more unfavourable calculation, making the dissipated or lost part to be no less than fourteen-fifteenths. He probably over-estimated the loss considerably; but that a very large portion of the efficacy of fuel is forfeited in the use of common chimneys, is just as certain as it is that an open fire is an object which every eye delights to rest upon. It is also unquestionable that often a common fire is found to give a partial kind of warmth, heating the side of our persons next to it, but leaving the rest cold; that it produces draughts into our rooms which are anything but safe or agreeable; that frequently one active fire deranges the action of the chimneys of other fires, and fills the house with smoke; that smoke and dust are annoyances more or less inseparable from it in all its shapes; and that it is by no means a mode of heating free from danger to both property and persons. These are disadvantages of which every one is aware; and although they are not sufficient to extinguish the pleasure which we take in our 'sea-coal fires,' they may certainly be allowed to furnish reason for inquiring if, by any modification of present plans, fuel could be applied more economically, and at the same time agreeably. There is also, we must recollect, the necessity for modes of heating applicable to public buildings, where the common fire is of little service.

Warming by Highly-Heated Surfaces.

One of the first attempts to arrive at a mode of warming more economical than the common fire, and applicable to large buildings, suggested the raising of plates of iron to a high temperature, and causing air to pass over them on its way to supply the rooms or halls where it was required. In some part of the building a furnace was employed to heat the plates, which were of cast-iron, and the air, after passing over them, was sent forward through a tunnel, and ushered into the hall or other space required to be heated, either through a grated aperture in the floor, or by pipes distributed round the walls or galleries. This mode was introduced into many churches in the early part of the present century, and it was fully tried in the London Custom-house. In the latter building there are several large rooms, in which a great number of clerks and other officers are assembled for business. Into one, called the 'Examiners' Room,' the air rushed at a temperature of 170°, to be reduced to a more moderate heat by its mixing with the air already in the apartment. In another, called the 'Long Room,' the air entered at a temperature varying from 90° to 170°, being liable to be reduced by a regulated admission of cold air into the apartment from without. It is not easy to excuse the ignorance which dictated this mode of heating. When air passes over plates raised to a red heat, as these were, it is desiccated, or deprived of its natural humidity; animal and other matters floating in it are decomposed; it is charged with noxious fumes from the iron; and lastly, by the drying or desiccation, it is thrown into a state highly electric. The condition of the air is then nearly the same with that which African travellers recognise with terror under the name of the simoom. The consequence in the Custom-house was, a general falling off in the health of the officers, which became at length so alarming, that this mode of warming the apartments had to be given up.

The mode of warming by highly-heated surfaces is now generally condemned, on account of its deleterious effects on the air; but it is still in practice to some extent, and we have therefore thought ourselves called upon to introduce a brief description of it, in order to have an opportunity of explaining its unsuitableness, and warning against its use. It may be safely set down as a first principle in the science of heating, that no mode which materially alters the ordinary character of the air can be compatible with health. Common stoves are liable to this objection in greater or less degree, and are therefore rarely used, excepting in lobbies and similar apartments.

Warming by Moderately-Heated Surfaces.

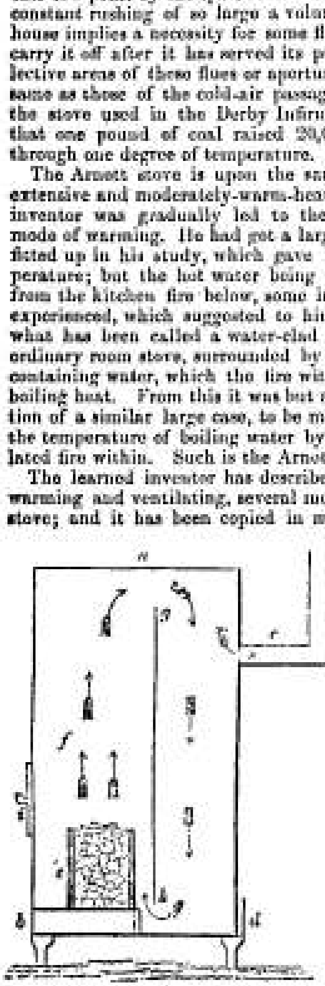
The objections to the above mode of heating would obviously be in a great measure overcome, if, instead of a small surface highly heated, a large one moderately heated were used. This may be done in various ways, as—1. By a furnace operating upon the heat-giving surface, as in a stove; 2. By steam in tubes; or 3. By hot water also in tubes:—

Stoves.—The first attempt of which we are aware to give warmth by hot air from large moderately-heated surfaces, was made by Mr William Strutt, of Derby, in 1792. The cotton-mill of the copartnery to which he belonged was in that year fitted up with a stove constructed upon this principle; and the same plan, after being tried in his own house and those of his friends, was introduced, with all the improvements of which it was deemed capable, into the Derby Infirmary in 1807. It has since been adopted, with some slight modifications, in various public and private buildings.

Briefly, and dismissing unimportant details, the Strutt stove consists of a *cockle*, or plate-iron box, of about two feet in height by one in breadth of sides, inverted with the open mouth downwards over a small close furnace, which heats it to about 260°. Another somewhat larger box surmounts this, leaving the space of an inch or so between. This outer box is perforated with numerous holes, into which short open tubes are fitted, projecting outwards. This apparatus being constructed in a small close room, a channel or culvert of considerable width is made to communicate between that room and the open air on the outside of the house. On the fire being kindled in the furnace, the cockle is heated to the desired height, and no more—a control being exercised over the fire by a valve for communicating air to the furnace. The air immediately without the cockle is warmed, and by virtue of its increased temperature, begins to ascend. To replace it, fresh air is drawn in through the culvert, and through the numerous tubular apertures of the outer case, and made to rush against the heated vessel within. This air is accordingly heated too, and pursues the same line of ascent. Thus there is a constant flow of moderately-heated air upwards. This may either be allowed to pass into an open hall, staircase, or any other single space which it is desired to warm, or it may be carried along in flues, and distributed into different rooms. It will be observed that the instrument or medium for warmth in this case is a stream of heated air: the temperature desired for it is about 64°, and it is kept at this low point by the spaciousness of the culvert. The constant rushing of so large a volume of air into the house implies a necessity for some flues or apertures to carry it off after it has served its purposes. The collective areas of these flues or apertures ought to be the same as those of the cold-air passages or culverts. In the stove used in the Derby Infirmary, it was found that one pound of coal raised 20,000 pounds of air through one degree of temperature.

The Arnott stove is upon the same principle of an extensive and moderately-warm-heating surface. The inventor was gradually led to the adoption of this mode of warming. He had got a large box of hot water fitted up in his study, which gave the requisite temperature; but the hot water being supplied by a pipe from the kitchen fire below, some inconveniences were experienced, which suggested to him the fitting up of what has been called a water-clad stove—namely, an ordinary room stove, surrounded by a close outer case containing water, which the fire within maintained at boiling heat. From this it was but a step to the adoption of a similar large case, to be maintained at about the temperature of boiling water by a small and regulated fire within. Such is the Arnott stove.

The learned inventor has described, in his essay on warming and ventilating, several modifications of this stove; and it has been copied in many various ways, generally with little regard to the original principle. We shall select for description one simple form, which seems to have been the first exemplified by Dr Arnott, and in which the fundamental principle seems to be as well brought out as in any other. This stove consists of a sheet-iron box (*a b d*), which may be of any dimensions, in proportion to the size of the room to be heated. It is divided by the partition *g h* into two chambers of unequal dimensions, which communicate freely at the top and bottom. A fire-box (*e*), composed of iron lined with fire-brick, rests at the bottom of the larger chamber. Access is obtained to it, for the purpose of supplying fuel, by the door *i*, which must fit closely. The refuse of the fire falls into an ash-pit, the door of which is at *b*. Here also is a valve for the supply of air to the fire-box. The fumes and heat of the fire pass in the direction indicated by the arrows, giving warmth to the outer case. The smoke finally passes off by the flue *c*, into an adjoining chimney. The aim of the inventor was to heat an extensive surface to about 200° Fahrenheit, so as to diffuse a moderate warmth into a room. He attains the power of keeping the heat at this height by the valve for admitting air. When this is opened widely, a large stream of air enters, and combustion becomes active. When, on the contrary, the aperture is reduced, a comparatively small stream is admitted, and combustion languishes. The temperature of the outer case is raised or depressed accordingly. By the revolution of the heat and smoke round the division of the chambers, their power of giving forth warmth is expended as far as possible on the plates of the outer case, so as to be serviceable for the end in view; and it might be possible to exhaust the whole for that end by lengthening the flue, or causing a greater extent of it to pass through the air of the room before entering the chimney. This apparatus certainly makes the most economical use of fuel of any species of contrivance for producing artificial heat yet known. Six pounds of Welsh coal or coke, of the value of one penny, will, it is said, supply an ordinary one for a whole day.



The Arnott stove is capable of something nearly approaching to self-regulation. When it was invented, about 1824, there was in existence a well-known means of adjusting the temperature of bakers' ovens by a self-acting thermometer. Though an old expedient, some person had recently secured a patent upon it, and Dr Arnott was therefore unable to take advantage of it for his stove. There are, however, many modes of producing the same curious mechanical results, and a few of these he specifies. That which he has employed in the stoves made under his own care, consists of a glass tube inserted horizontally into the upper part of the heated chamber of his stove, with a downward bend on the outside. Mercury is put into the bend of this tube, leaving the part which is within the stove empty of all but common air. This air of course expands in proportion to the heat of the stove, and in doing so, presses upon the mercury in that part of the outer bend next to it. The mercury in the other part of the bent tube accordingly rises. A float on its surface is thus raised. Connected with the float is a wire, which acts upon a valve at the door of the fire-box, causing it to open and shut according as the float falls or rises. By such simple means, the least increase of heat within immediately and unavoidably brings about a diminution of the supply of air to the fire, which therefore instantly begins to burn less intensely. So also any decrease of heat instantly produces a larger supply of air, by which the fire is, as it were, *poked*, and begins to burn more brightly. The cooling from a fresh supply of coke must of course cause that increased supply of oxygen which is necessary to make the new materials glow; and the new and great heat thus brought about must immediately check itself by the closing of the valve. It is also obvious that, when the materials are nearly burnt down, and the supply of air thus increased, the only consequence is, that the air rushes in as long as there is anything to burn, and no longer.

The express advantages of the thermometer stove are enumerated by the inventor under the following heads, which we shall abridge:—1. Economy of fuel. While in the case of a common open fire, seven-eighths of the heat goes up the chimney, nearly the whole heat is secured by the stove. A gentleman known to us saw Dr Arnott put a few leaves of a pamphlet into his fire-box, the ignition of which immediately heated the whole stove, and diffused an agreeable warmth throughout the room. An ordinary room can be kept warm by the stove for twenty-four hours, at the expense of one penny in coke or anthracite. 2. The temperature diffused by the stove is uniform throughout the room. 3. The stove is always alight, to the saving of much of that inconvenience and loss of time occasioned by the going out and kindling of ordinary fires. 4. No smoke, of the character of the smoke of a common fire, arises from the stove, but only a slight stream of volatile gases. 5. No dust is diffused throughout the room. 6. The dangers to which children, old people, and others, are exposed from a common fire, are obviated. 7. The danger to property is as little as the danger to persons. 8. The stove is obedient to command, and could be managed by a child. 9. It can be established at little expense. 10. It saves all expense for attendance. 11. It is easily moved. 12. It may be fashioned into any graceful or convenient form, so as to ornament a room. The inventor mentions that it may be in the form of a statue. 13. A drawer inserted into the heated chamber of the stove would serve for cooking meat, and a pot for boiling might be placed upon the fire-box; it is therefore, as the inventor remarks, peculiarly the *poor man's* stove. 14. No sweeping-boys or the like are required.

Under a sense of professional honour, Dr Arnott did not take out a patent for his stove. Regarding it as an invention for the improvement of health, he presented it to the world, as he had previously done his hydrostatic bed. It was therefore made by many furnishing ironmongers in the metropolis and elsewhere, some of whom took out patents for what they considered as improvements upon it. Though the intention of the inventor was good, his liberality has had a bad result. The principle, simple as it appears, was not well understood. The stoves made by all, except a very few ironmongers, were constructed erroneously, the prevalent fault being a diminution of the heating surface in proportion to the strength of the furnace. It is a curious fact in science, well worthy of being noticed, that twelve patents were taken out in one year for modifications of this stove, *all of which Dr Arnott considered to be upon false principles.* The consequence has been that many Arnott stoves, which had been introduced into houses with a good hope of their acting beneficially, have been given up on account of the inconvenience felt from the species of heat which they generated. It is also, however, to be observed that the stove, made even upon the most approved principles, would require certain adjuncts and conditions in order to operate healthfully and agreeably.

All metal surfaces, however well the principle of a large superficies moderately warmed may be observed, raise the temperature by two means—namely, by radiation and by conduction. Radiated heat, which is that given by a common fire, is perfectly safe; but the heat produced by the air coming in contact with a warmed surface is more or less deteriorated. The air, which forms the instrument or medium for heating the rest, has been altered in its character, particularly in being desiccated, or deprived of its humidity. It is necessary to counteract this result by an artificial infusion of humidity into the atmosphere. This may be done in various ways. The most common plan is to place a large open dish of water upon the stove; but in this case the evaporation does not proceed rapidly enough. It is better to keep a large wet cloth hanging near the stove. Perhaps the best possible arrangement is that consisting in a trough of water, with a roller moving in it, and a similar roller, forming a windlass, about two feet above. Between the windlass and the roller an endless piece of towelling revolves. The bottom of the piece of towelling passing of course through the water, it is only necessary to turn the windlass a few times in order to make the whole wet; and this process may be repeated as often as necessary. The vapour constantly arising from the cloth will, if sufficient in quantity, make good the want of humidity in the stove-heated air. Such an arrangement is necessary, not only in connection with the Arnott stove, but with Mr Strutt's contrivances, and with all the modes of heating by warmed metal surfaces. We shall consider some further arrangements which such modes of heating render necessary, under the head VENTILATION.

Sylvester's stove or grate, said to be coming into pretty extensive use, is a recent invention, the object of which is to moderate as much as possible the loss of heat which the open hearth involves, and yet to retain all the advantages of the open fire. It is thus briefly described by the editors of 'Knapp's Technology:'—'The fuel is placed upon a grate, the bars of which are even with the floor of the room, and air is supplied to the ash-pit below by a series of passages which pass under a hearth composed of separate bars of iron, arranged in a radiating or otherwise ornamental manner in front of the grate. The radiant and conducted heat from the fire is thus made to warm the hearth and the air passing below it, which is consequently warmed before reaching the fuel, and in an economical point of view this is of course advantageous. The warm hearth and the low position of the fire are also means of disseminating the heat much more effectually than is done by the ordinary arrangement of the fireplace. The sides and top of these stoves are constructed of double casings of iron, and in the sides a series of vertical plates, parallel with the front facing, are included in the interior, which collect, by conduction, a great portion of the heat generated from the fire—the mass of metal of which these are composed being so proportioned to the fuel consumed, that the whole can never rise above the temperature of 212° Fahrenheit under any circumstances. The sides and top of the stove are thus converted into a hot chamber, offering an extensive surface of heated metal; at the bottom, by an opening in the ornamental part, the air is allowed to enter, and rises as it becomes warmed, traversing in its ascent the different compartments formed by the hot parallel plates, and is allowed to escape at the top by some similar opening into the room. A current of air is thus constantly traversing the hollow sides and top of the stove, collecting the heat communicated to the metallic mass, and disseminating it through the room.' If allowed to enter the room by the top aperture, the air requires to be artificially moistened, as in the case of the other stoves above-mentioned. The Sylvester stove can either be placed in an ordinary chimney recess, or be made to stand ornamentally forward into the room. The feeding draught may be either taken directly from the apartment, or brought by flues from the outside of the building.

Hot Water and Steam Tubes.—In the hot-water and steam apparatus, the immediate agent for heating is the same as in the Strutt and Arnott stoves—namely, an extensive metallic surface moderately heated. But the heating is in these cases effected by hot water and by steam respectively, and the arrangement and character of the warm surfaces are different.

The idea of warming rooms by pipes filled with hot water occurred to the Marquis de Chabannes, who first exemplified it in his own house in England. The plan has latterly been patented, and extensively acted upon by the ingenious copartnery of Perkins and Heath, London. It proceeds upon a simple law of heat, that particles of any fluid warmed above the temperature of those surrounding them ascend. Thus in a kettle of water upon a fire, the particles at the bottom are heated first, and immediately ascend to the surface, their place being instantly taken by cool particles from above, which again in like manner ascend as soon as heated; so that there is a constant flow of cool particles downward and warmed particles upward, until the whole are heated. The hot-water heating apparatus consists of a stout metal pipe, pervading the house in all the parts which are desired to be heated, having a valve at the top, and a coil at the bottom exposed to a furnace. This tube being filled with water from the top (*b*), and the fire being kindled in the furnace, warm particles begin to ascend, and are quickly felt at the very highest part of the pipe. The water heats gradually from the top downward, until the whole is warm. The pipe then gives off heat to the surrounding atmosphere. Such is the principle. The arrangement of the pipe may be various: the plan generally followed is to place a considerable coil of it within a pedestal or bunker, with open trelliswork in front, in a convenient part of the room. It may also be made to wind round the room, behind the skirting-board, which, being perforated with holes, will allow of the entrance of the warmed air. The amount of pipe allowed to a room ought of course to bear a proportion to the size of the room, and other circumstances affecting its temperature. The pipes are generally round, and from three to four inches in diameter; but flattish pipes have sometimes been used. In the earlier stages of the history of the apparatus, a boiler was employed at the bottom for the heating of the water; but this was soon found to be attended with great danger, in consequence of the tendency of water in a tube to burst any vessel of capacity into which it may descend. The substitution of a coil of pipe was an improvement suggested by Mr A. M. Perkins. At the top of the apparatus, the pipe expands into what is called the expansion tube (a), which is left empty, to save the risk of bursting by the expansion of the water. Fifteen per cent. of space is found by experience to be an ample allowance for the expansibility of the water. A compendious and readily-understood specimen of the apparatus, calculated for a house of three storeys, is presented in the accompanying engraving. It is important to observe that the pipe, while operating, is closed in every part, the air having been previously pumped out of it. The heat usually maintained is 180°; but it can be increased to 400°, where such is necessary, as it is, for example, in certain drying-houses.

The hot-water apparatus has been fitted up by Messrs Perkins and Heath in various public buildings, warehouses, and gentlemen's houses; and, while sufficiently effective for the desired end, it has been proved to be attended with as few drawbacks as any regulated mode of heating whatever. But there is a great obstacle to its general adoption in its expensiveness. If this difficulty were not insuperable, the plan, from the natural principles on which it is founded, could be applied very easily to several buildings at once, or even to a considerable part of a town—if not, indeed, to an entire city. From some central establishment, on a low level, where the heat was applied, there might proceed pipes to the various houses, in the same manner as the pipes from a gaswork. There would of course be a waste of heat in all those parts of the pipe which passed through streets, and between one house and another; but this might be amply compensated by other economical features in the arrangement. [For a minute account of the hot-water plan, the reader is referred to Richardson's 'Treatise on the Warming and Ventilation of Buildings.']

There is a variation of the hot-water apparatus, in which it is made to take much of the form of Mr Strutt's plan, a large coil of pipe in one hot-air chamber being the means of supplying warmed air to be distributed over the building. The plan, in its ordinary form, has been likewise applied to vineries, conservatories, and forcing-houses, to which it must be considered as undeniably appropriate, if there be no objection on the score of expense.

Heating by steam-pipes is the only mode which remains to be considered. It was suggested nearly a century ago in the 'Philosophical Transactions,' but was not for many years after reduced to practice. At length it began to be introduced into factories, where a great facility existed for its operation in the boilers connected with the steam-engines. As respects its power of heating, and effect upon the surrounding air, it is identical with the plan last described, excepting that the surface of the pipes in this case can never be at a higher temperature than 212°. The size of the pipes and other arrangements are considerably different. The following is an account of the apparatus fitted up on this plan in the printing-office from which the present work is issued:—An iron tube, on which there is a stopcock, carries the steam from the boiler to a connected series of long tin pipes within the building. The diameter of these tin pipes is about ten inches, and they hang from the ceiling by means of small chains a few inches in length, so as to be quite clear of every article of furniture, and every head passing beneath. There is only one pipe going along each of the two lower storeys in this manner; and from each a small waste pipe goes outside, to let off the waste steam and condensed water. The pipes are varnished black, to cause the heat to radiate freely from them. The whole apparatus is exceedingly simple, and is managed with perfect ease. The smallest turn of the stopcock permits the steam to rush through, and to fill the pipes, when an immediate radiation of heat commences. So effectual is the process, that if the steam be admitted only twice a day, for an hour at a time, the premises are kept in a state of the most agreeable warmth for the whole of the day.

There can be no proper comparison betwixt this plan of heating and that of common fireplaces. Coal fires cannot warm the air in large workshops; they only heat the air in their own immediate neighbourhood; hence the workmen are often obliged to draw near the grate to warm themselves. According to the plan we have adopted, every part of the house is equally heated, and the whole of the workmen are as comfortable during the hardest frosts as if they were working in a pleasant summer day. In consequence of this abundant warmth, all the fires have been withdrawn. It is difficult for us to say what is the probable expense of supplying the heat, seeing that we happen to draw our steam from a boiler which is always in operation for other purposes. We believe, however, that the expense of keeping up a necessary supply of steam for such an apparatus must be very small, perhaps not more than that for a single coal fire. Our apparatus cost about £60, a sum which was saved in the course of a few winters. A similar plan of steam-heating by means of cast-iron pipes is pursued in many places, but we approve most of tubes of sheet tin soldered together. Tin is light and cheap, and allows the heat at once to operate, and, in case of explosion from improper management, would rupture or give way without causing any mischief; whereas iron is heavy and dear, takes long to heat, and in bursting would perhaps cause some injury. Excellent, however, as is the process which we have mentioned, we do not believe that it is calculated for private dwelling-houses. In the first place, few domestic servants can be trusted with the management of any apparatus of this description, and this forms an almost insurmountable obstacle to the general introduction of the process; secondly, the pipes are clumsy, and therefore unsuitable for passing through elegant apartments; and thirdly, there is at times a noise of the rushing of the steam in the pipes, which would be insufferable in a private residence.

'To determine,' says Dr Arnott, 'the extent of surface of steam-pipe or vessel necessary to warm particular apartments, it is to be considered that the loss of heat from them occurs in three ways—*1st*, rapidly through the thin glass of the windows; *2dly*, more slowly through the thick substance of the walls, floor, and ceiling; and *3dly*, in combination with the air, which escapes at the joinings of the windows and doors, or at other openings purposely made for ventilation. Different writers and manufacturers have made very different estimates of the quantities of heat lost in these various ways, and as yet no exposition of the matters has been made with the accuracy which the subject deserves; but an intermediate estimate, as applied to common cases, may be shortly stated thus—that in a winter day, with the external temperature at 10° below freezing, to maintain, in an ordinary apartment, the agreeable and healthful temperature of 60°, there must be of surface of steam-pipe, or other steam-vessel, heated to 200° (which is the average surface temperature of vessels filled with steam of 212°), about 1 foot square for every 6 feet of single glass window, of usual thickness; as much for every 120 feet of wall, roof, and ceiling, of ordinary material and thickness; and as much for every 6 cubic feet of hot air escaping per minute as ventilation, and replaced by cold air. A window with the usual accuracy of fitting is held to allow about 8 feet of air to pass by it in a minute, and there should be for ventilation at least 3 feet of air a minute for each person in the room. According to this view, the quantity of steam-pipe or vessel needed, under the temperatures supposed, for a room 16 feet square by 12 feet high, with 2 windows, each 7 feet by 3, and with ventilation by them, or otherwise, at the rate of 16 cubic feet per minute, would be—

For 42 square feet of glass (requiring 1 foot for 6), .	
— 1230 feet of wall, floor, and ceiling (requiring 1 foot for 120), ...	10¼
— 16 feet per minute, ventilation (requiring 1 foot for 6), ...	2⅔
Total of heating surface required, . .	20

which is, 20 feet of pipe 4 inches in diameter, or any other vessel having the same extent of surface—as a box 2 feet high, with square top and bottom of about 18 inches. It may be noticed that nearly the same quantity of heated surface would suffice for a larger room, provided the quantity of window glass and of the ventilation were not greater; for the extent of wall, owing to its slow conducting quality, produces comparatively little effect.'

LIGHTING.

The possibility of producing artificial illumination depends upon the well-known fact, that the action of high degrees of heat upon bodies which are not volatile is always attended with the *evolution of light*. There is, however, another important circumstance besides temperature to be attended to—namely, the density of the luminous body; for though hydrogen, for example, burns with intense heat, its pale-blue flame is wholly unsuitable for the purposes of illumination. There must, therefore, be present not only *burning* matter to produce heat, but *incandescent* (solid) matter, which, in consequence of the heat, shall evolve light. Carbon and hydrogen (carburetted hydrogens) become illuminators on this principle when they undergo simultaneous combustion; and the flame of an oxyhydrogen blowpipe, one of the palest but hottest of flames, produces the most intense light when directed against a solid indestructible substance like limestone. The natural and artificial products fitted for illumination are extremely numerous, and are derivable alike from the mineral, vegetable, and animal kingdoms. Economically, however, only a few are employed—these being the animal and vegetable oils, tallow, wax, resin, and coal. To their application in the form of candles, lamps, fires, and the like, we do not mean to advert, but shall restrict our remarks to their condition as gases in the ingenious process of

Gas Illumination.

The existence of an inflammable air, as a natural production, has been known from a period of great antiquity. It was observed to issue spontaneously from fissures in the earth; and we are told that it has been employed in such situations, as a source of light and heat, both in ancient and modern times. This natural gas is also found in abundance in some coal mines, where, being liable to mix largely with the air when ventilation is defective, it constitutes the 'fire-damp' so destructive to the miner. From an old wrought-out seam at Wallsend colliery, 'a discharge of this gas takes place, through a four-inch metallic pipe, of two cubic feet per second. The pipe is carried up as high as the head-gear above the shaft; and from its orifice issues, with a roaring sound, the stream of gas, which, having been ignited, forms a flag of flame seven or eight feet in length, conspicuous by day, and at night illuminating the entire neighbourhood.'

The artificial production of an inflammable air from coal is first mentioned in a letter by Mr Clayton, rector of Crofton, at Wakefield, in Yorkshire. In this letter, addressed to the Royal Society, May 12, 1688, he states that he distilled coal in a close vessel, and obtained abundance of gas, which he collected in bladders, and afterwards burnt for the amusement of his friends. Other experimenters, among whom Bishop Watson is conspicuous, followed Mr Clayton; and the properties of coal-gas, and the method of preparing it, thus became well known to chemists about the beginning of last century.

It was only, however, esteemed as a philosophical curiosity until the year 1792, when it attracted the attention of Mr Murdoch, an engineer, then residing at Redruth, in Cornwall. In that year he commenced a series of experiments on the gases obtained by the action of heat upon coal, wood, peat, and other inflammable substances, and actually prepared coal-gas on a scale sufficiently large to light up his own house and office. Five years after, while living at Cumnock, in Ayrshire, he again erected a coal-gas apparatus. In 1798, he was engaged to put up his apparatus at the manufactory of Messrs Bolton and Watt, Soho, near Birmingham, where he continued to experiment, with occasional interruptions, until the year 1802. It does not appear, however, that much attention was excited by these first efforts at gas-lighting, except among a very few scientific individuals, until the general illumination at the peace of Amiens afforded an opportunity for a more public display. On this occasion the front of the manufactory was brilliantly lighted up by the new method, and it at once attracted the wonder and admiration of every one who saw it. 'All Birmingham poured forth to view the spectacle; and strangers carried to every part of the country an account of what they had seen. It was spread about everywhere by the newspapers; easy modes of making gas were described; and coal was distilled in tobacco-pipes at the fireside all over the kingdom.'

By the exertions of a Mr Winsor, a company was formed in 1804 for supplying London with gas; but it struggled for many years with the difficulties at once of inexperience and public prejudice, and was a source of loss to many individuals. At length most of these difficulties were overcome, and gas-lighting began to spread over the kingdom. Its progress in dwelling-houses has been retarded by several considerations, most of which are now in a great measure overcome. It was injurious to delicate furniture, and to many of the wares exposed in shops; it often caused headaches when used in close apartments; and above all, it was dirty, and had a most disagreeable smell.

Science, however, has not been deaf to these complaints urged against the obnoxious qualities of her gift; by means of the joint labours of the chemist and practical engineer, all reasonable grounds of objection have been long ago removed; and the art is now so perfected in our best gasworks, that it is doubted whether much remains to be discovered either for simplifying the process or improving the quality of the product. It is true that unburnt gas has still a disagreeable smell, but this, instead of being an evil, is in reality a most valuable property; it thus gives warning of its own escape, at once directing the attention of the consumer to his stopcocks or fittings, without some imperfection of which the smell of gas cannot be perceived.

The success which has attended gas-lighting wherever it has been introduced, has now effected its adoption in almost every town and village of any importance in Great Britain. The continental nations are slowly following our example—employing coal, oil, and other sources of gas, according to circumstances. In America, it is used extensively in the large towns; and it has even reached the remote colony of New South Wales, the town of Sydney being now lighted in this manner. The employment of gas at a distance from towns is limited by the expense of the apparatus compared with the quantity of light required; but where the annual expenditure for light is not less than £40, it is probable that gas might be made with advantage.

The employment of gas made by the decomposition of oil was at one time common in Britain. It had two great advantages over coal-gas—namely, a greater brilliancy of light, and a much simpler mode of preparation. These qualities, however, have not enabled it to compete with the superior economy of its rival; and the several oil-gas establishments which were erected at different places are now converted into coal-gas manufactories, or entirely abandoned. Though refuse oily matters are still common as a source of gas on the continent, and though these, as well as resins, turf, wood, and the like, might be advantageously employed where good bituminous coal is scarce, we shall not advert to their treatment, but confine our notice to the manufacture of coal-gas, as commonly practised in Britain.

Nature and Properties of Coal-Gas.

In their physical properties gases are similar to common air, which is itself included among them. Like it, they are elastic, for the most part invisible, and possessed of little weight when compared with liquids and solids. They are either simple—by which is meant that they consist of only one ingredient—or compound. We find among them some that are capable of burning when supplied with common air; others that do not burn, but, like common air, assist the combustion of inflammable substances; while a third class have neither of these properties.

The gas prepared from coal is neither a simple nor a single gas; it is a very variable mixture, chiefly composed of two inflammable gases, commonly known by the terms olefiant gas and light carburetted hydrogen. Both these gases are compounded of hydrogen and charcoal in definite proportions. The first—namely, olefiant gas—is composed of 2 atoms of hydrogen with 2 atoms of charcoal; or by weight, 2 hydrogen to 12 charcoal. Its specific gravity—that is, its relative weight when compared with common air—is ·9722, common air being considered as unity, or 1·000. The weight of 100 cubic inches is 29·652 grains. When passed through red-hot tubes, it is easily decomposed, depositing charcoal, and evolving light carburetted hydrogen, and hydrogen. When pure, it has no taste, and scarcely any smell; it burns with a dense white light, combining with three times its bulk of oxygen; or by weight, 14 olefiant gas with 48 oxygen.

The second—namely, light carburetted hydrogen—is composed of 2 atoms of hydrogen, combined with 1 atom of charcoal; or by weight, 2 hydrogen to 6 charcoal. Its specific gravity is ·5555; the weight of 100 cubic inches is 16·944. It does not part with its carbon when passed through red-hot tubes unless the heat is very intense. It is this gas which is met with in coal-mines. According to the experiments of Sir Humphry Davy, it forms explosive mixtures with air when the latter is mixed with it in any proportion between 5 and 14 times its bulk; it burns with a yellowish flame, combining with twice its bulk of oxygen; or by weight, 8 light carburetted hydrogen to 32 oxygen. (See CHEMISTRY, p. 297.)

Other gases enter into the composition of coal-gas, though in smaller proportions; thus hydrogen, carbonic oxide, and nitrogen, are uniformly present; and it is inferred from the result of experiments by Dr Faraday on oil-gas, that coal-gas also contains certain other compounds of hydrogen and charcoal in a state of vapour. To these last, in which the proportion of charcoal is very high, both the smell and a considerable increase in the luminous property are attributed.

An analysis of 100 measures of coal-gas, of specific gravity ·650, by Dr Henry, is as follows:—

Olefiant gas,	10
Carburetted hydrogen,	82·2
Carbonic oxide,	3·2
Nitrogen,	1·3

Mr Clegg has given an analysis of 100 parts of gas, specific gravity ·471, as follows:—

Olefiant gas,	8
Carburetted hydrogen,	72
Carbonic oxide and hydrogen,	13
Carbonic acid,	4
Sulphuretted hydrogen,	3

The relative proportions of the different ingredients in coal-gas are ever varying, being dependent upon the quality of the coal from which it is made, and to a considerable extent upon the methods employed in its preparation; and, as may be supposed, it must vary also in its specific gravity and luminous quality. When it is made in the best manner from good coal, the specific gravity is sometimes as high as ·675, or even ·700; in other circumstances, it is as low as ·400, or even lower. The former specific gravity indicates with tolerable certainty a large proportion of olefiant gas; the latter a superabundance of light carburetted hydrogen and hydrogen. And as the amount of light evolved by combustion depends greatly upon the quantity of olefiant gas, which has a high specific gravity, the specific gravity of any specimen of coal-gas may be taken as a pretty correct indication of its actual illuminating value—the heaviest gas giving the greatest amount of light, and *vice versâ*.

It is a curious fact, that the dilution of the heavier gases by hydrogen does not only deteriorate their quality by the actual amount of dilution—as in the familiar example of spirits and water—but to a much greater extent. This fact, important to the makers of gas, has been experimentally proved by the author of the article *Gas-Light*, in the Encyclopædia Britannica. In this article it is thus stated:—'In the first experiment, we took a portion of coal-gas, of the specific gravity ·67, which we found consumed at the rate of 4400 cubic inches per hour, and yielded the light of 11 candles, being 400 cubic inches per hour for the light of one candle. This gas being diluted with a fourth part of its bulk of pure hydrogen, acquired the specific gravity ·55, and wasted away at the rate of 6545 cubic inches per hour, yielding the light of 10 candles. As a fifth part of the compound gas was hydrogen, the remaining four-fifths, amounting to 5236 cubic inches, was the quantity of the coal-gas, which, in its diluted state, gave the light of 10 candles for an hour; so that 524 cubic inches of the original coal-gas were requisite to give the light of one candle for the same time. But in its unmixed state, 400 cubic inches were sufficient to give the light of one candle for an hour, and consequently the deterioration caused by the dilution was in the ratio of 524 to 400, or of 100 to 76, being 24 per cent.'

A similar or even greater proportionate deterioration is caused by the carbonic oxide and nitrogen commonly present in coal-gas. Their amount, however, is small when compared with the hydrogen occasionally found, and is much less under the control of the gas-maker. Two other gases—namely, carbonic acid and sulphuretted hydrogen—are sometimes mixed with coal-gas; but they are to be regarded as impurities which ought to be separated by the manufacturer, and not as constituents of the gas. They may be detected by the following processes:—1. Shake a portion of the gas, with limewater, in a phial. If carbonic acid be present, the water will become turbid by the formation of carbonate of lime. 2. Write on, or wet a slip of paper with a solution of sugar of lead; and while still wet, expose to a stream of the suspected gas. If sulphuretted hydrogen be present, even to the amount of one part in twenty thousand, it will be at once detected by the browning or blackening of the solution of lead.

Manufacture of Gas.

The best coal for gas-making is that which is called *cannel*, or parrot. It is characterised by its great hardness and close texture; its colour is dark-brown, approaching to black; it does not soil the fingers when handled; and it has a splintery conchoidal fracture, the broken surface exhibiting a peculiar velvety lustre.

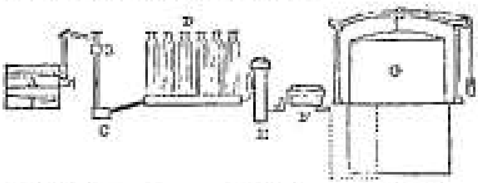
The best parrot we have seen is procured from the Fife and Mid-Lothian coal-fields, having a specific gravity of from 1·2 to 1·5.—The produce of gas from this coal, on the large scale, is usually about 1000 cubic feet from 200 lbs., and its specific gravity is sometimes as high as ·700. We have seen a small balloon filled with 800 cubic feet of this gas, which would not ascend, to the great disappointment of the experimenter, who had found no difficulty on former occasions with an inferior quality of gas.

The analysis of Newcastle coal, according to Dr Thomson, is as follows:—

Carbon,	75·28
Hydrogen,	4·18
Nitrogen,	15·96
Oxygen,	4·58

to which may be usually added sulphur and earthy matters.

When the coal is exposed to a high temperature, these ingredients are separated from each other, and enter into a new series of combinations, giving rise not only to coal-gas, but at the same time to a variety of other products—namely, water, tar, naphtha, carbonate and sulphate of ammonia, carbonic acid, and sulphuretted hydrogen. These substances are separated from the gas in the apparatus which we have attempted to exhibit by the following woodcut:—



Where dimensions are stated, they are taken from a small gaswork belonging to a town of 5000 inhabitants. A represents the retort, of which several are commonly in use at once. It is a cylindrical, elliptical, or D shaped vessel of clay or cast-iron, about 8 feet in length, and 20 inches internal diameter. It is built horizontally into a furnace, either singly or otherwise, in such a way that the fire can act completely around it, so as to keep it at a full red heat. Iron retorts have, until of late, been almost exclusively used, but they are inferior in almost every respect to the clay retort which has been lately introduced. For instance, the latter is only one-third of the cost of iron, and we state with confidence that it is more durable, that it can be heated with less fuel, that it is easier kept at a uniform heat, and that it consequently produces a larger quantity of gas. It is now the practice at some works to use a combination of clay and iron retorts—the former being so disposed as to receive the highest temperature.

The retort, whether of clay or iron, has two openings, both external to the building; one of them is the end of the cylinder, which is furnished with a closely-fitting lid of iron; the other is an aperture in its upper surface for the exit-pipe, which passes from the retort to B, a vertical section of the hydraulic main—this is a round or square vessel of iron, about 10 inches by 14 in size. It passes above and in front of the whole line of retorts; it is half filled with liquid, into which the exit-pipe dips; it serves to collect the gas and other matters from any number of retorts, and to cut off its escape by any retort which may be open. It is connected by means of a wide pipe with C, the tar-cistern, in which the tar and everything deposited from the gas by cooling is collected. From the tar vessel a tube rises in a sloping direction to D, the condenser—a series of tubes through which the gas is made to pass, that it may be thoroughly cooled. To the condenser there is sometimes attached E, an upright cylindrical vessel filled with brushwood, through which the gas passes before it is sent to F, the chemical purifier. There are usually several vessels of this kind, and of various forms; they contain quicklime, either dry or mixed with water to the consistence of cream. From the purifier, a tube passes to the bottom of the tank in which G, the gasometer, is suspended. This is a large vessel of sheet-iron for holding the gas, generally of a cylindrical form, and single; but sometimes, for the economising of space, made of several cylinders, which fit one into the other, and rise as they are charged with the gas, in telescope fashion; hence known as 'telescope gasometers.'

The retort being heated to a red heat, the charge of coal, about 200 lbs. or upwards, is quickly shovelled in, and immediately gives off dense smoke and flames. The mouth of the retort is now closed by its lid, which extinguishes the flame by shutting off the air, and leaves no outlet for the dense vapours arising from the coal, except by the exit-pipe; they rush through this tube, and are heard bubbling up into the hydraulic main until the charge is exhausted.

It is of importance in this part of the process to attend to the temperature of the retort; for if it is too hot, some of the heavy gas will be decomposed, depositing part of its carbon, and forming light carburetted hydrogen; if, on the contrary, it is not of a certain temperature, there will be formed a large proportion of tar, and the gas will be light and of bad quality. It is also essential to draw the charge before it is quite exhausted, as the last portions of gas consist chiefly of hydrogen and carbonic oxide, both of which, as already stated, have a most injurious effect upon the quality of the whole product.

The time required for a charge of cannel coal is from three to four hours. As soon as one is withdrawn in the form of coke, a second is thrown in, the process being thus continued uninterruptedly night and day. It is of considerable importance that the coals be thoroughly dried, and in pieces about the size of the hand; by these means much waste of fuel is avoided, and the process greatly accelerated.

The dense vapours which pass from the retort into the hydraulic main consist of coal-gas mixed with tar, water, naphtha, salts of ammonia, carbonic acid, sulphuretted hydrogen, &c. Being subjected to a process of cooling in all parts of the apparatus as far as the brushwood box, the impurities are condensed, with the exception of the carbonic acid and sulphuretted hydrogen; and from the sloping or descending direction of the apparatus to the tar-cistern, they collect in it, and are pumped off as occasion requires. A considerable quantity of carbonate and sulphate of ammonia is also deposited in the tubes of the condenser in a crystalline form, and requires to be cleared out periodically. This is easily accomplished by passing a current of steam down each pair of tubes, by which these salts are at once dissolved. The gaseous matter still retains particles of tar mechanically mixed with it, from which it is freed by being forced through the brushwood vessel. It is now made to enter the chemical purifiers, where it is either washed by agitation with a mixture of quicklime and water, or is passed through a succession of trays covered with thin layers of this substance in a slightly-moistened state. In this process the lime combines with the sulphuretted hydrogen and carbonic acid, forming hydrosulphuret and carbonate of lime, which, being both solid, are retained, and the gas, now purified, is at once passed into the gasometer, where it is stored for nightly consumption.

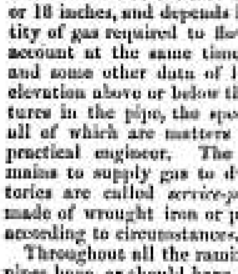
Various improvements are every year being effected in the manufacture of gas—these modifications having reference chiefly to the retorts, the purifying apparatus, and the separation of the impurities, so as to render them available in some of the useful arts. Thus clay and iron retorts of various shapes are now used; ammonia is separated by using alum, green vitriol, or dilute sulphuric acid; gasometers are also variously constructed; the tar is economically employed as fuel or in the preparation of naphtha; and this naphtha is used either as a solvent, as an independent source of light, or in the impregnation of coal-gas, whereby its illuminating power is vastly increased. (See p. 458.)

Distribution of Gas.

The distribution of the gas from the gasometer to its places of consumption is effected in cast-iron pipes called *mains*. They are cast in pieces of from 4 feet 6 inches to 9 feet in length, according to their diameter, and are jointed together to any required length. The diameter of the mains varies from 1½ inches to 16 or 18 inches, and depends in every case upon the quantity of gas required to flow through them, taking into account at the same time the distance it has to flow, and some other data of less importance—such as the elevation above or below the horizontal line, the curvatures in the pipe, the specific gravity of the gas, &c. all of which are matters of exact calculation to the practical engineer. The pipes branching from the mains to supply gas to dwelling houses or manufactories are called *service-pipes*. They are commonly made of wrought iron or pewter, and vary in diameter according to circumstances.

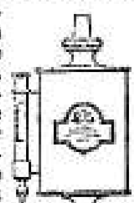
Throughout all the ramifications of the fittings, the pipes have, or should have, an inclination to the main, and the main itself should incline towards the gas-work. The necessity for this arrangement arises from the presence of watery vapour in small quantity in the gas; being condensed into water in the pipes, it naturally collects in the lowest part, and at last interrupts the continuous flow of gas, so as to cause a flickering of the flame in the burners. Where the proper inclination of the pipes cannot be attained, this is obviated by placing a stopcock and pipe at the part where liquid is apt to collect, so that it can be let off from time to time as it accumulates.

The quantity of gas charged for by gas companies was at one time regulated by the number and kind of burners employed, and the time they were allowed to burn; but this was everywhere found to be a most uncertain and unsatisfactory method of guessing the consumption by any individual. It is now obviated by the use of a very simple and ingenious instrument invented by Mr Clegg, and subsequently improved by Mr Crosby; it is called the *gas-meter*, and consists of a hollow case of iron, containing an inner cylinder or drum, so constructed, that the gas passing through it, by the pressure it receives at the gas-work, causes it to revolve on an axis; each revolution allows a known quantity of gas to pass through the water, with which the outer vessel is partially filled, to the exit-pipe, and as the revolutions are registered by wheel-work and an index, the quantity of gas consumed is indicated with considerable accuracy. It is usually examined quarterly by a person employed by the gas company, who charges the consumer according to the quantity indicated. Various improvements have recently been effected in the common meter, chiefly with a view to prevent fraudulent consumers from tampering with the apparatus, in order to make the gas pass without marking register.



The rate at which gas escapes from an open burner is determined, and to a certain extent regulated, by the pressure applied to it at the gas-work. This is increased or diminished by the application of weights to the counterpoise of the gasometer, and is measured by the elevation of a column of water in a bent glass tube. The usual pressure is about one inch of water above the atmospheric pressure. By the experiments of Messrs J. Milne and Son, Edinburgh, it appears that every addition of one-eighth of an inch to the pressure causes an extra expenditure equal to about fourteen per cent., and variations to a much greater amount than this are not unfrequent. It is of usual occurrence, for instance, in the vicinity of large manufactories, when their lights are extinguished; and though attention is usually paid to this at the gas-work, it is impossible so accurately to regulate the pressure according to the quantity of gas required by any particular main, as to obviate all loss or inconvenience from this cause.

An increase of expenditure is also experienced in the lights that remain burning. When other lights in the same premises have been put out, the gas that supplied these burners increases the pressure in the pipes, and is diffused over the other lights in the premises; and if not checked, there will be comparatively little reduction in the expenditure, although one-fifth of the lights are extinguished. To obviate these inconveniences, instruments called *governors* or *regulators* have been constructed; some operating as permanent escapes, and others opening and contracting by means of springs and levers acted upon by the current of gas. The following woodcut represents a regulator invented by Messrs J. Milne and Son, which has been found to answer well in the premises where this sheet is printed. It can be readily placed upon any service-pipe, and being adjusted to the pressure required, it gives a regular flame and expenditure of gas, notwithstanding any variation of pressure in the main.



It is a very general complaint in cotton-mills, that the light in the under floor is deficient, while at the upper floors there is a greater supply of gas than is necessary. This inconvenience arises from the upper floors being subject to less atmospheric pressure than the under one, every additional rise of ten feet making a difference on the pressure of about $\frac{1}{10}$th of an inch. Suppose a mill of six floors is supplied from the gas mains at a pressure of $\frac{6}{10}$ths, and that the difference of altitude between the highest and lowest lights is equal to fifty feet, the gas in the highest or sixth floor will issue from the burners at a pressure of $\frac{11}{10}$ths, the fifth floor at $\frac{10}{10}$ths, the fourth at $\frac{9}{10}$ths, and so on. To gain full advantage in this case from the regulator, one should be placed in each floor; and in this manner a regulator placed in the top or sixth floor, and adjusted to $\frac{6}{10}$ths of an inch pressure, will send the surplus pressure of $\frac{5}{10}$ths to the floor below; another regulator placed in the fifth floor, also set to $\frac{6}{10}$ths, will send the surplus pressure of $\frac{4}{10}$ths down to the fourth floor; a regulator on the fourth floor will send the surplus $\frac{3}{10}$ths to the third floor; and the regulator in it will send its surplus $\frac{2}{10}$ths to the second floor. Between that floor and the ground, the fall being ten feet, the remaining surplus of $\frac{1}{10}$th is lost; and thus a uniform pressure of $\frac{6}{10}$ths will be established over the whole building; and to prevent any inequality from outward pressure, a regulator ought to be placed in the ground-floor also.'

Burning of Gas.

When coal-gas is burning, it combines with the oxygen of from 10 to 12 times its bulk of common air, or even more, the quantity varying according to the quality of the gas. By this combination, which in fact constitutes combustion, watery vapour and carbonic acid are formed—the former being composed of all the hydrogen of the gas, with 8 times its weight of oxygen, the latter consisting of all the charcoal, united with oxygen, in the proportion of 6 to 16 by weight. These products, which are similar to those from a candle or lamp, mingle with the air of the apartment, and are removed with it in the course of ordinary ventilation. In some circumstances, the watery vapour is condensed on the windows; and in street-lamps it may be seen, when the weather is cold, bedewing the inside of the globes, and even collecting in considerable quantity at the bottom. The carbonic acid is not removed in the same manner by condensation, and it may accumulate to a hurtful extent; this can only happen, however, where ventilation is peculiarly defective, and the remedy is sufficiently apparent. When the carbon is not all consumed, it flies off in smoke—an occurrence which should be guarded against, not only on account of its offensive qualities, but also from the great loss of light in proportion to the gas expended, which it invariably indicates.

The emission of light, though usually an effect of combustion, is yet a different phenomenon. Many substances, as already stated, are incapable of burning, and yet emit the most brilliant light when they are intensely heated. Gases possess this quality in a very feeble degree. Air, indeed, may be so hot that a solid body becomes luminous in it, while it gives off no light of itself. The temperature at which solids begin to emit light is about 800° of Fahrenheit; they are then incandescent, or red hot; and if the temperature be increased, they become more and more luminous, until, at 4000° or 5000°, they are so brilliant, that the eye cannot look on them without pain.

The lime-ball-light is an example of this fact; it gives an intense light without being itself burnt. Pure hydrogen burns with a pale bluish flame; and coal-gas, when made to burn without depositing its charcoal, by reducing the flame to a speck, or by previously mixing it with common air, gives also a feeble blue light. The light from coal-gas, then, actually comes not from the gas itself as gas, but from the particles of charcoal which are separated from their gaseous combination by the incipient combustion: they exist as solid charcoal in the flame, and being heated by it to intensity, they are highly incandescent.

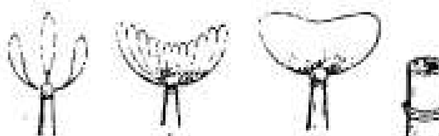
The presence of charcoal in a free state can be detected in a gas or candle flame by the very simple experiment of introducing the edge of a white plate into it; at the lowest part of the flame, where it is still blue, the plate is not affected—the charcoal is not yet deposited; the same happens at the top of the flame, the charcoal being now burnt; but in the middle, at that part whence the light is seen to be chiefly emitted, the plate is instantly coated with pure carbon.

It will now be understood that the manner in which gas is burnt may actually have an effect upon the amount of light derivable from a given quantity, the condition for obtaining the largest amount being, that the charcoal deposited in the flame shall be heated to the greatest possible intensity. This condition is very differently attained by the different burners in common use. It is found by experiment, that when an argand burner is constructed with holes of a proper size, and of a proper distance from each other, with an internal tube so proportioned as to admit the exact quantity of air necessary for the perfect consumption of the gas, it gives more light than can be obtained from the same quantity of gas by any other method of burning.

In the argand, the flame is steadied and the current of air increased by the use of a glass chimney, which sensibly diminishes the size of the flame, at the same time increasing its brilliancy. It has been proposed to improve this burner by heating the air with which it is supplied by means of a double chimney, the outer glass being so constructed that the air must descend between it and the inner glass before it arrives at the burner; and it has been stated that a saving of gas to the extent of 20 per cent. may be effected in this manner. This assertion has, however, been contradicted by other experimenters; and certainly the plan has not been adopted into common use.

The proper size of the holes for an argand burner, and the length of flame which gives the greatest proportion of light, have been experimentally determined by various individuals. Drs Christison and Turner state, that the diameter which appeared to answer best for coal-gas of the specific gravity ·6, when the holes are ten in a circle of three-tenths of an inch radius, was a thirty-second of an inch; the distance between the holes should be about one-seventh of an inch. A series of experiments, by the same individuals, on the relative amount of light from flames of different lengths in an argand burner, show that the light is increased about six times for the same expenditure by raising the flame from half an inch to three or four inches; but beyond this height the gain was comparatively little in the burners experimented on.

Other burners in common use are known by the names—single jet, cockspur, union-jet or fan, fish-tail, and bat-wing. In the single jet, the gas issues from a single aperture; in the cockspur (*a*), from three apertures, as shown in the figure; in the union-jet (*b*), from a series of small holes, so that all the jets may unite laterally; in the bat-wing (*c*), from a slit instead of a



a *b* *c* *d*

series of holes; in the fish-tail, by making two jets cross each other, and yet issue from the same hole; and in the argand (*d*), from a circle of small holes, the centre of which is an open space for the admission of air. The relative quantity of light which they yield from the combustion of similar quantities of gas is thus given by Dr Fyfe; namely, single jet, 100; fish-tail, 140; bat-wing, 160; argand, 180.

These burners are commonly used in street-lamps, and they are convenient in some circumstances; for instance, in small apartments where less light is required than is given by an argand burning at its full height—namely, three or four inches; and it should be distinctly known, that the greatest amount of light is only obtained from any given quantity of gas by burning it in this manner.

The single jet burners, with an aperture from a twenty-eighth to a thirty-sixth of an inch, give most light in proportion to the gas burnt when the flame is five inches in height. In the experiments of Drs Christison and Turner, they found that in the case of coal-gas of specific gravity ·602, while the lights emitted from a two-inch and five-inch flame were as 556 to 1978, the corresponding expenditures were to each other as 605 to 1437. Hence the ratio of the lights in reference to the expenditure was as 100 to 150.

If the flame smokes in an argand, it is evident that some adjustment is necessary, and the gas should either be lowered or the chimney contracted, until it gives a clear cylindrical flame of three or four inches in height. In the fish-tail burner, if the flame flares, or makes a noise in burning, the gas should also be lowered; but to diminish either much below these points, does not effect a saving of gas in proportion to the diminution of light. Hence the important conclusion, that it is more economical when the light is too strong to procure a smaller kind of burner, or where several lights are used, to put out some of them altogether, than to lower the flame in the whole.

Various calculations of the relative expense of gas-light, compared with other lights, have been made. Thus when tallow candles are 9d. per lb., wax candles three times the price of tallow, train oil 2s. per gallon, and coal-gas 9s. per 1000 cubic feet, it is computed that the relative expense will be as under—namely,

Wax,	100	Oil,	5
Tallow,	25	Coal-gas,	3

In a recent paper by Dr Fyfe, the relative expense is computed as follows:—Gas giving 12 per cent. condensation with chlorine—that is, containing 12 per cent. olefiant gas, at 8s. 6d. per 1000 cubic feet—being 1, the expense of wax-light of equal quantity will be about 14; sperm-oil, 8; tallow candles, 7½; rectified whale-oil, 5; common train-oil, in an improved description of burner, 2.

Many individuals, who complain that the adoption of gas-light has proved no saving to them, will be surprised at the above statements. They will find, however, on examination, that they now light up their houses far more brilliantly than they were accustomed to do when candles or oil-lamps were in use, and that their equal expenditure is thus accounted for.

In addition to its greater economy, gas-light may also be pronounced safer than any other ordinary light. It produces no sparks, it cannot be carelessly placed in contact with bed-curtains or substances easily ignited, and it requires scarcely any attention. It may be turned down in an instant to the most minute speck of flame, ready to be restored, when necessary, by the simple turning of the stopcock; and even when it escapes by the carelessness of an attendant, or a defect in the fittings, it at once indicates the accident to the whole household by the disagreeable smell which it occasions. From the large quantity which must be mixed with air before it becomes explosive, it is scarcely possible that this accident could occur in any ordinary apartment, even if the gas were allowed to escape on purpose. And as its smell so well indicates its presence in cellars, or other confined situations, where it may have escaped in quantity from the accidental breaking or leakage of a pipe, it is only by the grossest carelessness or ignorance that a light will be approached to it before it has been allowed to escape by the free admission of air. There is no such thing as the bursting of a pipe or the blowing up of a gasometer. A gas pipe may be broken, as any other pipe, by accident; and if a leaky gasometer is covered over by a building, an explosion may then take place; but these are accidents which can very rarely occur, and they do not concern in any way the ordinary consumer of gas.

Bude Light.—We have now to notice a comparatively recent method of using coal-gas, invented by Mr Goldsworthy Gurney, and called the 'Bude Light,' from the name of his residence in Cornwall, where it first became known to him. In 1823, Mr Gurney published a work on the elements of chemical science, in which he described the powerful light produced from lime by the action of the mixed gases. This light, about seven years afterwards, was employed by Lieutenant Drummond on the Trigonometrical Survey of Ireland, in consequence of which it took the name of the 'Drummond Light.' A committee of the House of Commons on lighthouses, in 1834, recommended the lime-light to be experimented on, with a view to remove the practical difficulties connected with the subject, and adapting it for lighthouse illumination. In consequence of Mr Gurney having first announced the discovery of the light, he was recommended by the committee to the Trinity House to carry out the experiment. In the course of his engagement in this office, he discovered the present light, which he considered better for lighthouse purposes, and, as already mentioned, called the Bude Light. This light is produced by introducing oxygen gas in the interior of the flame of a lamp. An ordinary flame is hollow, the exterior part being only ignited by the atmosphere; the interior part is unburnt, containing the vapour of oil and carburetted hydrogen; and the burning of this unused interior vapour, as quickly as it is distilled, by the admission of oxygen, forms the principle of the Bude Light. As soon as a small tube, conveying a stream of oxygen, is introduced into the heart of the flame, the light is immediately increased in its intensity. Since this valuable discovery was made, Mr Gurney has effected various alterations and improvements on the light. Formerly he used oil, but now he employs common street gas. This gas, however, is made to pass through a box containing naphtha, which naphthalises it, and renders it equal to the best oil, without the trouble of wicks. The London street gas, it is necessary to explain, is of bad quality, and is improved by the vapour of naphtha. The Edinburgh gas being much superior to it, would not require any such assistance. The apparatus for supplying the oxygen to the light, as used in the House of Commons, is placed in a vault beneath. It consists of two iron retorts built over a furnace, and in these is put a certain quantity of oxide of manganese, from which oxygen is evolved, and led away in pipes to a gasometer; from the gasometer small pipes proceed to the burners in the House, each conducting a stream of oxygen into the heart of the flame. The light so produced is most intense in brilliancy, but is softened by the intervention of ground glass, and illuminates with a powerful effect the whole interior of the apartment. A more perfect substitute, in every respect, for daylight, could not be found. The flame being supplied freely with oxygen, a comparatively small quantity of atmospheric air is abstracted or consumed, and all offensive heated air from the combustion is carried off by a small tube. Before the introduction of this beautiful light, the House of Commons was illuminated with 240 wax candles, dispersed about in different parts—a method of lighting which Sir David Brewster has described 'as most absurd, and such as no person at all acquainted with the physiological action of light on the retina, and the principles of its distribution, could have adopted.' Dr Ure, on being examined by the committee of members respecting the power of the Bude Light, previous to the substitution of gas for oil, observed—'I made experiments upon it very carefully in my own house last night, and compared its relative illuminative powers with argand lamps and candles with great pains, both by the method of shadows, and also by Mr Wheatstone's photometer. Mr Gurney's larger Bude lamp, furnished with a wick of five-eighths of an inch, but emitting a white flame of only three-eighths in diameter, was found to afford thirty times more light than a wax candle, and nearly three times more light than the standard flame of the mechanical lamp, which was equal to from ten to eleven candles. Secondly, Mr Gurney's smaller Bude burner, with a flame one-quarter of an inch, was found by the same methods to afford a light eighteen to twenty times greater than a wax candle.'

The adoption of the Bude Light in the House of Commons, as now improved and simplified by the substitution of gas for oil, has completely set at rest all theoretic speculations on the subject. The light is not only by far the most brilliant, without distress to the eye, but is cheaper by two-thirds than the old wax-candle plan of illumination. We believe the expense of using the Bude Light, in which naphtha is required, is about twelve times greater than that of common London gas, sizes of flame being equal; but that as the Bude flame gave twelve times more light, the expense was in reality the same, without the inconvenience of many burners, and a great consumption of air. The property of giving little heat, in comparison to what is produced by common gas, is in itself of great importance. Another useful property is, that the light may be varied in tone, from the most perfect white, down to the red ray, by increasing or diminishing the quantity of oxygen.

Inconveniences from Artificial Light.

We have now briefly to notice certain inconveniences occasionally attending the employment of gas, as well as every other kind of artificial light in common use. There are, in the first place, headache, giddiness, and other unpleasant symptoms, which are sometimes complained of in small or ill-ventilated apartments where gas is burned. These may be justly attributed to the heat and carbonic acid produced during the combustion of the gas, although they also depend to some extent upon similar changes effected on the air of the room by respiration, and would occur even to a greater degree were common oil or candles employed, so as to give an equal amount of light. The remedy for these evils is simply *ventilation*. The other inconvenience is of a more insidious nature, and may be ultimately attended with serious consequences; we allude to the injurious effect of artificial light upon the organ of vision.

It is well known that the eyes become fatigued and painful, and are actually weakened for a time, by exposure to any object strongly illuminated. This may be proved by reading even for a few minutes with one eye tied up, and then comparing the power of vision of this eye with the other. It is also remarkable that, although illumination by artificial means be much less brilliant than daylight, its weakening effect upon the eye is perceived in a greater degree. For example, let the same experiment be repeated by candle or gaslight. The exposed eye will be found now to be more weak than in the former case. The sensibility of its nervous structure in these circumstances is actually impaired for a time, and requires a short period of rest to restore its power. If the eyes be habitually exposed to this stimulus for long periods without rest, as is often the case with literary men and others, who work to late hours with artificial light, there is no doubt that a permanent weakness of the eyesight may be occasioned, which may even terminate in the destruction of the sensibility of the eye—a disease known by the term *amaurosis*, or nervous blindness.

The first intimations of these injurious effects are usually a sensation of heat and soreness of the eyelids, and pain of the eyeball, particularly at night, when artificial light is used; in some cases there is an unusual degree of irritability of the eyes, followed by flashes of light when they are touched, or specks floating before them, and ultimately dimness of vision, so that a stronger and stronger light is required. These symptoms may arise from other causes; but it is certain that they are often produced or augmented by the injudicious use of strong artificial light, when minute objects are contemplated. Happily, they may be obviated to a great degree without difficulty. To effect this, the eyes should in the first place be protected from the direct rays of the light itself, not only by raising it above the object out of the line of the eye, but also by the use of a shade placed upon it, so as to prevent its rays from falling upon the face; a minute object is now seen more distinctly than before, even with a less amount of illumination.

There is another method which may be adopted, and it has the advantage of being equally simple, though more philosophical. It is derived from the examination of the nature of light, and of the difference between daylight and that which is obtained from combustion. Sir Isaac Newton made the discovery, that light was not simple, but a compound of seven different coloured rays, such as are seen in the rainbow. More recent discoveries have reduced the number of simple rays to three—red, yellow, and blue—which exist in daylight in the following proportions; namely, red 5, yellow 3, blue 8. In artificial light the proportions are different, yellow and red preponderating to a great degree. Experiment proves that each of these rays can act separately upon the eye. For example, if the red ray only be admitted into it, as by looking at the sun through red glass, the nervous structure of the eye is for a time weakened to the stimulus of red; and when the uncovered eye is now turned to a white object, the other rays only are seen—namely, the yellow and blue, giving it a greenish tinge. If again the sun be looked at through a green glass, a white object seen immediately after will appear to be red, the eye being insensible to the complementary colours, yellow and blue. For a similar reason, when the eye, passing suddenly from daylight, views objects by means of a candle or gas flame, they appear of a yellowish hue; and, on the contrary, passing from artificial light into day, the whole prospect has a blue or purplish aspect.

It is also proved by experiment that the red and yellow rays have a more weakening effect upon the eye than blue; hence, to a certain extent, the more injurious effect of artificial light, which, as already stated, contains these rays in excess. This fact at once suggests a method of obviating the bad effects of gas or candle light, which is either to make it pass through a blue glass shade, so as to obstruct a portion of the red and yellow rays, or to reflect down blue rays by placing a blue reflector above the light; in this manner the quality of artificial light is made more nearly to approach to that of the sun, and objects are seen by it of a purer white, and agreeably cool and refreshing to the eye.

VENTILATION.

In a subsequent article on the Preservation of Health, the necessity of a constant supply of fresh air for that object will be so fully explained, that on this occasion little more than an allusion to the subject is required. Each human being consumes the oxygen of the sixth of a cubic foot per minute, replacing it from his lungs by carbonic acid gas, a substance which cannot be inhaled again without injury. Hence the necessity for a constant change of the atmospheric contents of any room in which human beings are placed—and the same law holds with regard to all the warm-blooded animals. In an ordinary apartment heated by a common open fire, there is an imperfect kind of ventilation always going on by means of the fire, which draws in through the door, windows, and other apertures, fresh air to supply that consumed by itself, or which the chimney-draught otherwise carries off. This is imperfect, in as far as the draught may only clear a certain space near the bottom of the room between the door or windows and the fireplace, and because it may over-rarefy the air of the room in instances where the apertures are usually well closed up; also, in as far as it only operates when there is a fire, and therefore not in the summer time. It therefore becomes desirable that a regulated mode of ventilation, calculated to be thoroughly and at all times effectual, should be applied to ordinary apartments. It is not less necessary that churches, court-rooms, theatres, and all large halls in which great numbers of persons assemble, should be subjected to a mode of ventilation regular, certain, and complete. Nor is it unworthy of notice that a regular means of ventilation is also required in stables, cow-houses, and other places where valuable animals are kept.

Ventilation by Apertures in Ceilings and Flues in Walls.

The simplest and perhaps the earliest expedient for ventilation was one formerly much employed in churches and other places of assembly. It consisted merely in a round hole of considerable size opened in the ceiling, and communicating with the outer air by a tube or trunk, having a cap over the top to keep out rain. The expired air of the assemblage, by virtue of its greater rarity, of course ascends to the ceiling, and tends to find its way out by this aperture; but it does not pass forth either rapidly or with certainty, and the plan is therefore to be considered as defective.

The plan adopted for carrying off used air in the Derby Infirmary, and other buildings warmed by Mr Strutt's plan, appears strikingly inferior in efficiency to the expedients for heating. The whole arrangement consisted in a flue from each room, terminating in the space under the roof, through which was a passage to the outer air, protected by a turn-cap. There cannot be, we apprehend, any certainty that such flues will act for the removal of used air.

Sir John Robison exemplified Mr Strutt's plans in his house in Randolph Crescent, Edinburgh, with an ingenious improvement upon the ventilation flues. Having small fires in each room—for the purpose, mainly, of drawing the warmed air from its reservoir, the well of the staircase, into each apartment—he passed the ventilation flues close beside the ordinary smoke chimneys. The consequence was, that the heat of the smoke chimney was imparted to the ventilation flue, an upward current established, and ventilation proceeded with certainty. This is a mode of ventilation which may be advantageously adopted in new houses, but could not easily be applied to those already built. In the instance above, the air of each apartment reached the ventilation flue through a slit masked by the stucco-work upon the ceiling.

In many cases it may be found expedient to adopt a simple mode of ventilation which was suggested by Dr Arnott, and applied in Buckingham Palace. An aperture of from four to six inches is cut in the wall over the chimney, as near to the ceiling of the apartment as may be convenient. Into this is fitted a short metal tube, having a valve suspended at the extremity next to the apartment, and capable of opening inward to the chimney, but not in the other direction, by which means a return of smoke is prevented. This simple apparatus may be painted, or otherwise made ornamental. It operates by virtue of the draught in the chimney. Whenever that is active from the presence of a fire, the valve is seen to open inwards, and a stream of air from the top of the apartment passes through into the chimney, and is carried off. The operation is precisely equivalent to the stream of air always passing into a chimney between the fire and the mantelpiece, but has the great superiority of draining off the most impure air in the room.

The Ventilating Fan and Pump.

This is a piece of mechanism which has for many years been used in factories, to which it is particularly applicable, from the readiness with which a mechanic power to keep it in motion can be obtained from the steam-engine. It is placed at the top of a flue, into which branches from all parts of the establishment proceed. Consisting simply of what its name imports, it only requires to be set in motion in order to draw off the air from every apartment communicating with it. Dr Ure calculates that a steam-engine of one-horse power will drive a fan which has equal effect with a draught produced by fuel equal to twenty-horse power; in other terms, the economy of ventilation is to that by chimney-draught as 38 to 1. Of its efficacy there seems no room for doubt; but as yet there has been scarcely any attempt to show how it can be conveniently applied elsewhere than in factories. Dr Arnott has shown pretty clearly that it has heretofore been used in a very uneconomical way, in consequence of ignorance. A far greater power has been in most cases applied than was strictly necessary, its constructors not being aware that air, like other fluids, cannot be forced more quickly through one part of a passage than it enters by another, without a super-expenditure of force. Under judicious arrangements, Dr Arnott thinks that fans which have required steam-engines to drive them, might be made to operate by a weight no greater than that required for a large clock. He seems, however, to prefer to the fan a valved piston moving like a pump in a square or round trunk. 'Such a pump,' says he, 'answers not only for extracting foul air, but also for forcing in pure air where wanted. It may,' he adds, 'be fixed in position, or may be a movable piece of furniture; to be used, for instance, to draw out air from the top of a window opened on a ball night, or from an opening in the wall, concealed from view by a picture frame. By such a pump, air of perfect purity, and in any quantity, may easily be sent from any neighbouring situation, as from the top of a tower, to supply a dwelling placed where unwholesome exhalations might enter by the doors and windows.'

Fire-draught.

One of the most certain and effectual of all means of ventilation is that by fire-draught. It proceeds upon the simple principle, that combustion demands a constant supply of air; a fire being placed in a certain convenient situation, and closed up from all supply of air excepting through flues communicating with the rooms to be ventilated, a flow of air out of those rooms is necessarily established, and this will proceed as long as the fire is kept burning. The plan has been exemplified with success in mines, where a fire being lighted at the bottom of a shaft, air is drawn off in all directions around and sent up the shaft; to replace which, fresh air is constantly pouring down other shafts. There is one objection to fire-draught ventilation—that in most circumstances it requires both attention and considerable expense; but this might perhaps be overcome by a little ingenuity. There can at least be no doubt that, where established, it most completely answers the end in view, while it is equally true that in some situations there are means of arranging it in such a way as to require neither attention nor expense.

The plan has been exemplified of late years by Dr D. B. Reid, first in his class-rooms in Edinburgh, afterwards in the temporary House of Commons, and since then in various other structures, public and private. We shall endeavour to give an account of Dr Reid's arrangements, but deem it necessary first to advert to the plans of Mr Joseph Fleming of Glasgow. Mr Fleming originally contemplated ventilation in immediate connection with the objects of his profession (medicine), and in 1833 published a pamphlet on what he called a Disinfecting Apparatus, which he proposed to apply in hospitals and in beds for the sick generally. It consisted simply in tubes communicating between the top or back of the beds and a fire solely supported by air through those channels, so that any infectious virus arising from the patient was in every case carried off without coming in contact with those who stood near.

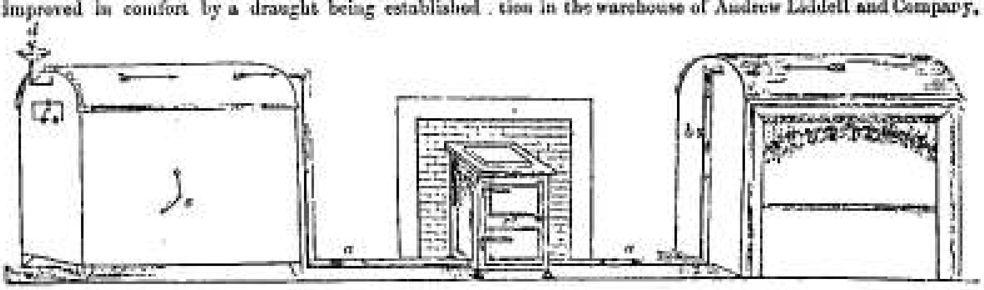
The plan was first tried in a large and densely-peopled house, which had long been remarkable as a focus of fever infection, in consequence of the wretchedness and filth of the inhabitants, and the narrow space allotted to them. This building, usually called, from its size and appearance, *the Barracks*, was connected with the factory of *Messrs* Houldsworth, in Anderston, a suburb of Glasgow. It was divided into a multitude of small apartments, each consisting of a single room and closet, and each devoted to the accommodation of a single family. The total amount of inhabitants is rarely under 500. We have inspected this building, and can testify that the habits of the occupants, with a few exceptions, are of that uncleanly and ill-ordered character which naturally results from a mode of life in which housewifely economy is not a part of female education. The huddling of so many human beings into such small space, joined to filth, poverty, and intemperate habits, rendered the building up to 1832 the permanent abode of pestilential disease. Five have been seen ill with fever in one room. In the two last months of 1831, the total cases of typhus were 57. It was then that Mr Fleming was allowed by the proprietor to apply his ventilating process. From an upper corner of each of the apartments he led a metal tube of about an inch and a half in diameter, which, passing into the adjacent gallery, there met and joined a general pipe, nine inches in diameter, suspended immediately under the ceiling. One of these general pipes passed along each gallery in the four storeys, and the whole joined in one vertical tube at the end of the house, communicating at the bottom with the base of an adjacent chimney-stalk serving the work. It follows that, when this flue is active—and practically it is so day and night—a draught is established upon the air contents of every room in the house. To regulate this draught according to necessity, a valve or damper is placed in the short horizontal channel of communication between the vertical tube and the basis of the flue. In ordinary circumstances, when the door of one of the rooms is shut, the rush of air into the aperture of the tube is sufficient to extinguish a candle held near. It becomes quite clear to any one inspecting the process, that while the chimney is active, and the aperture kept open, there must be a complete exchange of air in each room in no long space of time. It may be remarked, that no expedient has been adopted to obviate the chance of an over-rarefaction of the air contents of the rooms. The melancholy truth is, that the doors and windows are by no means deficient in the means of admitting a full supply of fresh air. At the same time, it is to be observed that few of the tenants complain of cold as a result of the ventilation.

Since 1832, when this apparatus was fitted up, Glasgow has suffered more from fever than any other city in the empire in proportion. During the five years ending with 1839, there were 55,949 cases. It may well be presumed from the ordinary conditions of the Anderston house, and its previous history, that it should have had its full proportion of fever cases during that period, which would have been about 112 (taking the population of the city at 240,000). But so far from this being the case, there were only four instances of fever in the house from the beginning of 1832 till December 1840, laying aside one year, during which it was not under Mr Fleming's charge, when there were a few more. Early in 1841, there were eight cases; but most of these, as of the previous cases, were ascertained to have been brought in from without. Since then, the house has remained free of fever. It is impossible to doubt that the change from extreme unhealthiness to the reverse is mainly owing to the ventilating apparatus—for no other condition has been changed. It is not unimportant to remark, that the expense of fitting up the apparatus in the Barracks was *under fifty pounds*.

Mr Fleming has since applied his ventilating apparatus in a steam vessel. There are no places adapted for the reception of human beings which require ventilation more than ships, for there the space allotted to each individual is necessarily smaller than anywhere else. The sleeping berths, in particular, would be much improved in comfort by a draught being established upon the close, stifling, and often positively fetid atmosphere which is generally experienced in them. Dr Reid, some years ago, showed how easily a ship might be ventilated in all its habitable parts; and in 1840-1, he was employed to exemplify his theory in the vessels destined for the Niger expedition. Since then, Mr Fleming has been called upon to adapt his ventilating plan to the Princess Royal steamer, a passage vessel between Glasgow and Liverpool. In this case he has led a small tube from the top of each bed into a general pipe passing along under the deck, the extremity of which enters the ash-pit of a common stove. There is thus a draught out of every berth in the ship; and the consequence is a degree of comfort for which every passenger feels thankful. It may be presumed that the ventilation of a ship or steamer would be made still more effectual if fresh air were supplied in some regular manner, instead of being merely drawn in by chinks in the cabin doors. It would be easy to have flues communicating directly between the outer air and a perforated board in front of each bed. It is also obvious that, in steamers, a valved passage into the funnel of the engine would answer the purposes of draught without the least danger.

In rooms where large numbers of workmen are assembled, a mode of ventilation is obviously of great importance. Not long since, conversing with a man who had once wrought as a journeyman tailor in London, we were informed by him that workmen of his order in that city are obliged to pursue their calling in warm close rooms, in consequence of it being thought by the masters that heat is necessary to the goods making a fair appearance in the eyes of customers. The consequence, said he, is, that working tailors generally break down at forty-five, and the latter part of their lives is often very miserable. Now, it may be true that a high temperature is necessary for the work; but a high temperature is not necessarily connected with defective ventilation. The rooms in which the tailors work might all be supplied with constant streams of fresh air, although Fahrenheit's thermometer should never stand in their apartments below 66°. A liberal-minded copartnery of clothiers in Glasgow, Messrs Lockhart, had their workroom fitted with a ventilating apparatus by Mr Fleming, the apertures in this case being distributed over the ceiling, while the means of draught was supplied by the furnace in which the irons were heated. The result in comfort was described as very great: we cannot doubt that in health also the best consequences followed.

The application of the plan to sources of morbid infection is equally simple. Mr Fleming has fitted up several specimens of ventilated beds for hospitals or private sick-rooms, and placed them for public inspection in the warehouse of Andrew Liddell and Company,



ironmongers, Glasgow. In addition to these, he has prepared a ventilating washing apparatus for the clothes of patients affected by infectious disease. The simplicity of the arrangement, united to its manifest efficiency, must be generally admired. In the accompanying wood-engraving, a stove is represented as placed in front of a common fireplace, having a bed for a patient on one side and a washing machine on the other. Air tubes (*a a*) branch off from the stove, and terminate, one in the semicircular roof of the bed, the other in the semicircular top of the washing apparatus. In the washing apparatus there is a plash-wheel, of which *c* is the handle, while *d* is a filler for the admission of air and water, and *e* a door.

Infected clothes being put in by the door *e*, a sufficient quantity of boiling water is poured into the washing box by the filler. The door being now kept shut, the plash-wheel is set in motion, and driven as long as may be thought necessary for disinfecting the clothes. During this process, the air to support combustion in the stove being supplied through the filler, passes on through the washing box, and carries with it to the fire, as soon as disengaged, all the infectious matter arising from the clothes. In place of boiling water, the clothes might be purified by steam or heated air, and the infectious virus would be carried off and destroyed in the same way. At the end of this disinfecting process, the clothes may be taken out and washed in the usual way, the foul water being previously run off through a tube placed in the bottom of the apparatus.

The infectious matter generated by a patient placed within the bed is in like manner carried off and destroyed in the fire. To insure its complete removal, the tube passing along the roof of the bed is perforated with a series of small holes. To regulate the ventilation, there is a stopcock at *b*, which the patient or his attendant may turn at pleasure. To prevent the escape of any infectious matter from the bed, the front only is left open. The opening may be increased or diminished at pleasure by the raising or depressing of the curtain at the top. It is clear that there must be a stream of pure air constantly passing into the bed, and that any one standing in front is as completely exempt from all noxious influences, as far as that patient is concerned, as if he were at many miles' distance.

A description of the arrangements made by Dr Reid in the House of Commons involves the principles of heating, or rather of temperature regulation, as much as those of ventilation. 'The air,' we quote the account given by Drs Reynolds and Richardson of this much-agitated affair, 'is supplied from Old Palace Yard to the basement of the building, passing first through a fibrous veil 42 feet long by 18 feet 6 inches deep, for the exclusion of visible soot, it arrives at the heating apparatus, consisting of large chambers intersected by steam pipes, and proceeds from thence to other chambers, where it can be mixed with cold air, and brought to any required temperature. The floor of the house is double, and the space below the floor can be connected by means of valves with the hot-air chamber. The floor is perforated by a great number of apertures, and these are covered with hair-cloth, so that the hot air in escaping from the floor into the body of the house is infinitely divided, and no perceptible current is experienced. Having performed its functions, the vitiated air ascends to the ceiling, which is also double and perforated, in the same manner as the floor, whence it is carried off by the draught created by a powerful fire under a chimney shaft erected in another part of the building.' [For further information on this subject, the reader is referred to Dr Reid's work entitled 'Illustrations of the Theory and Practice of Ventilation.'—Longmans, London, 1844.]

The plan adopted by Mr Barry for warming and ventilating the House of Peers, the royal antechamber, and the public lobby, differs from that just described both as respects the admission of the air and its removal. The floors of the rooms are impervious, and are heated in the first instance simply by the passage of hot air below them; the hot air then escapes by passages along the external sides of the rooms to the ceiling, which is divided into two compartments—the one for the admission of the warm air, entering at the sides from below the floor, and the other for the exit of the viciated air. The warm air, after passing below the floor to the roof, becomes somewhat cooled, so that its temperature on entering the ceiling is a few degrees lower than that actually present in the room; it consequently descends to the level at which it is at once heated again; and deteriorated by combustion, respiration, &c. rises through the centre of the room, passing through the ceiling to a foul-air chamber above, whence it is conducted to a chimney, and carried off by the peculiar motive power first applied by Mr Bell to the production of draught. This power consists of a jet of steam, which, when produced under a pressure of 32 lbs. to the square inch, is capable of setting 217 times its bulk of air in motion; 10,000 cubic feet of air are thus gradually diffused through the three apartments per minute, no draught of any kind is perceptible, and no inconvenience is experienced from dust or other solid particles being carried mechanically forward by the air, as is said to be the case when the air enters from below.

In other cases, as at the prison in Millbank, warm air is admitted at the ceiling, and carried off by the draught of a chimney in connection with the sides or lower part of the rooms. At the Reform Club House, and at the new Hospital for Consumptive Patients at Brompton, warm or cold air is forced forward, or pumped into channels, conveying it over the whole building by a steam-engine in the basement, and is allowed to find its own escape through chimneys and other apertures. Although it is not probable that precisely the same arrangement can be adopted for heating and ventilating all extensive buildings, differing in construction, and in the uses to which they are applied, yet it is to be hoped that the various experiments which are now being tried upon a large scale, may lead to a knowledge of the most effective and economical plan for gaining an object so conducive to health and comfort.

It is abundantly evident that the choice of a mode of ventilation, and also its minor arrangements, must often be determined by considerations of local convenience and of economy. A factory and a steam-vessel present an ever-active furnace or chimney, into which a flue for ventilation can be conducted. In these situations, accordingly, there may be ventilation absolutely without cost. In the same situations, the mechanic power for a fan or pump can be readily obtained; but in that case the power is both a matter of cost, and it requires attention to regulate it. Generally, therefore, though not perhaps in all instances, the plan by fire or chimney-draught will be preferable in such situations. Where there is an apparatus for warming as well as for ventilating, and where economy is an object, the draught might without much difficulty be effected by the fire which is used for the former purpose. It would only be necessary to conduct flues from the various rooms down to the ash-pit of the furnace. In this case, however, there would be a certain loss of control over both processes. In buildings already completed, there might be a tolerably efficient ventilation obtained by flues conducted into the kitchen chimney, which, being always active, would keep up a nearly unvarying draught. Dr Arnott has suggested that the fresh air in entering might be heated to nearly the desired temperature, especially in churches and other crowded places of assembly, if the flues for its admission were made to pass longitudinally through the centre of those by which the used air was passing out. Another and simple mode of draught has been practised in connection with the hot-water warming apparatus, consisting merely of a flue into which a small coil of the hot water-pipe is introduced. This small coil, situated in the flue, and near its bottom, acts precisely like the fire in the chimney for ventilating the Houses of Parliament.

For obvious reasons, the admission of warm air is generally at the bottoms of rooms, while the used air is drawn off by apertures in or near the ceiling. Mr Perkins, it appears, pursues exactly the reverse plan, conceiving that it 'introduces the warm temperature insensibly, and removes the impurities of the room more effectually.' Mr Alfred Ainger, an architect, also adopts this plan; he remarks that, 'with upward ventilation, a great part of the vitiated atmosphere [of crowded rooms] being specifically heavier than common air, is liable, by the slightest check or condensation, to be thrown down and mixed with the air which is already partly unfitted for the purposes of life. But let the current descend, we have a bright atmosphere, consisting of an immense reservoir of pure air, arriving immediately at the lungs, and which, as it becomes contaminated, is drawn downwards by a force with which most accidents will co-operate.'

In conclusion, we thoroughly concur in the opinion that 'the plans proposed and carried out in some of the large buildings of the metropolis, and in other places, are so various, and in many cases new, that they must all be considered in the light of experiments, the respective values of which can only be ascertained after a more lengthened trial has been vouchsafed them. The main object is, however, the same in all, and involves the supply of a certain portion of fresh air to a certain locality, either warm or cold, within a certain space of time; the amount of air constituting this supply varying of course with each individual case. Indeed it does not appear that philosophers are agreed as to the mean quantity of air required by a number of individuals during a given time, and until this point has been definitively settled, the calculations which must obviously be based upon it will necessarily differ, according to the standard assumed by each observer. There can be no doubt, however, that it is preferable in the meantime, until that question shall receive a definite answer, to supply an excess of fresh air rather than a deficiency, which has as yet been the prevalent error in practice.' It may also be safely added, that much unnecessary matter has been written, and much labour and money expended in vain on the subject of ventilation. Where heating and ventilating are combined, some skill and mechanical ingenuity may be requisite; but where fresh ventilation is alone desired, nothing appears to be more direct and simple, if we could only live less in dread of 'draughts' and 'currents.' We enjoy, and are better for, the breeze in the open air, and we shrink from, and suffer cold under, the slightest in-door current, because we immure ourselves in packing-boxes, which we call apartments, and smother ourselves amid carpets, curtains, and drapery. Nature has surrounded us with an atmosphere of life and health: we exclude it by our absurd conventionalities, and then struggle to regain it by tinkering and patchwork.

PREVENTION OF SMOKE.

The smoke arising from the furnaces employed at factories has, within the last thirty years, been felt as a great nuisance in most manufacturing towns, polluting, as it does, the pure air of heaven, and begriming every exposed object within the range of its influence. Those employing furnaces have also become generally aware that smoke is only a volatile form of fuel, and that if either less of it were generated, or if, when generated, it could be consumed, there would be a great saving in the expense of raising steam. These circumstances have led to various devices for the combustion and prevention of smoke, the chief of which it is our duty to describe in this place.

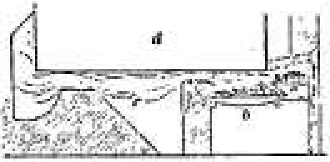
Ivison's plan consists in the projection of a stream of steam into the space between the fire and the boiler. It proceeds upon the supposition, that the steam so introduced being decomposed by the heat of the furnace, its oxygen unites with the carbon of the smoke, and causes the combustion of that material, while the hydrogen also burns through its own inflammable quality. The arrangement for the introduction of the steam is simple: a small iron pipe, proceeding from the top of the boiler, bends over and enters the furnace immediately above the door, the termination being fitted with a fan-shaped expansion, full of small holes, by which the steam is dispersed throughout the fiery space. By a stopcock on the pipe at the furnace door, the discharge can be regulated or altogether stopped. The due working of the apparatus depends on admitting into the furnace a certain quantity of hot air, and this is done through two pipes which, opening from the open air, pass into the furnace and out again, the inner terminations being inserted in the door. With regard to the prevention of smoke, Mr Ivison's plan seems to have established for itself a certain measure of success; but we understand that the hypothesis is extensively doubted, and that the plan is not likely to be universally adopted. It was tried on the furnace of the steam-boiler used in the office where this work is printed, and was found to be defeated, in consequence of the extremity of the steam-pipe being constantly liable to be destroyed by the fire. This difficulty may be obviated, and the whole benefit of the plan may, we believe, be secured, if the steam-pipe be introduced below the bars of the furnace.

Juckes's plan is designed for consuming smoke and economising fuel. The following description of it was given by himself at the meeting of the British Association at Manchester, June 1842. 'His grate-bars are endless chains passing over rollers, and moved forward about an inch per minute. The coals employed are common siftings or screenings, which are heaped on the bars outside the furnace door, which slides upwards. The door is left a little open, and by passing under it, the small coal is spread uniformly over the bars. The air is constantly supplied through the bars directly to the fuel while burning, and in this way perfect combustion is obtained. The bars, being slowly moved on, carry the ashes to the ash-pit, which lies at the back of the grate. Clinkers are prevented from incrusting the bars by their passing under a gauge, which effectually removes them; and the burning away of the bars is prevented by their constantly moving away from the hottest place. The bars or chains, with their rollers and driving-wheels, are fixed in a frame which can be completely drawn out from under the boiler, for the purpose of removing injured bars, or any other purpose. A boiler has been at work for two months at Mr Baird's saw-mill, Wapping, and given great satisfaction. No smoke is ever seen, and the consumption of coal is only 12 cwt. or thereby per day, whereas, with the old boiler, they had used a ton of coal, besides a ton of wood and sawdust.'

Smith's boiler was suggested by a consideration of the upper and under currents in the ocean and atmosphere often flowing in opposite directions. The inventor has tried to avail himself of this principle in his furnace, considering that, from the great rapidity with which the gases leave the fire, it is impossible to effect their perfect incorporation with atmospheric air and consequent combustion; and believing that, when these gases are allowed to pass off directly through the flues in nearly straight lines, the gases and air pass along in separate threads or films, sufficient time for their proper mixture not being given under the ordinary systems of combustion. Mr Smith, therefore, constructs a boiler and furnace in the following manner:—Beyond the bridge of the furnace he places a chamber within the boiler entirely surrounded by the water; this chamber only leaves room for a small water space along the sides and bottom of the boiler; it is arched elliptically, and of course, like all internal flues or fire-boxes, leaves sufficient space above for water and steam. The funnel or chimney is placed on the same side as the fire, and as low as possible. The hot gases and air rush over the bridge gradually, from the size of the chamber, losing their initial velocity. When they impinge against the opposite side of the chamber, the current is directed downwards; and the return current, with diminished velocity, flows back to the chimney under the stratum of gas and air issuing from the fire-bridge. In this way time is given for combustion, and the gases are inflamed or exploded before going up the chimney. From the chamber being quite within the boiler, nearly all the heat is made available. Mr Smith considers his plan particularly applicable to marine boilers and reverberatory furnaces. He lately had one established at Messrs Page and Grantham's, Liverpool, working an engine of ten-horse power, the pressure in the boiler being 50 lbs. This did as much work with 8 cwt. of coal as the best tube boiler which these gentlemen ever tried had performed with 12 cwt.

Waddington's patent is a contrivance for introducing coal in a gradual manner. Put in at the sides of the boiler, it is made to descend inclined planes to the bars, before reaching which it is coked by the fuel burning on the bars, and smoke is prevented. *Greenway's* plan is of considerable ingenuity, as well as simplicity. He employs in each case two boilers and two furnaces. The furnaces are supplied with dampers, so that their communication with their respective flues can be cut off, and a communication opened between the two fires by an intermediate flue. When fresh coals are put on one fire, the damper of that fire is shut, and the intermediate flue opened, so that the smoke is obliged to descend through the bars, and ascend through the burning fuel of the other fireplace. By alternating this as fresh coals are put on the fires, smoke is said to be prevented. Mr *Kurtz's* is by hollow bars admitting fresh and heated air to a hollow bridge. Mr *Samuel Hall's* is a plan of much the same nature, by air heated in a quantity of pipes in the flue between the boiler and the chimney, passing thence to perforations in or near the bridge. Mr *John Chanter's* is by an 'auxiliary boiler,' the bars under which are inclined, and have below an iron plate termed a 'deflector.' At the lower end of this furnace a common furnace is constructed, which receives the coke or charred coal in an incandescent state from the upper bars. Mr *E. Rodda's* is by a furnace divided into two parts, one for coking the coal, the other for receiving the coke—the gas from the coal passing through lateral openings into the second division, where they are to be destroyed by the bright fire. A stream of fresh air is admitted, joining the smoke in the passage, thus effecting its combustion.

Mr *Howard's* invention, which is simple and ingenious, and closely allied to that of Williams's, about to be described, will be most readily comprehended by referring to the accompanying diagram:—*d* is the boiler surrounded by common flues; *a* is a coking-plate; *b*, the body of the furnace, with the ash-pit beneath, which is closed against the admission of air; *e*, a fire-bridge, like that of a reverberatory furnace; and *c*, a space for the regulated admission of heated air. The coal is first coked on the coking-plate, and then pushed over on to the grate-bars, where there always exists a bright surface of burning coke. The gases generated in coking a fresh portion of coal pass over this heated surface before they come in contact with a fresh supply of warm air at *c*, and thus an almost perfect combustion of smoke is the result. The saving in fuel effected by this plan is said to vary from a fourth to a half of the whole. It is therefore deserving of attention; and where any prejudice exists against patent modes, the same results might be obtained by simply coking the fuel in the front part of the furnace, pushing it forward by degrees, and admitting a supply of air behind the fire-bridge.



It may also be remarked, that coal may be economised, and the escape of its fumes much diminished, without any peculiar contrivances, simply by careful and skilful feeding of the furnaces by the firemen. In Cornwall, where no contrivances exist, fuel is managed in such a way by the firemen that the consumption in general is only about 2½ lbs. per horse power per hour, and smoke is said to be 'never seen.' The coal is regularly weighed to the firemen, and the 'duty' of the engines is reported every week. This excites emulation among the men, and when a falling off in their attention takes place, it is instantly detected. The great object held in view is to keep thin bright fires, coking the coal in front.

Williams's plan is most in esteem at present, and seems likely to prove generally serviceable. The inventor aims not at burning the smoke, which he holds to be a chemical absurdity, but at preventing its formation. 'One of my objects,' he says in his treatise, 'is to show how the combustion of the volatile portions of coal may be effected as completely when issuing from the throat of a furnace as from the beak of a gas-burner.' To pursue the explanations afforded in the Polytechnic Journal:—'It is ascertained that 20 cwt. of bituminous coal affords about 10,000 cubic feet of coal-gas—some qualities more, some less; now, chemistry teaches that every measure of this gas requires for its perfect combustion ten measures of atmospheric air, thus making, from a ton of coal, a gaseous mixture of about 100,000 cubic feet. With more or with less air we still have imperfect combustion. This is the whole theory of the process; it is what every chemist has long known, and no obstacle is offered to its solution or comprehension. How can so large a body of air as ten cubic feet to every single cubic foot of gas by any possibility be admitted without cooling down the furnace? Opening the door would let in air enough, with the disadvantage of cooling the furnace and lowering the steam. The doctrine of the diffusion of gases, due to the elaborate and interesting experiments of Dr Dalton, comes to our aid. For perfect diffusion, we require time; the process of the furnace will not afford time. We must, then, resort to some mechanical arrangement to overcome this difficulty in the simplest possible manner. Now, we may have enough of air; but from having it applied in the wrong mode, as is done in opening the door, though we lose the smoke, we lose the steam also. In this case it is somewhat like the two conditions of gas burnt from a common pipe with and without an argand burner. Why does it in the one situation smoke and give little heat, while in the other it is smokeless and intensely hot, seeing it is surrounded in both instances with an abundant supply of air? Merely because the numerous minute jets of gas supplied by the argand burner afford that more perfect diffusion refused by the wide bore of a single orifice. So, in the furnace, if we can admit the ten measures of air in the same way by means of small jets, we do all we want by obtaining rapid diffusion, complete mixture, and therefore perfect combustion.'

In the 'Practical Mechanic and Engineer's Magazine' for 1841, there is a paper on Mr Williams's plan, illustrated by sections of the furnace and boiler. From this we learn that a long boiler is supposed, and that the grate is placed under one end, having its ash-pit below as usual. The fumes of the coal pass onward under the boiler, towards a chimney at the opposite extremity. Under the centre of the boiler, and quite separate from the ash-pit, there is a square chamber, having a flue by which air can be admitted from without. From the iron plate forming the roof of this chamber, three short vertical tubes, unclosed at the lower ends, project upwards into the space beneath the boiler along which the fumes pass. These tubes are perforated all round the sides and tops with holes of a quarter-inch, set one inch apart. The air, accordingly, passing first into the square chamber, then proceeds upwards, and rushes into the space above in the form of small jets. At every charge of fresh coal on the fire, the first product is, not smoke, but a very large body of crude impure coal-gas, the unconsumed portion of which, as it passes the bridge, meeting the air, mingles with it, and instantly inflames, being encompassed with a hot gaseous atmosphere. The effect then is, that each jet of air seems to be a common gas flame; and these vertical tubes have not inaptly been compared to trees of fire. To those who are not familiar with the fact of flame from a jet of air in gas, it may be interesting to quote the observations of Professor Brande on this subject:—'I fill a bladder with coal-gas,' says he, 'and attach to it a jet, by which I burn a flame of that gas in an atmosphere of, or a bell-glass filled with, oxygen; of course the gas burns brilliantly, and we call the gas the combustible, and the oxygen the supporter of combustion. If I now invert this common order of things, and fill the bladder with oxygen, and the bell-glass with coal-gas, I find that the jet of oxygen may be inflamed in the atmosphere of coal-gas, with exactly the same general phenomena as when the jet of coal-gas is inflamed in the atmosphere of oxygen.' The saving of fuel by these means is said to be about 25 per cent.

SUPPLY OF WATER—BATHS—SEWERS.

AMONG the complicated arrangements of civilised life, few are of higher importance than those which relate to the command of water. Whether for dietetic and domestic purposes, for the bath, or for carrying away the corrupting refuse of our towns and cities, a liberal supply of good and wholesome water is an indispensable requisite. Admitting the necessity, we intend in the following pages to give some account of the waterworks, baths, sewers, and other sanitary provisions adopted in reference to the supply and emission of this element, both in ancient and modern times—dwelling on what seems more especially applicable to the wants of our own populous localities.

SUPPLY OF WATER.

Water, as explained under CHEMISTRY, is a compound of hydrogen and oxygen, and is, when pure, and under the ordinary temperature of the atmosphere a transparent liquid, without taste, colour, or smell. In nature, however, it is never found in a state of absolute purity. In the ocean, it is salt and brackish, from the presence chiefly of chloride of sodium; in springs, it is either carbonated — that is, contains carbonic acid; sulphureous, from the presence of sulphuretted hydrogen; chalybeate, from the union of the sulphate or carbonate of iron; and so on, according to the nature of the mineral ingredients through which it percolates. When it contains a chemical compound of lime, it is said to be *hard*, and in this condition it decomposes the soap which is employed with it, and destroys its detergent properties. The impurity of water may thus arise either from chemical union or from mechanical mixture with other bodies. The latter can generally be removed by filtration; but when the union is chemical, distillation is necessary to produce a pure liquid. In this state of purity, water is seldom required in the arts, and apparently as seldom in the economy of nature. Under the ordinary pressure of the atmosphere it absorbs carbonic acid, and to the presence of this ingredient do our common spring and well waters owe their agreeable flavour. Distilled water is neither nourishing nor pleasant; both animal and vegetable life seem to thrive best when supplied with water holding in solution certain ingredients; and it is only where foreign ingredients are too largely present, or are of a deleterious nature, that the use of water containing them has to be avoided. 'It is probable,' says Dr Robertson in his Treatise on Diet and Regimen, 'that unless in the case of water being in a state of greater or less putridity, or of its containing a large amount of saline impregnation, or a perceptible impregnation of vegetable or animal matters, it has seldom much effect on the health of a population. When individual systems have once become habituated to its use, the instances are rare in which it proves to be of any importance whether the water reaches the surface by passing through sand, clay, limestone, or even shale; a small quantity of iron in water not appearing to have any bad effect on the health of those using it. In general, and more particularly in towns, the importance attaches rather to the quantity of water for domestic uses with which a district is supplied, than to the character of its mineral impregnation.' Admitting the force of these remarks, and asserting, moreover, that few of our populous towns can boast of anything like an adequate provision, we shall now briefly advert to the nature of the sources whence our ordinary supplies are derived.

Fresh or common water, as distinguished from that of the ocean, is obtained from rain, springs, rivers, lakes, or wells, and is characterised by peculiar properties, according as it is obtained from one or other of these sources. *Rain water*, if collected in mountain districts, far from human dwellings, is perhaps the purest of all; but if collected in the neighbourhood of towns, it is found to be largely impregnated with soot, and other extraneous substances; and the rapidity with which it putrefies, demonstrates the presence likewise of organic matter. Being soft, it is valued by the housewife for washing; but is unfit for internal or culinary purposes without undergoing rigid filtration. Unimpregnated with mineral substances, its action on lead is more rapid than that of other waters; and it should never therefore be kept in lead cisterns. All *spring water* is less or more impregnated with the substances through which it has percolated to the surface; but with the exception of those commonly termed 'saline' or 'mineral,' most springs yield water of sufficient purity for domestic purposes. Those issuing from the primitive and igneous rocks, or from extensive beds of sand and gravel, are generally the purest; those from the carboniferous and other secondary strata always hold in solution compounds of iron, lime, sulphur, salt, and magnesia. *River water*, which is a combination of rain and spring water, is often well fitted for human purposes. Its impurities are more of a mechanical than of a chemical kind, and may be removed by careful filtration. Much, however, depends upon the soil and district through which the river flows; meadows, morasses, and forests yielding organic matter, and factories and towns bequeathing heterogeneous impurities, not to be got rid of by any ordinary process. Water drawn from fresh *lakes* is less turbid than that from rivers; but is always (unless from deep mountain tarns) more largely impregnated with vegetable and animal matter. *Well or pump-water* is that obtained by boring or by sinking shafts into the rocky strata. It must of necessity, like spring water, partake more or less of the mineral ingredients through which it percolates; and not unfrequently is injured by the pumps, pipes, and other apparatus by which it is raised.

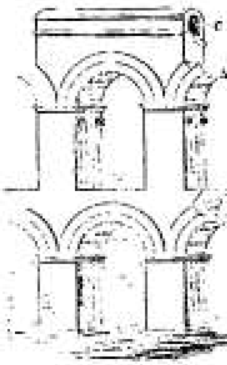
Such are the ordinary sources of fresh water. In rural or thinly-peopled districts little skill or mechanism is necessary to render them available. A trough for the spring, a hand-pump or chain and bucket for the well, or a simple dipping of the pitcher in the river, is all that is requisite. In towns and cities, where the supply must be great, and readily obtained, and where it must be brought from distant and unpolluted sources, aqueducts have to be built, pipes laid, pumping-engines erected, filtering apparatus constructed, and a system of distribution established, requiring all the skill and ingenuity of the machinist and engineer. To these means and appliances, as practically exhibited, we shall now direct attention.

Ancient Aqueducts.

The word *aqueduct* is derived from the Latin *aquæ ductus*, and signifies merely a conductor or conduit of water. In this sense all leaders or channels of water would be aqueducts; but the term is restricted to those artificial structures by which streams are conducted from their sources, by a uniform and continuous descent across valleys and through mountains, towards the city they are destined to supply. Passing over some imperfect traces of aqueducts in India, and advancing westwards, the first worthy of notice is that which Procopius records to have been built by Cosroes, king of the Persians, for the supply of Petra, in Mingrelia. This seems to have been a square conduit, covered by flags, and supported in part of its course upon three tiers of arches, each tier supporting a channel; so that no less than three streams were made available in Petra at different elevations. We have also accounts of aqueducts constructed under the reign of Solomon; and the remains of them still existing in Palestine, give evidence of an extensive acquaintance with the principles of hydraulics among the architects employed by the Hebrew rulers. The 'Pools of Solomon,' near Bethlehem, were evidently connected with a scheme for supplying Jerusalem with water. 'These large, strong, noble structures,' says Mr Stephens in his Incidents of Travel, 'in a land where every work has been hurried to destruction, remain now almost as perfect as when they were built. There are three of them about 480, 600, and 660 feet in length and 280 in breadth, and of different altitudes, the water from the first running into the second, and from the second into the third. The water from these reservoirs is still conveyed to Jerusalem (a distance of six miles) by a small aqueduct, a round earthen pipe about ten inches in diameter, which is sometimes above, and sometimes under the surface.' It was not, however, in the eastern hemisphere alone that the ancients excelled in the construction of aqueducts; we have evidence of the existence of kindred works in pre-Christian Central America. The ancient city of Mexico, which was built on several islands near the shore of the lake, was connected with the mainland by four great causeways or dikes, the remains of which still exist. One of these supported the wooden aqueduct of Chapoltepec, which was constructed by Montezuma, and destroyed by the Spaniards when they besieged the city.

It was among the Romans, however, that the construction of aqueducts was carried to the greatest magnificence and perfection. Masters of half the world, wealthy, and luxurious, it is not to be wondered at that they should have expended an enormous amount of labour in conducting streams into their cities; and less when it is considered that the capital of their empire was unfavourably situated by nature in regard to pure and wholesome water. The glory of a reign was in general perpetuated by the erection of a temple, palace, or other public building; what more fitting monument than an aqueduct—a species of structure susceptible of architectural display, as it was essential to the public welfare! It was to Appius Claudius, about 312 years before the Christian era, that the Romans were indebted for this scheme of improvement; but for several centuries after his time, additional works were constructed, as the necessities and luxuries of the city demanded. Among those who signalised themselves in this department of public utility were Curius Dentatus, Lucius Papirius, Quintus Marcus, Agrippa, Augustus, and Claudius; that erected by the latter being upwards of forty-two miles in length, and discharging about 97,000,000 of gallons in the twenty-four hours. In the remains of these aqueducts, some portions are elevated above the ground on solid stonework, or upon arches continued and raised one above another; while others are subterraneous, such as that seen at Vicovaro, beyond Tivoli, where a tunnel of about five feet deep and four broad pierces the rock for a distance of more than a mile. One of these aqueducts was formed of two channels, one above the other; they were, however, constructed at different periods, the most elevated being supplied by the waters of the Teverone (*Anio Novus*), and the lower one by the Claudian water. It is represented by Pliny as the most beautiful of all that had been built for the use of Rome. It was subsequently repaired and extended by several emperors, is now called *Aqua Felice* (after the conventual name, Brother Felix, of Sextus V.), and still administers to the supply of the modern city. The Aqua Marcia, Aqua Julia, and Aqua Tepula, entered Rome by one and the same aqueduct, divided into three ranges or storeys, each of which supported its own independent channel-way. This accounts for the extraordinary height of this structure, which far surpassed that of its compeers, which generally ranged from seventy to eighty feet, that being the height required to bring the plain which surrounded Rome to the average level of the city.

In general, the conduits or water-courses were built of stone, rough or hewn, occasionally of bricks, and in either case cemented by the finest tempered mortar. Some were of a square form, paved, and covered with flag-stone or tiles; others were arched over, as shown in the accompanying cut; and some were throughout of an elliptical form. This conduit, or stone pipe (*c*), if we may apply such a term, was conveyed through hills by tunnels, and across valleys upon single arcades, or even upon double and triple tiers of arches. In general, these arches supported only one water-course; but occasionally each tier had its own conduit, so that an aqueduct presented a double or triple form. The channels were constructed with an imperceptible descent, that the current might be accelerated by its own weight; and where following a direct line would have given too great an impetus to the flow, they were conducted over many miles of country by frequent and winding mazes. This device not only reduced the impetus of the current, and thereby preserved the interior of the channel from a rapid abrasion, but allowed the water to deposit its sediment, and to become softer and better fitted for domestic uses. For the latter purpose, tanks or cavities were formed in the channel in which the stream lodged, until it had precipitated its mud and feculence; and open ponds were constructed, in which it expanded, till purified and sweetened by atmospheric influence. There were also *spiramenta* at regular distances, by which a superfluous flow of water might be disembogued, and which also served for the discharge of the whole stream, in the event of the channel being stopped by accident or requiring repairs.



Parallel to the course of the conduit, in some of the more magnificent aqueducts, there were footpaths, forming at once a novel and cooling promenade. Having arrived at their destination, the waters were generally received in reservoirs, and conducted by leaden pipes, or by stone grooves, into private cisterns, or dispersed throughout the cities by means of public fountains, which were often adorned with all the magnificence and allegorical allusion of ancient architecture. These structures were invariably under the charge of a public functionary (see *Cloacæ*, p. 476); and it is from the treatise of Sextus Julius Frontinus, who was inspector of the aqueducts of Rome under the Emperor Nerva, that we derive most of our information respecting the water-works of the imperial city.

Without adverting more minutely to these structures, a general idea may be formed of their extent and importance, when it is stated that Rome was supplied with water from sources varying from thirty to sixty miles in distance, and that at one period of its history, not fewer than twenty aqueducts brought as many different streams across the wide plain or campagna in which the city stands. In the time of Frontinus (A.D. 100), the entire length of aqueducts exceeded 255 miles, the daily discharge of which was about 300,000,000 of gallons—a supply to which that of modern London is a mere insignificant dribblet.

The chief provincial cities of the Romans, as well as their own metropolis, were supplied with water by aqueducts; hence in Greece, Gaul, Spain, Italy, &c. portions of these extensive constructions remain to the present day. That of Nismes, built by Agrippa, son-in-law of Augustus, is perhaps the most ancient of their provincial aqueducts. It was about thirty miles in length, when entire, and traversed a very mountainous country, piercing through hills, and crossing valleys by means of arches upon arches. It was constructed of squared stones throughout, and was coated in the interior, which was 4 feet by 5½, with finely-prepared cement. The '*Pont du Gard*' is that part of the aqueduct of Nismes which crosses the deep valley in which flows the Gardon. It is composed of three ranges of arches, one above another. The first range under which the Gardon runs is formed by six arches, the second by eleven, and the third by thirty-five—all of which are semicircular, and form a total height of 160 feet above the water of the river. The entire length of the bridge is 300 yards. Passing the ancient aqueducts of Lyons, in which the inverted syphon, as well as the inclined channel-way, was used, and of Bourgas, near Constantinople, the only other provincial structure of the kind to which we shall allude is that of Metz, of which a number of the arcades still remain. 'These arcades,' says an ancient authority, 'crossed the Moselle, a river which is broad and vast at that place. The copious sources of Gorze furnished water for the representation of a sea-fight. This water was collected in a reservoir; from thence it was conducted by subterraneous canals formed of hewn stone, and so spacious, that a man could walk erect in them. It traversed the Moselle upon its superb and lofty arcades (3600 feet long, and 100 feet high), which may still be seen at the distance of two leagues from Metz; so nicely wrought and so finely cemented, that, except those parts in the middle which have been carried away by the ice, they have resisted, and will still resist, the severest shocks of the most violent seasons.

Modern Aqueducts.

Of the aqueducts erected within a comparatively modern period, we may mention the following:—The aqueduct of Spoleto, constructed in 741 by Theodoric, king of the Goths, to communicate with the town of Spoleto, situated on the summit of a mountain. It is one of the handsomest structures of the kind, and remains entire to the present day. In crossing the river *De La Morgia*, the channel-way is supported upon two tiers of Gothic arches, the lower containing ten grand arches, and the latter thirty. The length of this arcade is 800 feet, the breadth 44, and the height 420! The aqueduct of Caserta, built in 1753 by Charles III. of Naples, is also an expensive and gigantic structure, one of its arcades consisting of three tiers of arches, 1724 feet long, and 190 feet in height. In France, that which conducts the waters of St Clements and Du Boulidou to Montpelier is perhaps the most beautiful. It was built under the superintendence of M. Pitot, and required thirteen years for its completion. The principal arcade is 90 feet high, and consists of two tiers—the lowest containing 50, and the upper 210 arches. That of Arcueil deserves next to be noticed. It was originally built by the Emperor Julian, A.D. 360, to bring water to Paris, and supplied the palace and hot-baths, but was destroyed by the Normans. After it had been in disuse for 800 years, it was rebuilt in 1624; again repaired in 1777; and fresh sums have lately been devoted to the same purpose by the city of Paris. The arcade over the valley of Arcueil consists of 25 arches, is 72 feet high, and 1200 feet long.

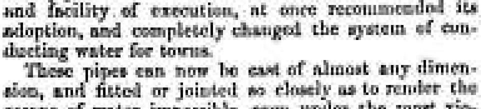
Of recent aqueducts, that of Lisbon and that of New York are the only two deserving notice. The former, completed in 1738, is about three leagues in length, and in some parts of its course has been excavated through hills; but near the city it is carried over a deep valley for a length of 2400 feet by several bold arches, the largest of which has a height of 250 feet, and a span of 115. The Croton Aqueduct, which conveys the waters of the Croton River for a distance of thirty-eight miles to the city of New York, is one of the most stupendous underakings of modern times. It was commenced in 1837, and finished in 1842, and is calculated to discharge upwards of sixty millions of gallons in twenty-four hours! Some idea of this magnificent supply may be formed from the fact, that the daily consumption of the principal London water companies (eight in number) amounts only to *twenty-one millions of gallons*. Of the architectural structure of the Croton Aqueduct, it would be impossible to convey any clear idea without the aid of sections and diagrams. A general sketch of the undertaking may, however, be presented:—The fountain reservoir covers about 400 acres, and is formed by a dam 38 feet in height, creating a source 166 feet higher than the city of New York. At this dam are sluices or gates for regulating the discharge of water, and of course under the superintendence of a competent manager. The interior of the aqueduct is throughout of an arched or elliptical form, founded upon hydraulic concrete, built of square stones, and finally lined with brick prepared for the purpose. In crossing flats slightly below the intended level, it is raised upon solid embankments; in crossing valleys or rivers, it is supported upon arches; and in passing through hills, these are tunnelled, to admit the mason-work of the aqueduct. Roads and other thoroughfares are of course left unobstructed by the erection of bridges, just as they are in our country when a railway is laid down. As the magnificence of aqueducts depends upon the height and number of arches requisite to carry them across valleys, it may give some idea of that under consideration, when it is stated that Harlem river is crossed by fifteen arches, seven of which are of 50 feet span, and eight of 80 feet, the greatest height being 150 feet from the foundation to the top of the mason-work. This, it is true, is the *chef-d'œuvre* of the aqueduct; but there are other bridges and embankments of no mean magnitude, the design and construction of which do credit to American engineering. No essential change occurs in the form of the channel-way from the fountain reservoir on the Croton to the receiving reservoir on the island of New York, a distance of thirty-eight miles, except in crossing Harlem river to reach the island, and in passing a deep valley on the island, where iron pipes are used instead of masonry, to provide for the pressure consequent upon a depression from the regular plane. Thus the course of this artificial stream may be said to combine two principles—that of the ancient aqueduct, and a descent and ascent as in ordinary pipes. (See p. 468.) Should it ever be resolved on to remove the tubes from these depressions, and to substitute arcades to maintain the regular inclination of the channel-way, a second tier of arches will be required in crossing the Harlem river, and a bridge of great elevation to span the ravine on the island.

Having by the means now described reached the receiving reservoir, at the rate of 1½ miles an hour, the surface-level of the water is still 119 feet above the level of mean tide. From this it is conducted (a distance of two miles) to the distributing reservoir, where the surface-height falls to 115 feet, this last being the height to which the water can be made available in the city. The receiving reservoir covers about thirty acres, and contains one month's supply; whilst the distributing, which is entirely built of stone, is 436 feet square, 45 feet deep, and contains 20,000,000 of gallons. This last reservoir may be considered the termination of the Croton Aqueduct, and is distant from the fountain reservoir 40¼ miles. The whole cost of the work, according to the published accounts, was about 9,000,000 dollars; and adding to this the cost of pipes, and arrangements for distributing the water in the city, it will make the total cost of supplying New York with water about 12,000,000 dollars.

Syphon-Pipes.

Till within the last century, the only mode of conducting supplies of water on a large scale was the covered channel or aqueduct; and where the ground presents a gradual and direct descent, no other mode can be more simple or satisfactory. But where hills have to be tunnelled, valleys crossed by tiers of arches, and rapid descents overcome by circuitous routes, the aqueduct becomes the most laborious and expensive of contrivances. The Romans and others must have felt the full force of this objection; but the condition of the arts and sciences among them left them no alternative. They must either have reared the magnificent, but toilsome and expensive aqueduct, or submitted to the privations which its absence implied. Not that they were ignorant of the hydrostatic principle of water always rising to its original level, no matter how tortuous or complicated the course by which it is led;* but that they were not in possession of any material sufficiently strong to resist the pressure of the contained fluid in its risings and fallings along the surface of the country. The syphon-pipes employed by them were of lead, a metal not well adapted to sustain a great degree of pressure, and objectionable besides on the score of communicating its deleterious properties to the water. There was therefore no alternative to the hydraulic engineer till the invention and improvement of cast-iron pipes, when that material, in point of cheapness and facility of execution, at once recommended its adoption, and completely changed the system of conducting water for towns.

These pipes can now be cast of almost any dimension, and fitted or jointed so closely as to render the escape of water impossible, even under the most violent pressure arising from the height of the fountain-head. All that is necessary is, to join the several lengths securely, and protect them from frost or from the heat of the atmosphere, by covering them with a few feet of soil. They are all but indestructible, and communicate no deleterious principle to the current of water. Thus, in the following diagram, if *a* represent a lake or reservoir situated in a mountainous district, and *b* a town separated by several miles of irregular country, then on a pipe (indicated by the dotted line) being laid from *a* to *b*, the water will issue with a force sufficient to raise it nearly to the height of the original reservoir—a certain amount of force being lost through friction and atmospheric pressure. Several of our large and many of our minor towns are now supplied by this mode; the whole system consisting of the feeding reservoir—which is generally situated in some hilly district—the line of pipes, with a few air-cocks for the escape of the accumulated air, branches or mains to lead the water into



the different districts of the town, and ultimately small service-pipes and cisterns for the houses of the consumers. We may take for illustration the Crawley line of pipes, from which the inhabitants of Edinburgh derive the greater portion of their supply. 'This spring,' we quote the Encyclopædia Britannica, 'issues from the side of a rising ground on the southern base of one of the Pentland Hills. It is scarcely seven miles distant from Edinburgh in a straight line, but eight and three-fourths in the line of the pipes, these having been carried round a considerable way to the eastward, to avoid the Pentland ridge, the eastern extremity of which lies in the direct line to the city. The spring is elevated 564 feet above the level of the sea, and 380 above the level of Princes Street. There is therefore ample height to carry it over the highest parts of the town. The original issue of the spring was greatly augmented by a drain, which was carried for about half a mile above the spring up the valley in which it is situated. The soil of this valley, consisting of an immense bed of gravel, in many parts forty feet deep, constitutes a vast natural filter, through which the water, descending from the high grounds on each side of the valley, percolates in a high degree of purity, and being all intercepted by the drain, is by it conducted, along with all the original discharge of the spring, into a reservoir or water-house, from which the pipes take their rise, and continue in one connected train all the way to the city.

In the first three miles they vary from 18 to 20 inches diameter, and descend 65 feet in a pretty regular series. In the remainder of the track they are 15 inches diameter, and descend 286 feet. The descent is not perfectly regular, being in some parts steeper than in others, according to the natural declivity of the country. In one or two instances also they undulate slightly. Near Burdiehouse, four miles from the city, they ascend a little; and after descending rapidly to Libberton Dams, they again ascend 20 or 30 feet to the high ground on the south side of the Meadows. There are, however, no sudden inequalities, all such having been carefully avoided by levelling; for which purpose considerable embankments and cuttings of the ground have been undertaken without scruple; and as the line approaches the city, it has been carried through a tunnel 2160 feet in length, under Heriot's Green, about 70 or 80 feet below the surface, and another under the Castle Hill, 740 feet through the solid rock, and 120 feet under the reservoir. From this main line of aqueduct a branch pipe leads off on the south side of the town to the reservoir at Heriot's Green, near Heriot's Hospital, which aids the former source in supplying fully the southern districts; a second leads off from the same place to the eastward, and affords an additional supply to the south side of the town, directly from the pipes; and a third leads off to the reservoir on the Castle Hill, and aids it in supplying the rest of the Old Town. The main body of the water, however, proceeds onwards to Princes Street, along Hanover Street, and across Queen Street; and from thence branch pipes are laid through all the other streets in the New Town, and from these again service pipes to each house or floor of a house.

Each pipe in this aqueduct is about nine feet in length, the metal being about half an inch thick. After being cast, their soundness was proved by a forcing-pump applied to each separately, and with a gauge-valve loaded with a weight equivalent to a pressure of 800 feet; and if under this they betrayed the smallest flaw, they were rejected. They are all joined together with what is termed spigot and faucet joint, the end of the one being let several inches into a swelled part or socket at the extremity of the other. This forms a much more perfect joint than by flanches and bolts, as it admits of a slight degree of expansion in the pipes without opening the joining. After being entered, a ring of hemp or rope-yarn is wrapped round the end of the pipe, and beat into the socket of the other, and then a mass of lead run in to fill up the opening, which the yarn prevents from running into the pipe: the lead being hard rammed, and stoved with a chisel, forms a joining completely water-tight. Air-cocks are placed at intervals all along the pipes to let off the accumulated air, which is done by the hand at regular intervals, perhaps every three or four days. The supply of water conveyed by this aqueduct amounts to 180 or 200 cubic feet per minute at an average.'—The simplicity and facility of this mode is so obvious, that it is sure to be adopted in every case where there is a sufficiency of fall between the fountainhead and the seat of discharge. The ease with which the mains can be led from the grand trunk, and the service pipes from the mains, at the same time that fire-plugs can be inserted with regularity and system, are prominent features of the syphon-pipe system. There is no change as in the aqueduct from channel to reservoir, and from reservoir to distribution pipe, but one compact and direct principle pervades the whole.

* We have evidence of this in the aqueduct of Mont Pila, the water of which was partly conveyed by leaden pipes, and partly by the usual stone channel-way. In one case the pipes (nine in number, and eight inches in diameter) were carried across a valley upon a range of low bridges, about 200 feet below the regular inclination of the aqueduct; and in crossing the Rhone, a series of similar pipes was laid down in the bed of the river. Towards the end of last century a portion of these pipes was dragged up by an anchor. The fragment is preserved in the museum of Lyons; it is soldered at the joints by the same material, and on each joint are the words in relief, C. CANTIUS POTHINUS, F., which is apparently the name of the maker.

With respect to the material for the conducting tubes or pipes, there can be no doubt of the superiority of cast-iron. It can be cast of any size, shape, or strength; can be jointed, laid, and re-laid with facility; and admits of being pierced for the insertion of plugs or service-pipes. Various concretes have been proposed, and may answer well on a small scale, though totally unfit for large mains under a high pressure. Earthenware tubes internally glazed, when carefully laid and puddled, are very sweet and cleanly; but they cannot be used on a large scale, nor are they well fitted for the insertion of plugs or branch pipes. The same remark applies to glass tubes, which have recently been much spoken of, and which, coated with asphalte, are now employed to some extent in France. As to lead, the great rival and auxiliary of cast-iron, its pliability, the readiness with which it can be cut, jointed, and soldered, and its comparative cheapness, must ever recommend it for small junction and service-pipes; but its inferior tenacity unfits it for a high pressure, while the deleterious qualities which it is apt to impart to certain waters must ever render its adoption a matter of dread and caution. On the latter point, the researches of Professor Christison have proved that water which is exposed to the action of lead by continually running through pipes of that metal, becomes impregnated with the carbonate of lead, to an excess which, when the water is habitually made use of, exposes the drinker to a disease called the lead colic. If it be asked how it is that so many persons are daily partaking of the so-called 'harmless beverage,' without experiencing any ill effects? the answer is, that it is only very pure water which is liable to deteriorate; that the impure water, which is decidedly in most frequent use, generally carries a protection in certain neutral salts containing saline matter, which prevents the lead from impregnating the water in proportion to the quantity of acid contained in the salts. Thus the greater the original purity of the water—such as rain and distilled waters—the greater its danger of developing carbonate of lead.

Pump-Works.

In all places where there is a deficiency of level to carry the water naturally to the highest parts of a town, there is no resource but in the employment of machinery. A steam-engine or other agent is applied to the working of pumps, which first draw the water from rivers or wells, and then force it through a train of pipes to all the different points of consumption. This mode is adopted in some of the densest centres of our population—as in London, Liverpool, Glasgow, Aberdeen, Perth, &c.: as with us fuel is cheap, and steam-engines of unrivalled power and construction, pumping as a system is not without its advantages. The water-works of Glasgow, which are compact, and systematically constructed, may be taken as an illustration:—They are situated on the banks of the Clyde (which yields the supply) about two miles above the city, and occupy both sides of the river, the motive power being on one side, and the aqueducts and filters on the other. 'The works on the northern bank,' we quote from a description in Chambers's Journal for October 1842, 'consist of a series of buildings occupied by nine large steam-engines, two of which, called Goliath and Samson, are of great magnitude and power, and well merit the names which have been given them. They were made in 1839 by the Neath Abbey Iron Company, Glamorganshire, and have each a 72-inch cylinder, with a 10-feet stroke. They are kept in excellent order, and present the finest and most elegant specimens of workmanship of the kind we have ever had the pleasure of inspecting. The room in which they perform their Herculanean labours is tastefully painted and papered, and entirely free from disagreeable effluvia. The erection of these magnificent machines, with their appurtenances, cost the Company £20,000. Four of the other engines, possessing 54-inch cylinders, with an 8-feet stroke, have received the appropriate names of Jupiter, Saturn, Achilles, and Ajax. At Cranston-hill works, which we did not visit, there are also four steam-engines in constant operation. The aggregate amount of motive force thus at the disposal of the Company is estimated at about 700 horse-power. Attached to the working-beam of each engine is a very ingenious piece of mechanism, with seven dials, resembling clockwork, and furnished with a pendulum, which vibrates in unison with every stroke of the engine, and registers, with amazing accuracy and precision, the number of strokes given in the course of an hour, a week, a month, &c. The superintendent has only to consult this self-acting index to ascertain the quantity of water thrown into the city by each engine during any given period. Connected with the water-pipes we observed mercurial pressure-gauges, of very fine workmanship, for indicating the height to which the water is raised in the city, where corresponding gauges are kept in the engineer's office, by which it can be known at a glance how the supply is maintained by the engines, though in operation at the distance of nearly three miles. The quantity of water furnished by the works daily amounts to upwards of 8,000,000 gallons, besides about 600,000 gallons of unfiltered water, raised directly from the river for the use of several public works.

Having examined the varied and ingenious means and appliances on the northern bank for propelling and conducting the water through the city, we were carried across the stream in a boat, to inspect the aqueducts and filters on the other side. These occupy a triangular peninsula, of a honeycomb-like structure, washed on two sides by the Clyde, and perforated in various directions by water-channels. The principal aqueduct or filter consists of an elliptical tunnel 7½ feet in diameter, and upwards of 600 yards in length, sunk ten feet lower than the level of low water, in a bed of sand and gravel, through which the water filters naturally. This tunnel forms a curve parallel with the bed of the river, at about fifty feet from its margin. There are, besides, about eight acres of meadow land, and nearly two of sand-filter, on which the water is raised by steam power. The whole water produced by these filters is conveyed through a gravelly subsoil into the tunnel above-mentioned. The water thus purified is brought across the stream through four suction-pipes, laid in the bed of the river, and connected with the engines on the northern side. It is worthy of remark, that two of these pipes were designed and laid under the direction of the celebrated James Watt, whose genius and skill triumphed over the first difficulty which presented itself, arising from the bend or curve in the bed of the river, by devising a flexible main or tube, constructed of iron pipes, and so connected by movable joints and hinges as to adapt its form to the bottom of the Clyde. The water is conveyed into the city through the medium of four principal pipes or mains, as they are called, respectively of 14, 21, 25, and 36 inches diameter. As the ground on which Glasgow is built is of great variation of elevation, four intermediate stations or reservoirs have been formed, into which water is raised to the elevation requisite to supply the several districts, and no more; thus economising the power required to be exerted by the steam-engines, and furnishing at the same time an abundant supply to those who occupy the highest houses. Besides these reservoirs, there are two others now in course of erection at the west end, to meet the increased demand arising from the rapid extension of the city in that direction. One of these is an extremely handsome massive structure, and harmonises admirably with the elegant buildings by which it is surrounded. It is lined throughout with cast-iron plates, and is 123 feet in length by 84 in breadth, and 10 in depth. The whole extent of pipes, with their varied ramifications throughout the city, amounts to upwards of 140 miles.

The supply to the inhabitants, we were informed, begins about six in the morning, and is continued without intermission throughout all the pipes till from eight to ten in the evening. The population of Glasgow, according to the last census, is nearly 300,000; and these works pour unceasingly, like the heart in the human system, the life-blood of a city—WATER—through a thousand channels, until it reaches the most distant and obscure member of the community. One has only to witness, for a brief period, the effect of a partial suspension of the works, to be convinced of the incalculable benefits they confer.'

As it is our wish to present principles rather than descriptive details, our space will not permit of any account of the Companies' water-works which supply the Metropolis. These companies are eight in number, and obtain their water partly from the Thames and partly from wells—employing a system of pumping-engines, filters, and reservoirs, aided, as in the case of the 'New River,' by the principle of the open conduit. By these means, the supply of water to the inhabitants of London has been brought to a considerable degree of purity and efficiency, though still wanting that sparkling transparency and coolness which give to water its most valuable properties as a beverage, and that overflowing abundance without which the great sanitary projects of the day can never be carried into full effect.

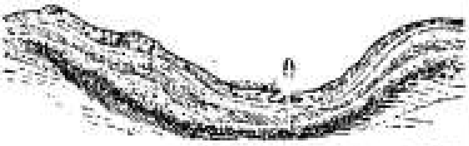
Artesian Wells.

Common wells, of whatever depth or construction, require no detailed notice. If the water rise to the surface, it may be led away either by syphon-pipes or by conduits; if it rise only to a certain height in the shaft, then it must be lifted by pumping, or other kindred apparatus. Wells of this kind are common all over the world; in Britain they are found in every locality, from the solitary farm-house to the crowded city. At one time they formed the sole source of supply for our towns, and are still to a great extent available; more, however, by private parties than by the general community. Being fed by subterranean springs, their water is frequently impregnated with mineral substances; and many of the springs being intermittent, the supply is often deficient during the droughts of summer. Laying aside these objections, which are less or more applicable to every other source of water, the common well, if carefully built with stone (bricks are objectionable), and fitted with an improved pump, is an invention by no means to be despised, though of course not for a moment to be compared with the full-pressure system of the aqueduct or syphon-pipe.

Artesian wells—so called from Artois, a province in the north of France, where it appears the greatest attention has been paid to the discovery of subterranean springs—are distinguished from common wells by the circumstance of their waters rising above the surface, often to a considerable height, and with considerable violence. This fact, that water will rise spontaneously to and above the surface, in certain localities, when bores of various depths are made into the earth, seems to have been long known to mankind. An Alexandrian writer of the sixth century narrates that 'when wells are sunk in the oasis of the desert, to a depth varying from 100 to 500 ells, water springs from the orifices, so as to form rivers, of which the farmers avail themselves to irrigate their fields.' In more modern times, travellers relate that, in some parts of the Desert of Sahara, the natives sometimes bore the earth to the depth of 200 fathoms, and always succeed in finding water, which flows often up the bores with such force, as to drown those engaged in making the excavations. In China also, and in European countries, there are proofs of wells of this nature having been early formed. In many cases the water of these wells not only spouts to the height of several feet above the surface, but might be conveyed with ease in pipes to the tops of the highest houses.

Artesian wells are common on the continent, particularly in France, which consequently furnishes the finest examples. That of Grenelle, near Paris, is, we believe, the most gigantic, the borings being carried through tertiary and chalk strata to a depth of 1798 feet, or one-third of an English mile. The bore is 20 inches in diameter at the orifice, but is contracted by stages, till at the bottom it is only 7 inches. The bore is lined with iron tubing; and the current, which discharges between 500 and 600 gallons per minute, rises to a height of 100 feet above the surface—thus forming an inexhaustible supply of excellent water, running from such an elevation as to be easily distributed to the loftiest situations in the city. The work was commenced under the superintendence of M. Mulot in November 1833, and finished in February 1844 at an expense of 303,000 francs. In Britain, as well as in France, there are others of large dimensions; several of them, however, discharging their supply partly upon the Artesian principle, and partly by pumps. The Polytechnic Magazine notices the following:—'The fountain at Cheswick, belonging to the Duke of Northumberland, is 584 feet deep, and throws the water 4 or 5 feet above the surface. An Artesian fountain in the monastery of St André, half a league from Aire, ascends 11 feet above the surface-level, and discharges two tuns per minute. At Gouchem, near Bethune, the waters from four borings turn the millstones, and churns, and serve for other purposes. At St Pol, a mill is turned by similar means. At Fontes, near Aire, the waters from ten borings turn some large millstones, and also works the hammers and bellows of a forge. All the machinery of the silk manufactory of M. Champoiseau, at Tours, is kept in motion by water from a similar well, 273 feet deep; and at Tooting, near London, the water from an Artesian fountain belonging to a druggist, works a pump, by which water is forced three storeys high in his house.' To these we may add the recently-sunk well at Southampton, which is 1300 feet deep, 600 of which is a built shaft, the remainder a bore of large diameter. The water rises within forty feet of the surface, and is then pumped by steam-engines at the rate of 55,000 gallons per day! Another at Hanwell, 290 feet deep, partly shaft and partly a bore of 14 inches diameter, discharges 100 gallons per minute, and rises upwards of 26 feet above the surface. In consequence of the law of increasing temperature as we descend into the earth, the waters of Artesian wells are frequently five, six, and eight degrees above that at the surface; and calculating upon the uniformity of this increase, it has been gravely proposed to sink at Paris to such a depth as to obtain the water at a temperature of thirty-two degrees Centigrade—this thermal current to be economically applied in heating the hothouses of the Jardin des Plantes, and the hospitals of La Pitie and La Salpetrière.

The geological and hydrostatic principles upon which the forcible discharge of Artesian fountains depend are sufficiently obvious. The greater portion of the earth's crust consists of stratified formations, which are variously broken up and inclined; here thrown into ridges, there into basin-shaped hollows, and again into long gradual slopes. The rain, percolating through the loose soils and subsoils, makes its way into and between the various rocky strata—those that are soft and porous imbibing the greatest quantity. Naturally seeking the lowest level, this water again makes its escape to the surface in the form of springs—these springs appearing in valleys, at the bases of hills, and other low-lying situations. Any rent, or fissure, or dike (see GEOLOGY), breaking the continuity of the strata, must also interfere with the passage of the contained water; and thus it is that natural springs are most frequent along the line of these interruptions. It must be obvious then, that among the hard and impervious strata of the primary formations, in broad flat districts, and in districts where the continuity of the strata is much broken up by igneous rocks, that the springs will be comparatively few and small; while among the softer and more porous strata of the secondary and tertiary formations, and in districts where these strata are variously inclined, and thrown into large basins or hollows, that the springs will be numerous and abundant. It is thus that the finest Artesian wells are found in secondary and tertiary basins, the principle being as follows:—Let the annexed section represent a tertiary basin, composed of alternating strata of sand, clay, gravel, and loose sandstones. It is clear that the thick bed of sand and gravel *a*, lying between two layers of impervious clay *b* and *c*, can have no outlet for the water with which it is saturated by percolation. It is, in fact, a great subterraneous sheet or reservoir of water, whose



maximum pressure is at the bottom of the basin. Let a well or bore be sunk in the valley, and the result will be, so soon as the bore strikes the bed of gravel, a rush or jet of water, forcible in proportion to the extent of the bed, and the height to which its sides rise above the surface of the valley. Of course the friction in passing up the bore, the weight of the atmosphere, and the self-weight of the ascending column, will all tend to prevent the jet from rising to precisely the same height as the water in the stratum; but these allowed for, a uniform column will be obtained so long as the bed of gravel holds the same quantity. Summer droughts will necessarily lessen that amount, and winter rains increase it—influences which are felt on shallow Artesian bores, but which are altogether imperceptible in those of immense depth. Depending upon these principles, no Artesian well should be attempted without consulting the geologist or mining-engineer. A deflexion of the strata, the occurrence of a dike, or some such phenomena, which the geologist alone can interpret, may render abortive years of the most assiduous and expensive labour.

The mode of executing Artesian fountains, though laborious and expensive, requires less ingenuity and knowledge than the determination of the site and depth. In the case of shafts, digging, hewing, and blasting, as in the case of coal-pits, are the means resorted to; and where the strata are soft and yielding, the shaft must be cradled—that is, lined with stone or iron—as the work proceeds. Where boring is resorted to, it is done after the ordinary methods, only with much greater expense, as the bore is frequently required to be of large diameter. Boring, as the reader may be aware, is performed by a cutting chisel, whose edge corresponds with the diameter of bore demanded. This chisel is at first worked by hand, and supplied with water much in the same way as the quarryman bores for blasting. As the bore deepens, lengths with alternate male and female screws are attached, so as to form a rod; and when this rod becomes of great weight, a windlass or other machinery is necessary to work it. The débris is removed from the bore by unscrewing the chisel, and attaching a cylindrical auger or gouge, fitted with a valve so as to prevent the return of the sand or clay, which is in a state of pulp or paste. This is one of the most troublesome parts of the operation; but is necessary not only to clear the hole, but to show the superintendent the nature of the strata passed through. Removing the débris, and attaching fresh chisels, are duties which consume much of the borer's time, and this just in proportion as the depth increases. Instead of working by rod, a heavy chisel worked by rope is sometimes substituted—the rope being lighter and more manageable, while torsion can be readily given to it so as to shift the edge of the chisel. By whatever means the bore is made, whether sunk of the desired width at once, or widened by degrees, it is customary in a soft strata to line the bore with iron tubing, let down by lengths soldered together. This casing prevents the filling up of the bore by lateral percolation, and prevents also the main spring from being rendered impure by discharges from intermediate beds of clay and shale. Fitted with a perforated cover, this tubing may be said to complete the operation.

Fountains—Jets-d'Eau.

Fountains or jets-d'eau are contrivances by which water is violently spouted or projected upwards in a continuous stream, so as to become at once ornamental, refreshing, and salubrious to the locality in which they are situated. The projecting force is acquired either from the hydraulic pressure of the water at the fountain-head, by the spring and elasticity of a confined volume of air, or by mechanical appliance; but generally by the former power. (See HYDRAULICS and PNEUMATICS, No. 15.) The water is conveyed from the reservoir to the fountain in pipes, and if the orifice from which it issues be directed upwards, it will spout to a height approaching that of the reservoir. It will always, however, fall short of this height, for the following reasons:—namely, the resistance of the atmosphere, the friction of the discharging orifice, and the resistance or weight which the first propelled particles of water offer to those which follow.

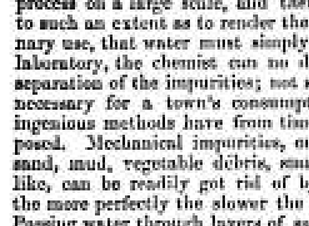
Decorated fountains of this kind were much in request among the Greeks and Romans, not only in their streets and gardens, but also in the courts of their houses. The 'Pirene,' a fountain at Corinth, was encircled by an enclosure of white marble, which was sculptured into various grottos, from which the water ran into a splendid basin of the same material. Another fountain in Corinth, called 'Lerna,' was encircled by a beautiful portico, under which were seats for the public to sit upon during the extreme heats of summer, to enjoy the cool air from the falling waters. We read of many others in both Greek and Roman authors; and this fondness for fountains still exists in Italy and the East, where there are numerous elaborate and fanciful designs. The French are also celebrated for their fountains, those at the Tuileries, Versailles, and St Cloud being superb structures; and indeed, with the exception of our own, most of the large towns of Europe are adorned and refreshed by these contrivances. The most remarkable jet-d'eau in the world is said to be that at Cassel in Germany, where the waters rise from an orifice of 12 inches diameter to a perpendicular height of 250 feet. The source from which it is supplied is at the top of a mountain near by, being about 500 feet above the level of the town.

Viewing jets as auxiliaries to health, as well as ornaments, we are inclined to advocate their erection wherever it is practicable. In our public gardens and squares, along promenades, and at the crossing of streets, nothing could be more appropriate and ornamental, independent of the cooling effect which they must exert over the surrounding atmosphere in summer. Where the supply of water is abundant, there is every scope for the ingenuity of the artist and engineer in the designing of fountains—from the most grotesque and fanciful, to the most severely classical conception. Nor is there any reason why small, permanent, or portable fountains should not be more generally introduced into our market-places, shops, and public buildings, where the atmosphere is apt to become heated and contaminated, producing oppression, listlessness, and languor.

Reservoirs—Filters.

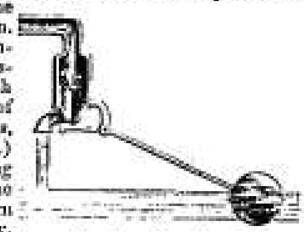
Reservoirs or tanks are necessary appendages to most water-works, and require to be constructed with skill and care. Occasionally, they are little more than simple excavations, the excavated earth forming the retaining banks; but in general they are puddled with clay, or lined with masonry; and if of considerable depth and size, the embankments should be strongly constructed, as serious accidents may arise from their breaking down under the pressure of the water. As the pressure of any given amount of liquid can be calculated with precision, there is no excuse for the engineer who blunders either as to the proper slope or weight of a retaining embankment. Besides the regulating sluices, large reservoirs should be furnished with waste outlets, to prevent damage to the banks in cases of freshets or land-floods. For small domestic or covered tanks, cast-iron plating securely rivetted, hewn stone, common masonry lined with some of the patent cements, glazed bricks, Welsh slate, or the like, form excellent materials, and are preferable to wood, which requires to be lined with lead or other metal. In all cases, large or small, there is necessity for regular cleaning, as the purest of our waters will in time give rise to offensive sediment.

As already stated, all natural waters are less or more contaminated with chemical or mechanical impurities. To get rid of the former, there is no cheap available process on a large scale, and therefore if they prevail to such an extent as to render the water unfit for ordinary use, that water must simply be avoided. In the laboratory, the chemist can no doubt readily effect a separation of the impurities; not so in the large supply necessary for a town's consumption, though several ingenious methods have from time to time been proposed. Mechanical impurities, on the other hand, as sand, mud, vegetable débris, small animals, and the like, can be readily got rid of by filtering, and that the more perfectly the slower the process of filtration. Passing water through layers of sand and gravel is the simplest perhaps of all methods: to these are sometimes added potsherds and charcoal—the latter ingredient exercising an antiseptic power, and destroying all fetor and putrefaction. Whether on a large or small scale, the materials most in use are those we have mentioned, together with porous earthenware and certain sandstones. As the intercepted slime and sediment will in all cases tend to clog and fill up the pores of the filter, considerable ingenuity has been displayed by various parties in arranging the materials so as to retard this clogging, and in the construction of what are termed 'self-cleaning' filters. That invented and used by Mr Thom at Greenock, Paisley, Ayr, &c. is one of the most effective, and may be taken in illustration:—In the accompanying transverse section, *a* is the conduit for supplying the water to the filter; *c* a sluice for regulating the flow; *b* a valve which admits the water above or below the filtering material at pleasure; *e* a floor of perforated tiles resting on a puddled basis; *f* the filter, composed of layers of gravel and sand, gradually increasing in fineness towards the surface, the top layer consisting of fine sand and grained animal charcoal. The whole apparatus being completed, the water is allowed to enter the filter at the top, and passing through the different layers, it issues quite pure and free from taint. When the filter becomes foul, which is shown by the decreased quality of water passing through, the valve *b* is reversed, and the current made to enter from below, carrying the particles of mud to the surface of the top layer, whence they can be readily removed. The cost of the Paisley filter was £600, and the quantity of pure water produced regularly every twenty-four hours is on an average 100,632 cubic feet. There are a number of other filters in use, but the same principle pervades the whole—namely, the passing of the water through successive layers of porous, and occasionally antiseptic, materials.



Modes of Distribution.

The manner of distributing water in towns by the ordinary mains and service-pipes, may be either 'intermittent' or 'constant.' The intermittent or periodical system consists in *laying on* the water, as it is termed, at regular or irregular intervals—once a day, or once in two days, as the case may be. Of course in the interval no water can be drawn from the service-pipes in the interior of the houses, so that means must be adopted for storing a sufficiency for domestic requirements during the time the supply is withdrawn. This necessarily involves the use of cisterns or tanks, with all their apparatus of pipes and ball-cocks, the latter (see fig.) ingeniously shutting off or admitting the supply as the cistern may be full or empty. The constant system, on the other hand, affords a supply at all times, to be drawn directly from the service-pipe, without the intervention of cisterns. Constant supply at high pressure is obtained by having the source from which the supply is obtained at a considerable height above the town, so that by the force of gravitation the water may be delivered at the highest house; or failing this, steam power must be applied to raise it to reservoirs at such a height, or to force it at once into the pipes. Of the two systems, the latter is the more advantageous both in a sanitary and economical point of view. In the constant high-pressure system, the mains and service-pipes may be reduced one-third in size; all the expensive and ever-failing apparatus of cisterns and ball-cocks is done away with; the casualties by fire are materially lessened; and the constant flushing of the drains and sewers is sanitarily of vital importance. Though the consumption of water be much greater, yet none of its efficacy can be said to be lost; and indeed until our towns and cities be in possession of a constant high-pressure system, they cannot be said to be adequately supplied.



BATHS—WASH-HOUSES.

Referring the reader to our article on the Preservation of Health for the sanitary value of personal ablution, we shall here treat of baths as a social arrangement, and of the various mechanical appliances requisite for the establishment of a system.

Baths of the Ancients.

The use of the bath has existed, in all probability, from the beginning of the world, since it is founded in the most natural wants of man. In barbarous ages, however, in which art had as yet accomplished nothing for the conveniences of life, men merely plunged into rivers, streams, fountains, and other natural reservoirs of water. They were far from dreaming of the erection of apparatus by means of which they might be enabled, as at a later period, to take their baths at any time, season, or place, and of an agreeable and salutary temperature. Doubtless the discovery of hot springs, which must have existed then as in our own times, at various parts of the earth's surface, suggested to them the happy idea of communicating different degrees of heat to the water they employed, and of erecting more commodious and less dangerous receptacles. It was amongst the nations of the East, the earliest reapers of the benefits of civilisation, that industry and the arts made the first efforts to satisfy the wants of men, and perpetuate the taste for, and employment of, warm baths. The custom was carried from Asia to Europe by the colonists, who successively established themselves in Greece, Italy, Iberia, and Gaul.

Greece knew the use of warm baths in the time of Homer, for mention is made of them in several passages of the writings of that poet. Among the Greeks, the Lacedæmonians were the first who adopted the custom, borrowed from Asiatic nations, of appearing naked at the public games; anointing themselves with oil, and covering themselves with sand prior to the contest, and then plunging into hot baths. But the employment of baths in private families was not even yet very general in the time of Hippocrates. This prevented his recommending the bath in many diseases which called for its adoption. As to the public establishments, they formed part of the *gymnasia* to which they were attached.

The Romans were accustomed, in the early period of the republic, after a day employed in labour in the fields, to wash only the arms and legs; and every ninth day, when they came to the city, to be present in the assemblies for state business, they bathed the entire body. At that period the Tiber or neighbouring streams formed their bathing resorts, vapour and hot-water baths being scarcely known to them. It was only at a late period they thought of establishing public or private baths. The city, by reason of its situation on hills, presented great difficulties for the conveyance of water. As already stated, it was not until about 441 years after the foundation of Rome that water was brought, for the first time, from Tusculum by means of an aqueduct. These structures were multiplied afterwards; and baths, or *thermæ*, were erected in various parts of the city, characterised as yet by the ancient Roman simplicity.

The new custom which the Romans adopted towards the last years of the republic, of attaching baths to the gymnasia, rendered them indispensably necessary; and the frequent application which physicians, from this period, made of them in the treatment of disease, powerfully contributed to the increase and embellishment of these salutary and useful structures. But it was not until the reign of Augustus that they began to give to their warm baths that air of grandeur and magnificence which is yet to be observed in the ruins which remain. To conceive a just idea of them, we should examine the plans of the principal edifices as traced by Palladio. In beholding his designs of the bas-reliefs and pictures which adorned the walls and ceilings, we are at once astonished at the perfection of the objects they represent, and at the exquisite purity of taste which then prevailed in the arts. The rarest marbles, precious vases, bronzes, columns, statues from the chisel of the greatest masters, and gildings skilfully applied, contributed to the brilliancy of the interior of these gigantic monuments.

It is difficult to enumerate the immense number of uses they were devoted to. Besides the vast basins, and the thousands of recesses (the thermæ of Diocletian contained three thousand) appropriated to the different baths, there were found there theatres, temples, amphitheatres, palaces, festive halls, vast open promenades planted with trees, schools frequented by youth, academies where learned persons assembled for discussion, and libraries, to which every one might freely resort.

The most complete establishments contained numerous apartments devoted to the various processes connected with an elaborate system of bathing. The bather, after having undressed in the *apodyterium*, was conducted into the *unctuarium*, where his body was freely anointed with strong oils; afterwards, in an adjoining apartment, it was covered with fine sand or powder. He now repaired to the *sphæristerium*, an immense hall or rotunda, in which he engaged in wrestling, or other gymnastic exercises calculated to develop physical power. When the locality admitted of it, the sphæristerium was uncovered and exposed to the sun; or rather, in the best-appointed baths, there were two sphæristeria. The various games were continued until the sound of a bell announced that the vapour and hot-water baths were ready. To these the crowd of bathers now proceeded, each person taking his seat on a marble bench, placed below the surface of the water, around immense basins, wherein swimming might be executed when agreeable. While here, they diligently scraped the skin with a species of ivory or metal knife, termed a *strigilis*, by which they detached all impurities from the surface. The *tepidarium*, or tepid bath, and *frigidarium*, or cold bath, were finally employed for a short time, for the purpose of bracing the pores of the skin, relaxed by so long a proximity of moist heat. Before dressing, those who desired to employ perfumes—latterly a numerous party—again repaired to the unctuarium.

The baths of the ancients, although usually built after a similar plan, yet offered a notable difference. At Rome, even in the most splendid establishments, the greater portion of the extent of the edifice was appropriated to baths, properly so-called, which obtained for them the name of thermæ, from the Greek word *thermos*, heat. But with the Greeks the gymnasium occupied almost the entire structure, the bath itself being but of very limited dimensions. This difference exhibits the passion for bathing which seized the Romans towards the end of the republic, and continued to possess them until the fall of the Empire. With regard to the mechanical arrangements—the heating, ventilating, and supplying of the Roman baths—little is known with certainty, though the remains of Pompeii has thrown some light on the subject. It would appear that the water was conveyed from the aqueduct to a reservoir, and from this directly to the cold baths by lead or earthen pipes. The hot baths were supplied from a copper or boiler, the furnace of which also furnished hot air for the flues which heated the pavement and walls of the vapour baths, the tepidarium, and other apartments. The light was admitted from the roof, and the ventilation regulated by openings furnished with ornamental valves. Of course their comparative ignorance of the metals prevented them from arriving at that nicety and rapidity of heating known in modern times; still their architects were sufficiently acquainted with the laws of caloric to make arrangements by which as little as possible of the heating power should be dissipated and lost.

At first, the public baths were only opened at two o'clock in the afternoon, and closed at five: the sick alone having a right to enter them at any time. Latterly, the emperors, wishing to conciliate the people by their favourite amusement, ordered the doors to be opened sooner, and closed later. Nero had them opened at twelve; Alexander Severus allowed the baths to be entered from the break of day, and even furnished at his own expense lamps and oil for lighting them. From that time the Romans may be said to have passed their lives at the baths. They frequently bathed twice a day; and hot water constituted one of the indispensable elements of their existence. We must not, however, attribute this singular passion exclusively to fondness of bathing. The desire and hope of meeting with friends, of discussing the topics of the day, and passing the time agreeably, were no less powerful motives.

Of all the Grecian people, the Lacedæmonians were the only ones in whom the gymnasia and baths were common to both sexes. The ancient Romans were far from following such an example, and carried modesty so far as to consider it improper that a father should appear at the same bath with his son, or even son-in-law. Later, however, the corruption of manners made such progress, that in the reign of Domitian, women and men bathed pell-mell together. This custom, then generally adopted, was afterwards prohibited by Hadrian and Marcus Aurelius; again tolerated by Heliogabalus; and finally abolished by Alexander Severus. The baths were, however, frequented indiscriminately by individuals of all ranks. The noblest and richest persons there found themselves mingled with the poorest plebeians.

It was not only the Roman metropolis which contained public and private baths. They existed in all the towns of Italy, and in the palaces of nobles and freedmen. They were found also in all the Roman provinces. In our time even, it is easy to perceive the vestiges of the Roman thermæ in every country which formed a portion of their extensive empire.

The greater number of these magnificent edifices, which, during the most illustrious period of the Empire, had constituted the pride and delight of Rome, were destroyed by the Vandalism of the barbarian hordes. Those which were not pulled down were otherwise employed, or, being no longer repaired, gradually fell into ruin. Baths, which formed one of the requisites for the effeminate and luxurious life of the Romans, were, for the warrior and invading nations, mere means for the preservation of cleanliness. Utility and cleanliness were the only objects held in view in the construction of the thermæ, which were henceforth erected in Italy or the other countries of Europe. Baths were much frequented, however, during the whole of the middle ages, until the sixteenth century—the epoch at which the use of linen became general. 'The barbarism of the middle ages,' says Grosley, 'not being able to attain magnificence, confined itself to the convenience of the public baths, and other establishments, which were erected in Europe. The idea was due to the Arabs, among whom the arts and sciences had found an asylum. The Crusades and commerce had opened up to Europeans the countries which flourished under the rule of this people, and the natural taste for imitation did the rest. The vapour and public baths were, for a long period, as much frequented in Europe as they are at the present day in the Levant. People were attracted to them for the sake of health and cleanliness; but, above all, from the want of society felt by persons who saw little of each other except in these places. Some took water baths, others vapour baths; while several came only to gossip, comfortably protected from the cold. For these last, the baths were what the stoves of Germany, the *estaminets* of Holland, and the cafés of Paris, are to this day.'

Modern Baths

Although the increasing use of linen has much diminished the hygienic necessity of the bath, and has occasioned the ruin and neglect of the establishments of the middle ages, yet public attention has not ceased to be directed to the advantages of such establishments—thanks to the salutary counsels of medicine, the progress of civilisation, and the amelioration of the material comforts of the masses. 'Eminent physicians,' says Dr Clarke, lamenting our inferiority in this respect to continental nations, 'have endeavoured to draw the attention of the British government to the importance of public baths, and of countenancing their use by every aid of example and encouragement. While we wonder at their prevalence among all the eastern and northern nations, may we not lament that they are so little used in our own country! We might, perhaps, find reason to allow that erysipelas, surfeit, rheumatism, colds, and a hundred other evils, particularly all sorts of cutaneous and nervous disorders, might be alleviated, if not prevented, by a proper attention to bathing. The inhabitants of countries in which the bath is constantly used, anxiously seek it, in full confidence of getting rid of all such complaints; and they are rarely disappointed. I may add my testimony to theirs, having not only upon the occasion which gave rise to these remarks, but in cases of obstructed perspiration much more alarming, during my travels, experienced their good effect. I hardly know any act of benevolence more essential to the comfort of the community, than that of establishing, by public benefaction, the use of baths for the poor in all our cities and manufacturing towns. The lives of many might be saved by them. In England they are considered only as articles of luxury; yet throughout the vast empire of Russia, through all Finland, Lapland, Sweden, and Norway, there is no cottage so poor, no hut so destitute, but it possesses its vapour bath, in which all its inhabitants, every Saturday at least, and every day in cases of sickness, experience comfort and salubrity. Lady Mary Wortley Montagu, in spite of all the prejudices which prevailed in England against inoculation, introduced it from Turkey. If another person of equal influence would endeavour to establish throughout Great Britain the use of warm and vapour baths, the inconveniences of our climate would be done away. Perhaps at some future period they may become general; and statues may perpetuate the memory of the patriot, the statesman, or the sovereign, to whom society will be indebted for their institution.'

Since this sensible and energetic appeal was made, a better state of things seems to be approaching; and for some years past the institution of baths has much engaged the public attention. The houses of our higher classes are now invariably fitted up with accommodation for hot and cold bathing; portable baths on the sponge, shower, or plunge principle are common in the dwellings of the middle classes;* and deficient as we yet are, the last ten years has witnessed the erection of a number of private and public establishments, at which the masses may enjoy a bath for the merest trifle of their weekly earnings. It were greatly to be wished that these establishments were increased tenfold, and that some public fund were raised for their establishment and partial maintenance. We have abundance of fuel for heating; in general, a fair supply of water; and as fine architecture and expensive fittings are not required, it is difficult to account for the tardy progress we make in this department of social economics. Without entering minutely upon the *mécanique* of baths, which may be varied almost to infinity, the following points seem to require consideration in the organising of such establishments:—

1. An abundant supply of soft fresh water. The quantity desirable for a single bath is from forty to fifty gallons. Whether for single or public plunge-baths, the number of bathers per day may be multiplied by forty, and the quantity of water to be consumed will thus be ascertained. There is nothing so unpleasant as the idea of laving in the water that has been used by others, and we know that in many instances the dread of doing so has deterred from the use of the bath, where there was otherwise a wish and a willingness. The practice of using the same water in succession, even though filtered, is highly objectionable, and ought never to be resorted to.

2. The water should flow into a large tank, from the tank to the boiler, and the boiler to the baths, the waste escaping by a conduit. If the tank is placed in a lower situation than the boiler, steam power will be required to pump it. In most situations it is desirable to be as economical of space as possible, and for this purpose it is generally contrived to have the reservoirs underground; the plunge-bath, shower, and douche baths, heating apparatus, and waiting-rooms on the ground-floor; the private baths in the upper storey; and the hot-water tank above all. In planning and laying out the apartments, the greatest attention ought to be paid to privacy and decorum; for whatever may have been the customs of the ancients, or what may now be the practice of continental nations, our countrymen have in general the keenest sense of delicacy in this respect—a feeling which ought never to be offended through any mal-arrangement or mistaken parsimony.

3. The establishment should possess washing-rooms, single private bath-rooms, a large plunge bath-room, and waiting-rooms for the several classes of bathers; also a separate apartment for the washing and properly drying of the towels and hand-cloths.

4. In the washing-room or rooms there should be basins, at which all persons proposing to use the plunge-bath ought, in the first place, to wash their hands, face, arms, and neck. If a regulation of this kind is not enforced, the water in the plunge-bath will very shortly become unendurable.

5. The plunge-bath may be made of a circular or

* In absence of *permanent* baths, which ought to form part of every modern house of any pretensions, just as much as its kitchen or laundry, *portable* baths, now procurable at the ironmongers in every variety, will be found to be no indifferent substitutes. Among the most approved are Read's 'Universal Bath,' which comprises in one the cold, warm, shower, douche, and vapour bath; the 'Omnidirection Bath,' which allows the stream to be directed against any particular part of the body; and the 'Portable Shower Bath,' which has the merit of going into very little space, and may be used in any apartment. For a permanent hot bath, the kitchen range may be constructed so as to have a supply of from ten to twenty gallons of warm water always in readiness, and this, after the original outlay, at a cost almost inappreciable.

oblong form. That generally recommended is oblong, measuring 40 feet in length by 30 feet in breadth; the depth, by means of a sloping bottom, to be from 4 to 6 feet, but never more. Within the bath there may be a step to assist in descending and ascending. At one end, near the surface of the water, there should be several inlets, to be kept constantly running, and at the opposite extremity outlets for escape. By the careful adjustment of these orifices, the water may be kept in a state of considerable purity, notwithstanding its continual use. Besides this, the whole volume of water should be discharged twice a week, and the bottom of the bath well scrubbed. The number of persons admitted at one time will require to be regulated according to circumstances. Over the bath there should be the means of ventilation for the watery vapour and heated air.

6. Where possible, the whole suite of baths should be lighted from above; and each room should be furnished with hot-water pipes, so as to raise its atmosphere to any desired temperature. We have spoken of a boiler, but this is only one means of heating that may be adopted. Steam-pipes, or a circulation of hot water, may be employed to keep the swimming bath at the proper temperature; and the hot-water tank may also be heated by steam, which will be found in most cases to be the most effectual and economical method. These, as well as other matters of detail, ought in each case to be intrusted to an experienced architect and plumber. So far as experience has gone, it has been found that, at the rate of 100 bathers per day, a single cold bath may be furnished for 2d., a single hot or tepid bath for 3½d., and a swimming bath for 2d., and that these charges may be made remunerative.

7. Another important requisite is, that the situation be as central as possible for the great body of those for whose use it is intended. A short walk one would suppose to be rather agreeable than otherwise to the working-classes; but experience has found that unless a bathing establishment be in their immediate vicinity, and be continually before their eyes, they are apt to seize every trifling accident—as a little unusual fatigue, a wet night, or the like—as an excuse for abandoning the ablution.

Such ought to be the leading characteristics of a bathing establishment suited to the wants and requirements of our population. With us the bath is a necessity, not a luxury. The great majority of our artisans and factory workers are engaged in labour of a kind by no means cleanly, and without daily ablution of some sort or other, disease, injured constitutions, and debased moral sentiments, are certain sooner or later to be engendered. What we desiderate is means for thorough, regular, and cheap ablution; the effeminacy of anointing, shampooing, and other kindred practices being wholly unsuited to, as they are unneeded under, our northern climate.

We have spoken above of public baths; but where steam engines are employed in connection with cotton factories or other works, there is usually a certain quantity of waste steam or waste hot water at disposal, which could at an insignificant cost be directed into baths for the use of the workmen of the establishment; and we hope this will be done wherever it is practicable. The improved health and cheerfulness of the parties benefited will be more than compensatory for the necessary outlay. We are aware of one instance where seven baths were comfortably fitted up at the small expense of £30, in which the men and women bathe on alternate days, to the number of from thirty to eighty a week—paying a mere trifle to the keeper, who attends an hour and a half each evening, and finds towels, soap, &c. nothing being charged by the proprietors for the original outlay.

Wash-houses.

These are recent inventions, forced upon us by the exigencies of our peculiar social condition. In a country where the labouring classes are in a comparatively easy condition, and thinly scattered, the house is at once the domestic brewery, bakehouse, and laundry, as it is the family sanctuary. But where the masses are densely packed in lanes and alleys, where house accommodation is dear and limited, where the necessaries of life have to be continually struggled for, and these conventional evils increased, in too many instances, by improvidence, the house is but a night shelter, affording little or no convenience for the necessary operations of the housewife. Independent of this, in point of economy, a public wash-house is preferable to any number of isolated efforts. By co-operation, superior accommodation, better apparatus, and a cheaper and more satisfactory result can be obtained; and thus the public wash-house, where self-paying and self-supported, may be classed among the co-operative arrangements which characterise the social features of the age. Several establishments of this kind, partly of a charitable and partly of a self-supporting kind, are now in existence in the metropolis, in Liverpool, and we believe in other of our populous towns.

As in the case of baths, wash-houses primarily depend upon a liberal supply of soft water, and upon economical modes of heating and drying. As only the needier classes are likely to make use of them, everything should be upon the cheapest possible scale—hot water, tubs, soap, soda, drying, smoothing-irons, and mangles. The establishment should consist, at the least, of a washing-room, furnished with tubs having stopcocks for hot and cold water; of a drying-room, fitted up with hot-air or other rapidly-desiccating apparatus; and of an ironing and mangling apartment. Seeing that hot water is always on the premises, a few baths may be conveniently attached—the persons of the occupants generally requiring ablution as much as their clothes. By using one furnace, and a system of steam-pipes, hot water for the tubs and baths may be cheaply procured; and by very little additional mechanism, the same source may be made to propel a current of heated air to the drying-room. When we consider the amount of fuel required for a kitchen fire on a washing-day, the time wasted by imperfect arrangements, the inconvenience experienced where the housewife has to wash, dry, and iron her clothes in the one sole room where she has to cook the family meals, and where that family has perhaps to eat, sleep, dress and undress, and perform all the minor offices of life, we can then appreciate the boon which a public wash-house is calculated to confer. Without dwelling longer on the arrangements of such establishments, which are so simple and intelligible, we shall present the practical results of one of the humblest of the kind—namely, that of East Smithfield, London, which is chiefly supported by charitable donations. It combines very properly bathing and washing, and provides every requisite, even to a change of clothing, to those who come to cleanse their solitary suit:—

The arrangements of the baths, which are six in number, though destitute of everything like ornament, and in some respects somewhat rudely constructed, are unexceptionable as respects privacy and decorum. The writer himself took a warm bath on the premises, and had soap and a clean towel allowed him, for all which accommodation he was expected to pay only a penny. The bath was certainly not so neatly or commodiously constructed, nor contained in so comfortable an apartment, as the second-class baths at the public baths and wash-houses in George Street, Marylebone, near Euston Square; but it ought to be taken into account, in instituting the comparison, that the charge for a warm bath at the latter place is fourpence, and that the establishment is a self-supporting one, and conducted on a much more extensive and pretending scale than that at East Smithfield.

As regards the other department of the institution, a large, lofty room, being the principal one in the house, is set apart for the washing and drying of clothes. There is always a number of women engaged in this work, superintended by the matron, amongst whom the greatest decorum and order are observable.

They are uniformly civil in their behaviour towards the matron and to one another, and all of them express themselves grateful for the privileges afforded. In this room there is a large steam boiler, used for the purpose of heating the water; not by *boiling* it in the ordinary way, but by pouring steam into wooden tubs filled with cold water, until it becomes heated. With the view of economising fuel, this boiler is used not only for heating the water in the wash-tubs, but also that in the baths placed in adjacent apartments; and what is more remarkable, it is likewise made available for the drying of the clothes when washed, through the medium of Davison and Symington's ingenious process:—A chamber, about the size, and having the appearance, of a large cupboard, is placed at the distance of a few yards from the boiler, with which it is made to communicate by a pipe of about eight inches in diameter, through which, by means of a revolving fan turned by hand, a column of heated air is sent into the drying chamber through the floor, which is of iron, and closely perforated. The clothes intended to be dried are suspended from horizontal poles placed within the drying chamber; and by the agency of the heated air ascending through the perforated floor, they are effectually dried in the short interval of a quarter of an hour.—This novel contrivance not only dries the clothes rapidly, but likewise ventilates and frees them from the peculiar smell that generally clings to long-worn garments; and thus, it is believed, all noxious and contagious matters that may lurk in the habiliments are effectively dissipated. The ironing and mending are carried on in adjoining apartments.

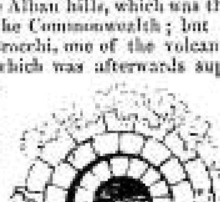
The institution is open from eight in the morning till eight at night. During part of the day—namely, from eight until four o'clock—women are exclusively admitted to wash their clothes and bathe; and on the women retiring, from four until eight in the evening men are admitted to these privileges.

The reader may be curious to know to what extent the class of people for whom these baths and wash-houses were more especially intended have availed themselves of the advantages which they offer. We are happy to mention that the result of the first year's essay was 27,662 bathers, 35,480 washers and dryers, and 4522 ironers—an abundant proof of the desire of the poor to be neat, clean, and wholesome when they can obtain the necessary means. The second year showed an increase of 16,920 bathers, washers, and ironers, and a decrease in the working cost, from improved arrangements, of £60, 15s. 4d. In the first year, the expenses contracted by supplying 63,142 bathers and washers amounted to £377, 17s. 9d., or less than three-halfpence each; in the second year, 73,288 cost in the aggregate only £305, 7s. 1d., or about one penny for each. In the first year, the cost of 4522 ironers was £4, 5s., less than one farthing each; in the second year, 11,296 cost £11, 15s. 4d. 'At the cost of one penny each,' says the official report, '34,615 warm baths were given in the second year, every bather having an ample supply of water, a clean towel, and a piece of soap; and 38,445 persons had a sufficiency of hot and cold water, of soda and soap, to wash more than a quarter of a million articles, the greater part of which, when washed, were dried and ventilated. The working expenses did not include rent or taxes or any water-rate for six months, or any charges for coal for seventeen weeks; but if the association had paid rent and taxes, and for water and coal, during the whole year, but had not given soap or soda, these expenses would have been £25 less than they were; so that, for the purposes of ascertaining how economically a bathing and washing establishment at which soap and soda are not given can be conducted, the experience of the association may be confidently appealed to.' While deprecating in the strongest possible terms any interference with a healthy and legitimate self-dependence, we think these gratifying results might induce corporations and others to direct themselves with some degree of zeal towards this department of our social economics.

DRAINAGE—SEWERS.

As efficient means should be taken to secure for our towns and cities a regular and abundant supply of pure water, so ought there to be a regular system of emission for that which is foul and waste. The rain which fall on our roofs and streets, and the waste water of our houses and public works, with all the animal and vegetable matter wherewith they are impregnated, must be regularly and speedily carried off, otherwise stagnation and putridity ensue, deleterious effluvia arise and are inhaled by the inhabitants, and disease, suffering, and death are the inevitable consequences. The most obvious method of discharge is by open gutters; but as these are offensive and unsightly, the great object both in ancient and modern times has been to establish a system of underground sewerage.

Among ancient nations, the Romans carried underground sewerage to the greatest perfection; and it is worth while in those days of sanitary preachments briefly to glance at their *cloacæ*. 'This term is generally used in reference only to those spacious subterraneous vaults, either of stone or brick, through which the foul waters of the city, as well as all the streams brought to Rome by the aqueducts, finally discharged themselves into the Tiber; but it also includes,' says Mr Rich, 'within its meaning any smaller drain, either wooden pipes or clay tubes, with which almost every house in the city was furnished to carry off its impurities into the main conduit. The whole city was thus intersected by subterranean passages. The most celebrated of these drains was the *Cloaca Maxima*, the construction of which is ascribed to Tarquinius Priscus, and which was formed to carry off the waters brought down from the adjacent hills into the Velabrum and valley of the Forum. The stone of which it is built is a mark of the great antiquity of the work; it is not the "peperino" of Gabii and the Alban hills, which was the common building stone of the Commonwealth; but it is the "tufa litoide" of Brocchi, one of the volcanic formations of Rome, and which was afterwards supplanted by the finer quality of the peperino. The arch of this cloaca is semicircular, and formed of three rings of voussoirs, as shown in the annexed cut, being 14 feet in width and 32 in height. The blocks are hewn, and joined together



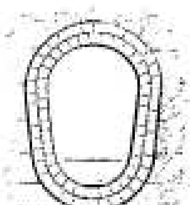
without cement. The passages in Strabo and Pliny which state that a cart loaded with hay could pass down the Cloaca Maxima, will no longer appear incredible, from the dimensions given of this stupendous work; though it must still be borne in mind that the vehicles of the Romans were much smaller than ours. Dion Cassius also states that Agrippa, when he cleansed the sewers, passed through them in a boat. The great sewer formed by Tarquin was only from the Forum to the river, but was subsequently continued as far up as the Suburra, of which branch some vestiges were discovered in 1742. When the habitations of the Romans were mere huts in comparison, it seems extraordinary that so costly a construction for the purpose of drainage should have been executed; but it shows that in the early history of their city, all that was undertaken for public utility was carried out with a spirit and magnificence surpassing anything done by other nations who have advanced more in civilisation and refinement. The expense of repairing and cleaning these cloacæ was defrayed partly by the treasury and partly by assessment. Under the Republic, the administration of the sewers was intrusted to the censors; but under the Empire, particular officers were appointed for that purpose, and who employed condemned criminals in the task.'

Notwithstanding the obvious and pressing necessity there exists for such a system of drainage in our large and populous towns, it is well known that there is scarcely one of them that is not notoriously deficient in this respect. What drain-courses do exist are either badly constructed or out of the districts most requiring them; while whole sections are entirely without a single underground channel. Such a state of matters is by no means creditable to British intelligence, and can only be palliated on the ground of the rapid increase of many of our towns, which were founded and arranged on plans of a very simple and primitive description, bearing no reference whatever to the probability of increase. Attention, however, is now energetically turned to this as well as other sanitary reforms, and the revelations made by the several recent Parliamentary Commissions are of too startling a nature to be readily forgotten.

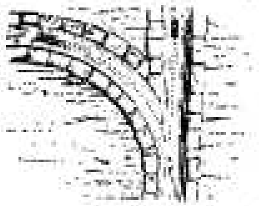
Setting out, then, with the axiom, that underground sewage is preferable both in point of health and convenience to open gutters, the first requisite is a plan of the district to be drained, with all its levels and facilities of discharge. Nothing, in fact, can be done without a descent for the sewage, and it is this want which occasions that stagnation and putridity so much complained of in many of our populous districts. Where natural descent is deficient, it is the duty of the civil-engineer to effect a remedy by carrying the tail or outlet to a greater distance, by inserting steps or falls at certain parts of the sewers, and by contracting and curving the drains occasionally, so as to increase the scour of the current. All these are remedies of a permanent kind; and where they cannot be obtained with full effect, it becomes necessary to adopt the system of flushing—that is, to insert sluices or traps at certain distances, which, being closed for a while, are suddenly withdrawn, and the dammed-up waters allowed to escape with a rush. These and such-like means being adopted to carry off the sewage with rapidity, the next point to be considered is the laying down of the mains and branches, so that no section of the town may be beyond the scope of the system.

According to the most eminent authorities, the network of sewers should consist of drains or pipes from every house or block of houses, these discharging themselves into branches or mains running under the principal streets and thoroughfares, and these mains again conveying their contents to one or more grand trunks or channels, as the levels of the district may allow. One great cloaca would be preferable to two or three, and should always be adhered to where practicable, as it not only concentrates the evil, and allows the solid contents to be collected and manufactured into manure with greater ease, but increases the flush of water, and thereby exerts a more thorough cleansing power. One main channel, however fetid and turbid, may roll its contents along comparatively harmless, but disperse these contents through several channels, and they creep lazily along, emitting in their course the most noxious effluvia. Connected with the main trunk is the regulation of the point of discharge—a subject of vital importance in any densely-peopled country. If discharged *en masse*, with sufficient descent in the ocean, for example, little or nothing requires to be done; but if on a low level, subject to tidal obstructions, then self-acting sluices are necessary, to prevent the influx of the tide, which is apt not only to injure the buildings, but to repel the confined air in the conduits, and send its deadly miasma through every pipe and grating in the city. The same remarks are applicable to low-lying towns situated on rivers; with this additional precaution, that no sewage ought to be discharged above any portion of the stream whence water may be drawn for domestic or other economical purposes. Of late years, instead of discharging sewage water as waste, attempts have been made to use it for the purposes of irrigation, or to collect its solid contents as manure. To the first of these practices there can be no objection, if sufficiently removed from the town; but if in the neighbourhood, nothing can be more prejudicial or offensive than the spreading of the fetid waters to the evaporating influence of the atmosphere. As to the collecting, desiccating, disinfecting, &c. of the solid contents, much absurdity has been promulgated. It is true that thousands of tons of valuable manure are annually swept away to the ocean by simple discharge; but it is equally certain that any system of tanks would in most cases but increase the evils complained of, or be conducted at such an expense as to render the project unprofitable. There can be no question as to the efficacy of sewage manure, and in all cases where it can be collected cheaply, and without danger, the attempt ought to be made; but for our own parts, we would rather forego any saving than run the risk of a system of open tanks and reservoirs steaming with poison and putrefaction.

The next points to be attended to are the materials, shape, and construction of the conduits and drains. The materials ought to be hard, durable, and impervious; everything of a soft crumbling nature being liable to break down in course of time, and obstruct the current; and if porous, percolation of the fetid contents is apt to take place, and affect wells, cellars, and other subterranean conveniences. As to the form, the egg-shaped sewer (see fig.) is allowed on all hands to be the most efficient. In the first place, it is stronger than either the common square conduit with flagged top, or the upright-sided conduit with arched top and levelled bottom. If the arch stones are well formed and jointed, no weight or side-pressure can break it down; and if the ground is soft and yielding, the arched structure sinks as a whole. Again, when formed of two rings or courses, as shown in the section, it is quite impervious either to moisture or effluvia, and requires less concreting and puddling than any other form. Further, the egg-shaped bottom gives to the minimum of water the greatest scouring effect; and while over a flat bottom the sewage might not exceed an inch in depth, it would amount to three or four in the egg-shaped; thus preventing, as far as possible, the lodging of slime and sediment. It is stated by Mr Roe, whose name is well known in connection with this subject, that with the same flow of water, the liability of the egg-shaped sewer to accumulate solid deposits is diminished one-half compared with the old upright-sided and flat-bottomed conduit. Lastly, as the oval sewer combines the greatest strength with the smallest consumption of material, a very considerable saving is effected in construction, amounting from two to five shillings per lineal foot over the ordinary upright sewers with footing. Mr Williams has shown that the saving in the Westminster district by the construction of the egg-shaped instead of the upright-sided, in ten years would have been upwards of £66,000; 'a sum,' says he, 'sufficiently startling to cause the inquirer to scrutinise with care the reasons that are advanced in favour of the adoption of a form theoretically imperfect, and found practically not to answer so well in some cases as the more perfect shape which could produce such a saving.' While such ought to be the form and construction of the mains, in the house-drains, bricks, stones, and mortar should be avoided, and cast-iron or glazed earthenware pipes adopted. These are more durable and impermeable, and are not so apt to be choked up if made of moderate dimensions. The chief fault in house-drains is their great width, the quantity of water sent through them never being able to flush or scour them sufficiently. Mr Dyce Guthrie, the able advocate for the adoption of earthen tubes, gives the following rule to ascertain the size of a house drain:—To the caliber necessary to carry off the water admitted into the house, add that required for the reception of rain or surface water, which is easily calculated by reference to the rain-gauges of the locality.



A very prevalent error in sewage is the joining of the house-pipes with the mains, and the mains with the grand channels at right angles. It is well known that if one current meet another at right angles, an obstruction or eddy is formed, which has the effect of interfering with the sluicing power of the receiving current, and thus solid deposits are gradually accumulated, often to the complete choking up of the system. There is nothing more common than to find such accumulations in our present sewers—accumulations which no flush of sewage can sweep away, and which has therefore to be removed by the offensive and dangerous process of hand-labour and cartage. This imperfection also involves considerable expense, as the pavement has frequently to be broken up and relaid, and this independent of the obstruction and annoyance to the public through the blocking up of the thoroughfare by one of the most disgusting operations. Science at once points out the remedy, by directing the entering channel with a sweep or curve, as shown in the accompanying diagram.



Acting upon this principle, the commissioners of the Holborn and Finsbury district (London) agreed to require that the curves in sewers passing from one street to another shall be formed with a radius not less than twenty feet. It is also required by them that the inclination or fall shall be increased at the junctions, in order to preserve an equal capacity for the passage of water, and of effect in scouring.

An important point in the construction of sewers is their internal dimensions, which, while sufficient for all ordinary contingencies, should never be so large as to diminish materially the scouring effect of the water. According to Dr Kebbell, to whose 'Lectures on the Diseases of Towns' we are indebted for several suggestions, the great size of existing sewers is one of their main faults. 'During even the heaviest thunder-storms, not one half of the internal capacity of the main sewers is occupied by the run of water; while the flow of water when there is no rain is a mere dribble compared with the size of the sewer. In the secondary sewers the run of water to the size of the sewer is still less. Now the general effect of this great disproportion between the size of the sewers and the run of water through them is, to impede the stream, and create deposits. The object of making the sewers of this large internal capacity is, to enable men to get into them and remove the accumulations. The above fault in the present system of sewage has been pointed out in the Report of the Metropolitan Commissioners, who strongly recommend the substitution of a much smaller system of sewers, to be kept in action by regular supplies of water. The general principle they advance is, that the size of the sewers should be so adjusted as to keep them as full of water as possible; and it is contended by men of experience and science, in accordance with this principle, that the drainage and sewage of a city might, and should be so constructed as to give rise to as little occasion for men to go through the main drains, as there is for men to go through the main pipes for conveying supplies of water. What is wanted are conduits through which the refuse matter may be carried away, not receptacles for its deposition and detention. The extent of diminution recommended is—for the main sewer, from 4 feet 9 inches by 3 feet, to 3 feet 9 inches by 2 feet 5 inches; for the second-class sewers, from 4 feet by 2 feet 5 inches, to 3 feet 4 inches by 2 feet. But while a more efficient sewer will be thus introduced, another considerable advantage will be gained in the reduction of the cost. The expense will be reduced from 14s. 2d. per foot run for the first-class sewers, to 7s. per foot run; and in the second-class sewers, from 12s. per foot run to 6s.'

Supposing that all these points were gained in the laying down of our sewers—that there was sufficient inclination, a regular system of ramification, a faultless construction as to size, shape, and material—still there is one great requisite, without which all others would be only partially successful; we mean an abundant supply of water, whereby these sewers might be kept always pretty full, and occasionally thoroughly scoured, from the remotest branch to the general embouchure. If we had such a supply always at command, the open gutter would in many situations be preferable to the underground sewer; and there would be no necessity for those abominations known as 'cesspools.' An overflowing supply of water is therefore necessary not only for the ordinary purposes of consumption, but for facilitating the removal of that portion which has been used, and become impregnated with filth and garbage. 'The drains,' says Captain Vetch, 'but furnish the ways or vehicles for transportation; the water is the moving power or carrier, and it is the cheapest that can be procured. In fact the supply of water to a town, and the discharge of refuse, are two branches of the same subject; and unless the water is abundant enough, and distributed enough to cleanse the drains, these last would be more offensive than useful.' Where artificial supplies of water cannot be obtained, the principle of flushing may be advantageously introduced. This consists, as already stated, in fixing in the sewers cast-iron gates or sluices, which, when closed, cause the ordinary flow of water to accumulate above them; and when a sufficient quantity is collected, they are thrown open, and the rush of water so caused is sufficient to sweep off the deposits. This plan was invented by Mr Roe, surveyor to the Holborn and Finsbury division, where it has been in operation for several years with marked benefit both as regards expense, and in keeping the sewers free from accumulations. Mr Roe has stated in evidence that the annual cost of cleansing the portions of the Holborn and Finsbury district, now supplied by flushing apparatus, by the old mode would be £326, 17s., and by the present system of flushing, £106—making a saving of £220.

Such are the requisites for a regular system of drainage, from which it will be seen that underground sewers are preferable in most instances to open gutters, and that neither can be efficient without a liberal and steady supply of water. We have said nothing of those chemical modes of destroying noxious smells and effluvia known technically as 'deodorising' and 'disinfecting'—leaving their merits to be discussed in the article devoted to the 'Preservation of Animal and Vegetable Substances.' Neither have we adverted to those numerous mechanical contrivances now in vogue for the prevention of effluvia from drains, water-closets, and cesspools. These, like the chemical deodorisers and disinfectants, may be all very good and ingenious in their way, but they do not apply themselves to the root of the evil: what our towns and cities desiderate is, a system of sewage that would render all such secondary remedies uncalled-for and unnecessary. And this brings us to speak of cesspools—a mode too frequently adopted to get rid of the refuse liquid from houses. In no case, and under no plea whatever, should these pits of poison and pestilence be permitted. Let them lie open in any degree—and it is impossible to have them hermetically sealed—and they are for ever giving off their noisome and noxious exhalations: they saturate the adjacent soil with their offensive contents; and there is no possibility of preventing the evil without the constantly recurring expense and annoyance of emptying them.* The rudest open gutter is preferable in comparison; for it is

* 'In one court,' says Dr Reid, 'the whole products of waste cabbage, water, &c. from the public kitchen, evaporated from a cesspool under it, which had not been cleaned for twenty years. When the cesspool was examined, I found that it had no communication whatever with any external discharge; and that, during the long period mentioned, there was abundant evidence to prove that all the liquid products it had received had no escape, except by evaporation into the atmosphere that supplied the courts above.' This is no solitary instance: we could cite hundreds equally startling and aggravated.

sure to force itself upon the attention, while the cess-pool, 'out of sight, out of mind,' is steaming and fermenting with the most subtile and deadly gases. So detrimental and barbarous is this system, that no opportunity should be lost of interdicting its application, or of indicting its continuance, as an insufferable nuisance. And here it may be remarked, in conclusion, that without clear and available powers of law on the part of Corporations, the most perfect system of drainage will often be unavailing. So much ignorance has to be dispelled, so many selfish interests have to be encountered, that we firmly believe there are thousands who would not take advantage of a remedial system though it were gratuitously offered them.

ABATTOIRS—MARKETS.

The situation and construction of abattoirs or slaughter-houses, and market-places, are intimately connected with the supply and emission of water, and deserve somewhat more than a passing notice.

Abattoirs.—Presuming that every one is less or more acquainted with the operations of the common slaughter-house, it must be evident that these establishments ought to be situated at a distance not only from the denser portions of our towns, but also from the markets or stalls where the meat is exposed for sale; and that they ought, beyond every other place, to be liberally supplied with water. So much filth and garbage of a rapidly-decomposing kind is necessarily associated with them, that without an absolute flush of water, and stringent regulations as to its application, they are apt to become centres of the most noisome nuisance and disease. Notwithstanding these facts, which are but too lamentably apparent in all our large towns, yet as a country have we done almost absolutely nothing towards the establishment of abattoirs, to which the animals might be led quietly, and without danger to the inhabitants, where their carcases might be dressed with regard to cleanliness, and where the offal might be sluiced away, and collected in such a manner as to become of value to the agriculturist. Our neighbours on the continent are infinitely before us in this respect; and with a view to convey some idea of their arrangements, we transcribe the following account of the abattoirs of the French metropolis:—

'The Emperor Napoleon, about the year 1810, ordered five of these establishments to be commenced at Paris, and they were executed at the cost of the city. A commission was formed of five architects, assisted by the vice-president of the Council of Public Works, the secretary, and a retired master butcher, who were instructed to examine several plans that had been presented, and to report upon their efficiency; but eventually M. Gauché, one of the five architects, was commissioned to furnish the designs which were adopted. The five abattoirs are those of Roule, Villejuif, Grenelle, Menilmontant, and Montmartre. Their dimensions were defined by the number of persons that each district contained. The two first had each 32 slaughter-houses, that of Grenelle 48, Menilmontant and Montmartre each 64, making in all 240. To each of the abattoirs are attached houses for the melting of tallow; reservoirs, and water laid on by lead pipes wherever required, every means for cleansing, stables and sheds for the use of the butchers, enclosures for the cattle, and apartments for the superintendents. A vaulted sewer receives and carries away all superfluous water; there are also buildings for preparing tripe, trotters, &c.' Of these sectional arrangements, Mr Cresy, from whom we quote, gives the annexed details:—'1. *Scalding-house*, used by the butchers for slaughtering. All the abattoirs have two or more ranges of these, each composed of two buildings divided by a yard. The stalls where the beasts are knocked down are formed of walls of wrought stone, and are 16 feet wide and 32 feet in length. Each has two entrances: one in the yard, by which the animal enters; the other in the outer side, to permit the removal of the meat, &c. Each stall is provided with a supply of water for cleansing, with a drain, and a windlass and pulleys, by which the carcase can be drawn up to be flayed. Two pieces of timber are placed across the building, at seven feet of height, fixed into the wall at one end, and carried or supported at the other by a stirrup of iron. On these, seven or eight carcases may be suspended, exposed to the air, previous to their being taken to their several destinations. There are pegs and hooks around for the calves, sheep, and lambs. The stalls, as well as the yard, are flagged with thick stones, the joints of which are filled with cement, that nothing offensive may pass through them. The bottom of the doors are cut, so that the air passes under them freely. The roofs project three feet beyond the external walls, which has the double advantage of sheltering the stalls from the sun's rays, and forming a cover for the carts which remove the meat. 2. *Sheds*, for the oxen and sheep on their arrival, where they are housed previous to slaughtering: these are 9 feet in width in the interior—one side being occupied by oxen, the other by sheep, calves, &c. Large stone arches support a floor above, over which are separate divisions for the butchers to stow away the forage which belongs to them. Water is laid on for the use of the cattle. 3. *Melting-houses*, where the fat is converted into tallow. 4. *Reservoirs.*—An abundant supply of water, and facilities for distributing it, is most essential in such establishments. In the five abattoirs, 75,000 oxen are slaughtered in a year, and the mean quantity of water for the service is from 240 to 300 cubic metres per day, to provide which there are two reservoirs to each—each containing 100 cubic metres, formed in masonry, and lined with cement. 5. *Keepers' Apartments.*—At the entrance of each abattoir are two small houses for the persons who have charge of the establishment. 6. *Stables, Sheds, &c.* are provided for the horses and carts, all commodiously arranged. 7. *Sewers* are most carefully constructed of hard gritty sandstone, their dimensions being 3 feet in width and 6 feet in height. To prevent any smell from escaping, a trap is introduced, which answers admirably well. There are also pits for the ordure, which is removed every day.' Such are the abattoirs of Paris; and no town of any importance on the continent is without some similar establishment—as at Nantua, Lyons, Blois, Rochefort, La Rochelle, Brussels, Orleans, Marseilles, Strasburg, &c.

It is much to be wished that some general arrangement like the above were adopted in all our large towns and cities, which at present, so far as the slaughtering of animals and the exposing of their carcases are concerned, are deficient in the extreme. With the finest animals in the world, the largest consumption of butcher-meat, and every facility for the construction of proper shambles, this department of our economy is conducted in a manner at once obnoxious to health, humanity, and decency. Attention is no doubt being directed to the matter, but so many contending interests have to be satisfied, so much ignorance and idleness to be moved, that years must pass by with all the danger, filth, pestilence, and inhumanity of the present non-system. What is desiderated are abattoirs or shambles sufficiently removed from the towns; fitted with the necessary accompaniments, like those of Paris; abundantly provided with water and sewerage; and stringently regulated, as the class to be dealt with are by no means among the most orderly or enlightened of the community.

Markets.—Leaving it for others to decide whether the existing shop-system of our large towns or that of the Oriental bazaar be the more convenient, there can be little doubt that concentrated and commodious market-places for the sale of butcher-meat, fish, poultry, vegetables, fruit, and the like, are highly advantageous for the bulk of the population. Legitimate competition is encouraged, fraud more easily detected, a better choice afforded, and a uniform system of inspection and regulation obtained, which would be utterly impracticable were each country supplier of the raw produce and each town-retailer to follow his own isolated plan. Market-places have accordingly been established in all our large towns; but in most cases they are little better than a collection of open stalls, with little regard to arrangement, supply of water, sewerage, shelter, or ventilation. It is true that London, Liverpool, Newcastle, and Aberdeen can boast of commodious, we were about to say magnificent markets; but these are the exceptions, not the rule of the United Kingdom. 'The great points,' says the authority above quoted, 'to be considered in these establishments, are central position, solidity and strength, convenience, health, and command of water. The strength requisite for an edifice is particularly required in one intended for the public service, and where the slightest accident might be of great importance. Convenience and salubrity require that all who attend should be sheltered from the inclemency of the weather; that the arrangements should be suitable for the provisions bought and sold; every possible means adopted for ventilation; and every precaution taken to insure the most perfect cleanliness. The walls of a market should be carried up a certain height in masonry or brickwork; the lower openings should be provided with Louvre boards, to exclude the sun, rain, and wind, without too much shutting out the light and air. Other openings must be provided under and in the roof to afford light and air. A certain width should be given to the markets, so as not to increase the extent of the outer walls; and pillars internally should not be introduced, as they obstruct and occupy room. Where they are indispensable, they should be of stone or iron, and placed as distant from each other as possible. The width of the building depends upon the number of stalls, which should be in pairs, so that one walk approaches two rows. Experience proves six feet and a half a sufficient width for the walk, and the same for the stalls. A public fountain is indispensable, and constitutes one of the chief ornaments. The architecture should be simple, yet imposing, from the mass, the arrangement, and the proportions. The divisions should be so arranged that all parts should be equally eligible, without any just grounds for preference; nothing should be sold out of the enclosure, that the entrances and streets leading to it may be free from all obstructions. The whole should be cleaned out daily, and shut in at night. When the market is of any extent, certain accessories are necessary—as stores, vaults, &c.—for warehousing unsold goods.'

Market-places possessing these requisites are common on the continent. Those of Italy—Naples, Florence, Bologna, &c.—are highly spoken of. They are in general lofty airy structures, with light roofs supported on colonnades; have paved areas, are well supplied with water, adorned with fountains, and are easily cleaned. The markets of France are also set down as models, especially the new ones of Paris, in which thorough cleanliness, and a systematic arrangement of the articles exposed, are rigidly enforced. Of our own markets, we have instanced those of London, Newcastle, Liverpool, and Aberdeen, as the most unique and systematic. Those of London are Covent Garden for the supply of vegetable produce; Smithfield for bestial; Leadenhall for poultry and game; Mark Lane for corn; Billingsgate for fish, and the minor depôts of Whitechapel, Newgate, Farringdon, and Hungerford. In illustration of these busy centres, that of Covent Garden may be taken as the most systematic:—It derives its name from the circumstance of there having once been a convent, with its garden, on the spot which it now occupies. The site of the market, which is spread over two acres of ground, as well as the ground in its neighbourhood, are the property of the Russell or Bedford family, as is indicated by the number of streets, hotels, &c. which are called from these and kindred names. Previously to 1830, the booths or stands in the market consisted of rough-looking, slightly-built sheds; but in 1828 the legislature took the matter up, and seeing the great public advantage, as well as ornament, to the part of London in which the market is situated, which would result from a suitable stone erection, an act of parliament was passed on the subject, which rendered it necessary that the Duke of Bedford should construct the present building, authorising at the same time the collection of such tolls on the goods sent thither for sale as should, in conjunction with the rents which would be derived from the different shops, and stands, or stalls, insure the noble proprietor a sufficient return for the money expended in the erection. The place was built at an expense of about £50,000, and most ample has been the return received by the duke for his money. It is understood that, reckoning rents, and tolls on articles sent to the market, his yearly revenue from Covent Garden market is from £12,000 to £15,000. The rents vary according to the situation of the different shops and stands. Shops in the middle or best part of the market, possessing a little accommodation in the storey above, individually bring rents of from £60 to £110 a year. And yet such shops are but small; they do not, judging from a glance of the eye, measure more than fourteen or fifteen feet, by about twelve feet. On all wagons, carts, and other vehicles bringing goods to the market, there is a toll, varying according to the nature of the articles brought.

The buildings are handsome, and at the east and west ends, and in several parts of the interior are supported by massy pillars of granite. There are three ranges of shops; the middle, or most handsome range, being double. Between the first and second, and second and third range, there is a large open space, which is occupied by various persons, and with various sorts of vegetables, the parties paying a certain rental per day. This rental varies, according to circumstances and according to situation, from one shilling to fourpence per square foot. The most southern range of shops is exclusively appropriated for the sale of potatoes. In the wide space between this range and the middle range of shops, you see hundreds of persons offering every variety of vegetables used in London for sale. The middle range of shops, which, as already stated, is double—that is to say, there are shops on each side of the thoroughfare—are chiefly used for the sale of all the finer varieties of fruits and vegetables. The remaining, or northern range of shops, is appropriated for the sale of oranges, apples, nuts, and for the sale of gooseberries, cherries, peas, &c. in their seasons.

That of Newcastle, which is still more unique, consists of a quadrangular area of upwards of two acres, all under one roof, and surrounded by the houses of four new streets. It has entrances from the different sides; and on entering it, we perceive that it consists of four principal arcades, crossed at right angles by four equally spacious avenues, the whole lined with open shops or booths, and well lighted from the roof. The length of the arcades is respectively 338 feet. The entire length and breadth has a remarkably neat and clean appearance, expressive of correct taste. In the long and broad arcade devoted to the sale of garden and dairy produce, there are placed at the cross avenues two handsome stone fountains or jets-d'eau, with basins capable of holding three thousand gallons each. It were matter for proud congratulation that all our larger towns had market-places one-half so elegant, so substantial, and commodious.

On the subject of *interment in towns*, which is generally treated in connection with the preceding sanitary arrangements, we need only remark that in no case, and under no pretence, ought the practice to be tolerated, whether by common burial or by the still more objectionable mode of entombment in vaults. It is, however, a gratifying feature of the times, that extra-mural cemeteries of an ornamental kind are every year becoming more numerous; and it would be still more gratifying that these were more frequently constructed upon principles of correct and becoming taste, and that the vault system, which they all less or more endeavour to perpetuate, were thoroughly and for ever abandoned.

AGRICULTURE.

Agriculture may be defined as the art of disposing the soil in such a manner as to make it produce, in the greatest abundance and perfection, those vegetables which are useful to man and the animals depending on him for subsistence. The earth, in a state of nature, unless where chilled by an ungenial climate, possesses a degree of fertility sufficient to produce plants more or less suitable for the subsistence of man and beast; but its spontaneous productions are small in amount compared with what can be drawn from it by industry and intelligence. Savage nations usually rest content with the natural produce, and they are accordingly found to be few in proportion to the surface which they possess, and generally in the lowest state of misery. But wherever man has arrived at a certain stage of civilisation, he has applied himself to cultivate the earth, so as to make it capable of supporting in comparative comfort a larger amount of population.

The earliest efforts in agriculture appear to have everywhere been simple, and limited in their object. The surface was ploughed, the cereals (wheat, barley, oats, &c.) were sown, and such a crop as nature gave was contentedly reaped. It cannot be said that by such a system more was done than merely to take advantage of the natural fertility, in order to raise farinaceous grains instead of the spontaneous herbage. Here, however, agriculture seems to have in every country taken its stand for many ages. It has only been in recent times that men thought of cultivating the soil on anything approaching to scientific principles, so as to *increase the natural productiveness*, and consequently render a given extent of country capable of supporting an increased population.

The rise and progress of agriculture amongst us have unavoidably been much affected by the natural peculiarities of the country. Great Britain and Ireland are islands, having the vast expanse of the Atlantic on the west, and German Ocean on the east, and lie within the 50th and 59th degrees of north latitude. Both from relative situation and latitude, therefore, they are exposed to a variable, and upon the whole ungenial climate. For about five months in the year, or from November till March, the ground is liable to be covered less or more with snow, or to be frozen in its surface; and herbage in either case is so scanty, that unless for sheep, and not always for them either, the open field does not afford nourishment for the stock of pasturing animals required in husbandry, or for the dairy and markets. In a word, vegetable food must be produced in sufficient variety and quantity during the seven milder months, to store up as a provision for the remaining five. This necessarily gives a peculiar character to the husbandry of the British islands, or of any other country similarly situated. Independently of this circumstance, the natural character of the soil throughout is far from being uniformly suitable for agriculture. Some land is good, some is of a medium quality, and a large proportion is positively bad, being in a state of nature no better than an unproductive morass or waste. Hence, under an unskilful system of agriculture, only the good land was cultivated, and a large proportion of the country was totally useless in an economical point of view. In former times, live-stock were either kept in such limited numbers, as to render their amount of winter provender attainable, or they were half-starved for several months while the inclement season lasted.

The improvements which were in time effected to remedy these deficiencies consisted of a series of moves, each depending on the other. Two things were desirable—to increase the extent of culturable soil for grain crops, and to raise sufficient food for bestial all the year round. Now these desirable points involved a thorough change in the practice of husbandry. How was it possible to break up and profitably cultivate indifferent soils, much of which had hitherto been considered beyond all hope of improvement, without an abundant supply of manure? And how could this manure be procured without keeping a large stock of cattle, for which there was evidently no means of subsistence? To overcome these difficulties, it was found necessary, in the first place, to introduce what are called *green crops*—that is, crops of artificial grasses, including clover, turnips, and other roots and plants; for by having a proper supply of these substances two important ends were gained—the support of cattle for manure, and the alternation or rotation of green with *white crops*; thus at once enriching the land, and relieving it from the scourging obligation to raise corn successively. On these main points then, along with plans for thorough drainage, subsoiling, and the application of specific manures, hang the great agricultural improvements of modern times. This course of improvement has been greatly assisted by rearing plantations for shelter, by laying down smooth and accessible roads, and by the general increase of machinery, whereby every process is facilitated, and much waste of time and strength avoided. It is to a brief exposition of agriculture so improved that we intend to devote the present sheet, referring the reader for certain general facts concerning the atmosphere, climate, soils, and vegetation, to Meteorology, Geology, Physical Geography, and Vegetable Physiology.

CHOICE OF A FARM.

In the choice of a farm, attention should in the first place be directed to the nature of the climate; after which the principal object of examination ought to be the quality and character of the soil. From want of attention to this matter, much labour and capital have been spent in vain attempts to grow crops not suited to the soil; and manure has been as improperly applied. This ignorance has also prevented many from improving their lands, though the expense would have been trifling, and the means within their reach. Under Vegetable Physiology (p. 67) we treated of soils generally, and touched upon their chemical properties; we shall now notice them in the order of cultivation.

Soils.

Agriculturally, soils may be classified under the following general heads; namely, sandy, gravelly or stony, clayey, chalky, alluvial, and loamy:—

Sandy soils, or those containing more than 80 per cent. of sand, are not naturally of much value, being liable to be scorched during warm weather, and incapable of affording sufficient nourishment for the heavier varieties of crop. When very sandy, the farmer should be exceedingly cautious in breaking up the natural herbage which ages may have collected on their surface, as the sand is liable to be blown up by the winds, and is long in rearing an artificial herbage of any value. So impressed with the importance of this fact have been the legislators of most countries possessing extensive tracts of sand downs, that laws have been enacted to prevent the pulling up or otherwise injuring the native covering, which is chiefly composed of bent, white clover, bird's-foot, and creeping trefoil. These form a sweet and early pasture; the value of which may be greatly enhanced by an occasional top-dressing of peat-moss and clay. In the vicinity of the sea, sand downs are open during winter, and form a dry, warm, and healthy sheep-walk. Light sandy soils may be permanently improved for tillage by an admixture of clay, marl, silt from pools and rivers, or of vegetable earth.

Sandy loams, or such soils as contain a greater proportion of vegetable and clayey matter than the above, have, since the general introduction of green-cropping and sheep-farming, greatly increased in value. If containing only 50 or 60 per cent. of sand, they are reckoned of good quality; and under a regular course of husbandry, are invaluable. At all seasons they are cheaply cultivated, are not liable to injury from the vicissitudes of weather, and being in general deep, when under liberal cultivation, they retain moisture well. The crops which can be raised on sandy loams are the following:—Turnips, potatoes, carrots, barley, rye, buck-wheat, peas, clover, saintfoin, and all the other grasses. If rather light, potatoes may be a hazardous crop in dry seasons; but for the other green crops and grasses, sandy loams can scarcely be excelled; their yield being clean, nutritious, and healthy. Beans, wheat, Swedish turnips, and other heavy crops, are never attempted on soils of this description.

Gravelly soils are in general called hungry soils, and being of an open porous character, the moisture sinks easily through them. Their fertility depends upon frequent falls of rain, as well as upon a due administration of nourishing manure. They are fitted for the production of potatoes, turnips, barley, rye, and grasses, and where dry and irregular in surface, form excellent sheep-pasture, whether natural or artificial.

Clayey soils present innumerable varieties—those being reckoned *strong clays* which contain from 85 to 95 per cent. of clay, and those *clay loams* which contain from 70 to 85 per cent. Strong clays are of so adhesive a nature, that they often continue moist throughout the driest summer. The plough turns up the earth in huge clods, which are broken with difficulty by the roller; and thus, generally speaking, their cultivation is attended with considerable labour and expense, and requires constant watching for a proper working season. Unless situated in a good climate, and under the care of a judicious farmer with sufficient capital, it is seldom that they produce remunerating returns. After being thorough-drained, turned up to the frosts of winter, and manured with proper composts, they generally assume the character of clay loams, and it is now chiefly in this character that the farmer is called to operate upon them. These soils are well adapted for beans, peas, wheat, oats, Swedish and yellow turnips, clover, tares, teasel, hops, &c.; but are not suited for barley, unless after summer-fallow. Formerly, potatoes and turnips were seldom cultivated on clay soils; but under the modern system of furrow-draining, these crops can now be raised with advantage. Clay soils produce good artificial hay-crops, but seldom good pasture after the second or third year: they are generally unsuitable for the grazing of heavy cattle.

Chalky soils consist chiefly of calcareous matter, mixed with various other substances in greater or less proportion. When clayey or earthy substances are found in chalky soils in considerable quantities, the composition is heavy and productive; when sand and gravel abound, it is light and not very fertile. The crops chiefly cultivated on these soils are peas, turnips, barley, clover, and wheat; and however much the land may seem exhausted, it will produce saintfoin. Chalky soils are in general fitter for tillage than for grazing; for without the plough, the great and peculiar advantages derived from them by saintfoin could not be obtained. English writers on agriculture assert that the plough ought not to be used on the fine chalky downs of Dorset, which, by very attentive management during a number of years, have been brought to a high degree of fertility as grazing-lands, and are extremely suitable for sheep in winter. Chalky soils which have been in tillage allow water to pass through them in winter, and reflect the sun's rays in summer, so that it is the work of an age to bring them into good pasture, more especially if the chalk lies near the surface.

Alluvial soils, produced by slow depositions from water, are generally called *marshes* in England, and *carses* in Scotland. They are composed of the finest particles of soil washed off by running waters, and deposited in low-lying situations, or on the shores of estuaries, where they are formed by the flowings of the tide, and enriched by marine productions. They have generally a rich level surface, and being deep, yield abundant crops of wheat, oats, barley, beans, peas, clover, and tares. Their fertility may be said to be nearly inexhaustible; but from their low and damp situations, they are not easily managed, and require considerable applications of lime. From the peculiar uniformity of the soil of such farms, and the crops grown thereon, their profitable cultivation requires a special training on the part of the farmer; and from the amount of heavy crops, such as wheat, potatoes, &c. grown, the quantity of manure is always much more than can be raised from the farm. Hence, for want of due training, and an adequate amount of capital, arise the numerous failures which have taken place among the occupiers of such land. The tenant of a mixed farm has, let the season be what it may, always some portion of his crop to fall back upon; not so with the carse farmer, for on one or two species of crop his whole success or ruin depends.

Loamy soils present innumerable varieties, and the term *loam* is perhaps the most indefinite in agricultural language. Loam may be generally described as an admixture of sand, clay, and vegetable mould—as moderately cohesive, less tenacious than clay, and more so than sand. Loams are the most desirable of all soils to occupy, being easily pulverised, and except in frost, can be cultivated at any season of the year. They are ploughed with greater facility than clay, bear better the vicissitudes of season, and seldom require any change in the rotations adopted. Above all, they are peculiarly fitted for convertible husbandry, for they can be changed not only without injury, but generally with benefit, from grass to tillage, and from tillage to grass. They are too valuable to lay out in sheep-walks; but for black cattle pasturage they are unequalled, as also for fattening the finer varieties of sheep for the shambles. According to their quality, they will bear any species of crop, and form by far the safest field for the application of specific manures.

In the selection of lands composed of any of the foregoing soils, that should be chosen which is the best of its kind, and most suitable for the crops required in the district. But before coming to a determination, the examination should be extended to the *subsoil*, the nature of which has a powerful influence on the productive properties of that which lies above it. If the land be dry and porous, and the climate also rather dry, the subsoil should be firm, so as to preserve the soil in as moist a condition as possible; but if the land and climate be wet, a porous subsoil is desirable. If the soil be as much as three or four feet deep, the nature of the subsoil is of little or no consequence.

Situation.

The degree of elevation of lands above the level of the sea has a material influence on the kind and quality of their produce. Land in the same parallel of latitude, other circumstances being nearly similar, is always more valuable in proportion to the comparative lowness of its situation. When in grass, the herbage of high districts is less succulent and nourishing, and the growth slower; when in grain, the head is smaller, the plant runs more to straw, is less perfectly ripened, and the harvest is later. In considering the crops to be raised on any particular farm, attention ought therefore to be paid to its height above the level of the sea, as well as to its latitude. It is considered that in latitude 54 degrees and 55 degrees (or about that of Edinburgh), an elevation of 500 feet above the sea is the greatest height at which wheat can be cultivated with any chance of profit. The ordinary height at which common grain-crops can be raised in Britain is from 600 to 800 feet; but in some situations, from particularly favourable circumstances, average crops of barley and oats may be produced at 900 feet, and even higher. In proportion as the climate is improved by sheltering plantations and drainage, the height at which grain-crops may be realised becomes the greater. In general, it is most appropriate to devote high grounds to sheep-pasturage than to tillage; and a consideration of this circumstance should regulate the selection and rent of land.

In making choice of land for farming, it should be a rule to prefer a gently sloping, or level, to a hilly and irregular surface. The labour of working land of irregular surface is very great, independently of other disadvantages; and if taken, it ought to be at a proportionably low rental. If possible, land which lies with an easy slope to the south should be preferred; though, if well sheltered, the inclination in other directions is of little consequence. If the land require drainage, or be exposed to heavy rains, observe if there be sufficient inclination to carry off the water. If there be no lower point to which the water may be conveniently drawn, avoid the risk of taking the land, for this defect in its character will prove a frequent source of trouble and loss. In the case of dry calcareous soils, and in moderately rainy districts, the inclination of the surface and means of drainage are immaterial.

Land on the banks of a running stream is likely to be more salubrious for crops than that which is near sluggish brooks or dull sedgy lakes. From stagnant waters there arise, in certain conditions of the atmosphere, dense pernicious vapours, which steal along the surface of the adjacent grounds, and tend to blight and otherwise injure the crops; and this generally in the summer and autumn months, when the crops are most valuable. Running waters purify the air, and are of great advantage for cattle. See, however, that the land is not liable to be flooded in winter, for a contingency of that nature should cause a diminution in value.

All these considerations respecting climate, soil, elevation, &c. sink into insignificance in comparison with the very important matter of *distance from markets and roads*. A long carriage to market, particularly if the roads be indifferent, is one of the greatest drawbacks which the agriculturist can possibly encounter. Where bad roads interpose, a distance of a few miles is practically as bad as a distance of hundreds where the carriage is easy. Goodness of roads to markets, or to seaports, should therefore form a very important matter of consideration to all intending purchasers and tenants of land. In fact, the best land in the world, without the means of disposing of its produce, or of hiring labourers to work it, is not worth the having.

Size of Farms.

Farms, as to size, are usually divided into—small farms under 100 acres; moderate-sized farms from 100 to 250 acres; and large farms of from 250 to 1000 acres and upwards, of land fit for cultivation. Each of these sizes is adapted to particular districts and other circumstances—especially to the degree of fertility and the amount of capital employed. It is a common but injurious mistake to suppose that the more land a farmer holds, the greater must be his profits. The profit does not arise from the land itself, but from the manner of using it; the best soil may be made unproductive by bad management, and the worst may be rendered profitable by an opposite course. 'Assuming always,' says a competent authority, 'that the expenditure on a farm be directed with judgment, it will be found that the profit upon the outlay increases in more than a proportionate degree to its amount. Thus, suppose that five pounds be the lowest, and ten the highest sum that can be employed in the common culture of the same acre of land, it is more than probable that if the five pounds return at the rate of five per cent., the ten will yield twenty, or any intermediate sum at the same progressive ratio. Now admitting this to be true—and it is presumed that no experienced agriculturist will doubt it—it follows that £1000 expended in the cultivation of 200 acres will only yield a profit of £100, while, if applied to no more than 100 acres, it would produce £200. For this reason, although a farmer of limited capital may not be driven to the extremity we have already supposed, and although he may be able to carry on his business with a certain degree of advantage, it is yet evident that his profit would be increased by diminishing the quantity of his land.'

It is impossible, however, to lay down any precise standard regarding the size of farms, as so much depends on the nature and situation of the soil, the character, skill, and capital of the farmer. In Ayrshire, where dairy husbandry is well understood, and has arrived at greater perfection than in any other part of Scotland, the farms are of moderate size, being in general from 60 to 160 English acres. A farm of about 127 acres is reckoned a good size, and on this from ten to twelve cows are kept. Sir John Sinclair recommends that a clay-land farm should not exceed 380 English acres; and he justly remarks, 'that those who grasp at having farms of a greater extent, where servants are not immediately under the master's eye, lose rather than gain by extending their land. Such a farm as 380 acres may be divided into six, seven, or eight fields, and they may be laid out so as not to extend beyond a reasonable distance from the farm offices. Where the soil is of a light description, a larger extent is necessary, as in such soils sheep and cattle are frequently fed in large numbers; and a farm of this description, of from 600 to 1000 Scotch acres, or 762 to 1270 English, is not considered too large. Where farms are almost entirely employed in pasturage, or in the breeding of sheep or cattle, as is usually the case in hilly districts, there can be no precise limits to their extent; some in the Highlands of Scotland, devoted to sheep-pasture, reach 25,000 English acres.'

The selection of a farm requires the whole ability and experience of the farmer. He must attend to all the advantages and disadvantages regarding it, so that he may fully make up his mind as to the amount of rent he considers it worth, taking care neither to be too cautious nor too rash. There is one common but very erroneous rule which guides the choice of a farm—namely, the success of the outgoing tenant. If he has made money in it, or is leaving it for a larger one, numbers will flock after it, and offer a high rent, without even inspecting it. But if the tenant be unsuccessful, all his misfortunes are attributed to the badness of the land, not to his own mismanagement; and few will be found willing to take the farm even at a reduced rent. These notions are very absurd; for the management of various farmers is so essentially different, that success or misfortune may be said to depend more on that than on either rent or quality of land.

The last advice which may be offered in reference to selecting and also managing land, is not heedlessly to carry prepossessions of what is right in one country to another country in which he may chance to settle. Agriculturists have commonly the reputation of being bigotedly devoted to their early opinions and usages, and this has an unfortunate effect in retarding their success in almost all cases in which they change their locality. Every country, and indeed almost every district of a country, has its own peculiar fashions in agriculture as in everything else, and the meaning of these should always be carefully studied before pronouncing on their error or inutility.

Leases and Rents.

A farm cannot be conducted properly, for the legitimate advantage of either landlord or tenant, except a lease of considerable duration be granted; for if the tenant be at all times liable to be dispossessed at the mere will of the proprietor, he can have no interest in improving the land, and therefore cannot afford to pay a sum suitable to the actual capabilities of the soil. According to the modern practice of agriculture, the profits of a farm are frequently prospective; a number of years must sometimes elapse before the ground repays the farmer for his sunk capital, and his trouble in effecting improvements. The duration of a lease consequently depends on the nature and condition of the soil, as well as some other minor circumstances. It is understood that a long lease is a much greater stimulus to spirited farming than a low rent. If the lease be long, and the rent high, great exertion is used by the farmer; but if the lease be long, and the rent low, a slovenly mode of farming, such as is found under the 'life-leases' of Ireland, may in general be expected. It appears, from all experience in Scotland, that a lease should neither be too long nor too short, but of a moderate duration, as nineteen or twenty years.

The connection between landlord and tenant is that of a disjunctive copartnery. The tenant trades upon a certain sunk capital of the landlord. The question, then, as to what is to be paid in the form of rent, is determined by the value of this capital, and what return it will produce annually on an average of years. From this return the tenant is supposed to draw one share, while the other is handed to the proprietor of the ground. 'The exact extent of these shares respectively is a matter of delicate consideration.' We find it stated in the 'Code of Agriculture,' that where land produces £10, 10s. per annum per English acre, the rent should be £3, 10s.; where it produces £6, 12s., the rent should be £1, 13s.; and where the produce is only £4, 5s. per acre, the rent should be 17s. It will be understood that these estimates are to be made on the aggregate produce of a farm, not on particular fields. With respect to grazing farms, they are let on the principle of how much stock they can regularly maintain; and not being liable to the same expenses for management, both landlord and tenant receive larger shares out of the general product. In some instances, proprietors, from negligence or a wish to retain an undue power over their tenants, delay the renewal of the farmer's lease till the period is almost expired. This is highly injurious to both parties; as, while uncertain if he is to continue on the land, the tenant will naturally be slack in his exertions to improve it, or even to maintain it in a fair condition. This evil might be easily avoided by the proprietor renewing the lease of his tenant a few years before the expiration of the time. In those districts where agriculture is in its infancy, through the ignorance, indolence, or obstinacy of the farmers in general, or of any particular tenant, or where a want of capital will not allow them to improve, it may be necessary for the proprietor to part with some of his tenants. When, on the other hand, a landlord has an intelligent and industrious tenantry, with capital sufficient to cultivate their farms to advantage, he ought to be very cautious of parting with them. Should the land have materially increased in value during the lease about to expire, it will be found most advantageous for the landlord to nominate a judicious valuator, and to offer the farm at the declared rental to the existing tenant, without bringing it to public competition.

In drawing up leases, it is customary to introduce clauses restricting the tenant to certain rotations of crops, manuring, &c. applicable to the few years which precede the termination of the contract. These clauses, and also others respecting the keeping of fences and roads in repair, are sufficient in all ordinary cases. Some landlords may be desirous of prescribing the exact mode of management of their farms; but this has a discouraging and injurious effect, and should therefore be avoided, except in what may be called improving leases, or engagements to improve the land in a certain manner. With regard to the form of a lease, it should commence, says Sir J. Sinclair, 'with the necessary preamble, stating the parties contracting, the situation of the property to be leased, the extent of the farm, a plan of which ought to be subscribed by the contracting parties, the duration of the lease, and the time of entry: it is then proper to enumerate, *1st*, The powers and privileges reserved to the landlord; *2d*, The obligations incumbent on the tenant; and *3d*, The stipulations obligatory upon both. Leases thus drawn up would not be liable to much uncertainty or dispute; and lest any should occur, it is expedient that a mutual obligation for settling by arbiters should be inserted.'

In modern farming, rent is altogether payable in money, or partly in money and partly in grain. The system of grain rents is yearly extending in Scotland, and is highly popular with the tenants, as it equalises in a great measure the risk of bad seasons and low prices between farmer and landlord—not requiring from the former a fixed amount of rental from an uncertain and fluctuating source. Thus, for example, a farm at the nominal rental of £500 a year would be let for £250 or £300 in money, the remainder being payable in so many quarters of wheat, barley, and oats, at the fiars' prices* of the county. When the rental is estimated at so many quarters of these grains, the average of the three is taken, under the title of the *Triple Quarter*; but frequently wheat alone is taken as the convertible grain, and then, as the case may be, nine or ten bushels are given per acre. In order still more to equalise the fluctuations in price—that is, to prevent the rents from rising too high in scarce years, and falling too low in plentiful harvests—it is becoming usual to fix a maximum and minimum price, at which the grain shall be convertible into money when the fiars' prices exceed or fall below them. Thus if the maximum for wheat be fixed at £3, 16s., and the minimum at £2, 10s., it will prevent a ten-bushel rent from falling below £3, 2s. 6d., or rising above £4, 7s. 6d. per acre.

The periods of the year at which tenants remove from and enter farms are very various. In many parts of England, Michaelmas, or 29th of September, is the period for both grazing and arable farms, that being the most suitable on account of the number of great stock fairs at that time, and other circumstances. In Scotland, Martinmas, or 11th of November, is the usual period. It is considered to be a most advantageous rule, that in all cases the removal of an outgoing tenant should be entire, not partial, as bit by bit removals too often lead to disputes between the retiring and entering individuals.

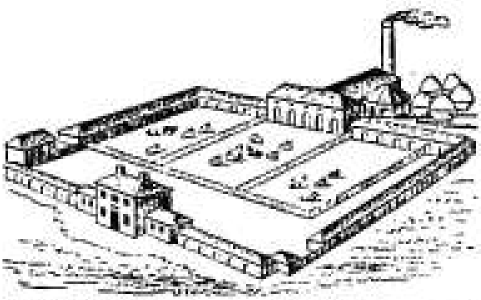
Farm-house and Offices.

Each farm must possess a residence for the farmer, offices adjoining for horses, cattle-feeding, preparation of grain for market, and other necessary purposes; also cottages for the married out-door servants. The whole, for convenience, ought to lie as nearly in the centre of the farm as possible. The comfort of the farmer and his family requires of course particular attention; but one of the chief objects of regard, along with this, is to make arrangements for housing and feeding the cattle, and causing all the liquid refuse to flow into a common centre. To gain this desirable end, offices for a mixed farm—that is, a farm in which both grain-cultivation and grazing are conducted—are now usually constructed on four sides of a square, the farmer's residence either making part of the quadrangle, or, as more frequently happens, standing a little apart.

The following engraving represents the appearance of one of the largest suite of farm-offices, including a dwelling for the farmer. The whole, it will be observed, form a quadrangle, with the farmer's residence in front; feeding-houses for calves and cattle on the left; cattle-sheds in the rear, over which is a straw-room connected with the edifices behind for the thrashing-mill, for which steam or horse power is employed; and on the right, stables, saddle-room, &c. In the centre are three fold-yards, open to cattle from the sheds behind, and into which straw may be thrown from the straw-room. The edifices on each side of the farm-house in front are for cart-lodges, boiling food, lodgings for unmarried male servants, or other pur-

* Fiars' prices in Scotland are the average prices for each county, as fixed by the sheriff with a jury, upon the evidence of the principal buyers of grain within the district. The average is usually struck about the beginning of March for the crop of the preceding year.

poses. A granary is supposed to be connected with the thrashing department. To this brief account of what constitutes a regular farm establishment, such as is



found in the best agricultural districts, we may add the following general observations:—

The size of the stables, cow-houses, feeding-houses, and cart-sheds, will depend on the extent of the farm; but it is proper in all cases to afford ample accommodation in every department. Where there is any danger of fire, the houses should be separated, from above the roof downwards, with strong dividing-walls. Each stall in the stable should be constructed for but one horse; and there should be a small separate stable into which a sick horse might be removed.

It is convenient to place the hay-stack so near the stable as to admit of the hay being thrown at once into the loft, which will save both hay and seed. Where there is no loft, the hay should be stored as near the stable as possible. Feeding-houses are required where either the turnip-husbandry or soiling is practised. These houses should be well aired, and constructed so as to occasion the least possible trouble in feeding, and in being kept clean and dry. Stakes for tying up cattle are placed at a distance of from three to four feet apart, according to the size of the cattle kept. The best way is to fasten the cattle to a chain, attached to a ring which moves up and down on the stake. This prevents them from throwing their heads too high, and incurring the risk of choking upon small turnips. Milch cows require warmth, and the greatest attention should be paid to the paving, draining, lighting, and ventilating their houses. The best constructed cow-houses are those in which the animals are arranged in stalls, with their heads opposite each other, with passages between for feeding, and access to the stalls from behind. Calf-houses, or pens, are usually placed at some distance from the cow-houses, to prevent the calves being heard by the cows. The chief object to be attended to is to keep the calves warm and dry.

A tight drain should be made along and under the passage behind the cattle, having branches at short distances to the gutter, with gratings to let off the urine. The dairy will be described minutely when we come to treat of that important subject (No. 30); and in connection with the brief sketch given of farm-offices, it may merely be mentioned that, of whatever dimensions, they should embrace a boiling and steaming-house, a cart-shed, and house for implements, and a root-house; also stack-yard, granary, straw-yard or pen, dunghill, and a covered tank for the preservation of the liquid manure. The size of the farmer's house will be regulated according to his means and family; and it will be found advantageous to have the houses of the married servants at no great distance.

Arrangement and Management.

With respect to the arrangement and management of a farm, we cannot do better than extract the excellent digest of rules from the 'Code of Agriculture:'—

'1. The farmer ought to rise early, and see that others do so. In the winter season, breakfast should be taken by candle-light, for by this means an hour is gained, which many farmers indolently lose, though six hours so lost are nearly equal to the working-part of a winter day. This is a material object where a number of servants are employed. It is also particularly necessary for farmers to insist on the punctual performance of their orders.

2. The whole farm should be regularly inspected, and not only every field examined, but every beast seen at least once a-day, either by the occupier himself or by some intelligent servant.

3. In a considerable farm, it is of the utmost consequence to have servants specially appropriated for each of the most important departments of labour; for there is often a great loss of time where persons are frequently changing their employments. Besides, where the division of labour is introduced, work is executed not only more expeditiously, but also much better, in consequence of the same hands being constantly employed on some particular department. For that purpose, the ploughmen ought never to be employed in manual labour, but regularly kept at work with their horses when the weather will admit of it.

4. To arrange the operation of ploughing, according to the soils cultivated, is an object of essential importance. On many farms there are fields which are soon rendered unfit to be ploughed, either by much rain or severe drought. In such cases, the prudent farmer, before the wet season commences, should plough such land as is in the greatest danger of being injured by too much wet; and before the dry period of the year sets in, he should till such land as is in the greatest danger of being rendered unfit for ploughing by too much drought. The season between seed-time and winter may be well occupied in ploughing heavy soils, intended to be laid down with beans, oats, barley, and other spring crops, by means of the scarifier. On farms where these rules are attended to, there is always some land in a proper condition to be ploughed.

5. Every means should be thought of to diminish labour, or to increase its power. For instance, by proper arrangement, five horses may perform as much labour as six, according to the usual mode of employing them. One horse may be employed in carting turnips during winter, or in other necessary farm-work at other seasons, without the necessity of reducing the number of ploughs. When driving dung from the farm-yard, three carts may be used, one always filling in the yard, another going to the field, and a third returning. By extending the same management to other farm operations, a considerable saving of labour may be effected.'

To this digest it may be added, that the farmer should habituate himself to keep regular accounts of his affairs, which may be done by means of a cash-book for all outlays and receipts as they take place; a labour-book, in which to mark the commencement and time of work of every individual employed; a journal for entering daily transactions and memorandums; and a ledger, in which a special debtor and creditor account is kept of every department, as well as a general account of the whole concern.

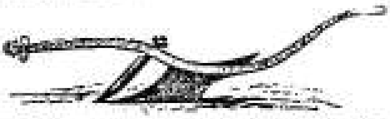
TILLAGE—IMPLEMENTS.

Tillage comprehends the ploughing, cleaning, and fallowing of the fields, with a view to their proper culture and improvement. The object of ploughing is to delve and turn over the soil in the ridges, to destroy the surface vegetation by burying it underground, where it rots and becomes a kind of manure; to bury the dung spread on the land; to form furrows for different purposes; and, generally speaking, to prepare the soil for the processes of cropping.

Ploughing.

Ploughs in old times were exceedingly clumsy in construction, and were dragged with much difficulty. This great defect was at length removed by the invention of the swing plough, about seventy years since, by James Small, a Scotch plough-wright. Small's plough, which is an elegantly shaped instrument formed on scientific principles, was originally composed of wood and iron, and did not weigh altogether above seventy-six pounds; it was afterwards made of malleable iron, and of a light appearance; but latterly the practice of making it of wood and iron has again become pretty general. The chief merit of this plough consists in the fore part being formed in such a slender and tapering wedge-like manner, as to cut the land with the least possible resistance. The mould-board for turning over the furrow is beautifully curved from the point of the sock to the heel of the wrest, so that it turns over the mould fully and with a small degree of friction.

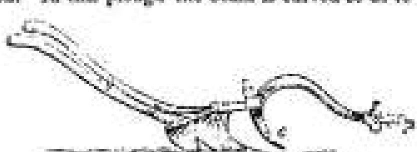
A sketch is here presented of the profile or side appearance of this valuable instrument. The degree



of bend in the mould-board is observed in the next figure, which represents the lower part or sole turned up to view. Small's plough, under different modifica-

tions, is adapted for every species of tillage which the plough is required to perform. In its own proper form it is particularly well suited for light soils, and proceeds actively through the ground, cutting to a depth of from seven to nine inches; but it may be made to go much deeper, if additional power be attached to it. In Scotland, and other countries in which it has come into use, it is almost invariably drawn by two horses, yoked abreast, and is guided and tended only by the ploughman, the reins coming to each handle of the plough. Considerable skill is required to steady and guide this sharp instrument as it advances through the ground; but this is a point on which properly-bred ploughmen pride themselves, and strive to acquire.

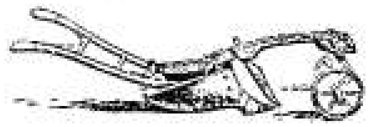
Small's plough may be said to be the parent of all those modern improved ploughs which are strictly adapted to peculiar kinds of work. In its ordinary form it is not very well suited for ploughing up moor or heathy land from a state of nature, as the heath and other tough vegetable matter is liable to collect upon the coulter, and so choke and retard the instrument. To remedy this deficiency, Mr Finlayson, an Ayrshire farmer, about twenty years ago contrived an instrument called the rid-plough, a representation of which is here given. In this plough the beam is curved so as to ter-



minate in the coulter (*c*); and when the heathy matter collects, it is pushed up as the plough advances, and falls off, so as to rid or clear itself of all kinds of loose fibrous rubbish. The sock and mould-board are also so contrived as to cut and lay over the slice, without the power of its springing back to its old position.

There are various kinds of ploughs with one or two wheels, and adapted to particular purposes, but chiefly designed to suit an unskilful class of ploughmen. Wherever agriculture is in an antiquated, backward condition, there wheel-ploughs are in use.

With Small's or Finlayson's plough, a skilful ploughman and a couple of active horses will make excellent work. 'It is not the man who makes the greatest ado with the horses,' we quote Mr Finlayson, 'who opens his ridges best, but more commonly he who goes steadily and directly forward himself, and keeps such a command by the reins, as to prevent them from deviating far from the right path, yet without laying *too much stress to their precision*, or checking them suddenly from one side to the other; and he who can take a straight



furrow at first, and continue so to the last, even on a ridge of fifteen feet, will finish with one, two, or three bouts less than one who is all along undoing and overdoing, and that too independently of the ease to himself and his team, and the preference of the work in every respect. If broadcast ridges are of unequal breadth, bent, or zigzag, the work cannot be so uniform, and in the turnings much time is lost, and harm done to the land which is ploughed; and with crooked drills there is a loss of ground, an unequal distribution of manure, if such has been applied, and the hoeings cannot be so effectually done where they are far distant, or done at all, without suddening the mould and injuring the crop, where they are narrower.

In fine, the grand criterion of ease and proficiency is that of the ploughman walking between the stilts, and in the furrow, with a free step and erect body; for thus he is more convenient for himself, has the horses and the plough better at command, and increases not the friction by his weight; for thus *he cannot go*, excepting the horses and the plough are properly adjusted, and proceeding with the least possible obstruction; and thus too he is more graceful to look on, than when wriggling with one foot foremost, or moving as if part of his muscles were under the domination of some violent spasmodic contraction.

It would perhaps be impossible to give anything like *a system of rules* for the most proper and convenient make, size, weight, turn, &c. of a plough for all the varieties of soil, or of diversity to be met with, even in the same ridge; but a few rules may be laid down, and observed as axioms in all ordinary circumstances—namely, 1. The horses should be yoked as near to the plough as possible, without too much confining, or preventing them from taking a free step. 2. When at work, they should be kept going at a good pace. 3. The chains or theets should, from where they are suspended over the backs of the horses, point in a direction leading through the muzzle to the centre of the cutting surfaces of the coulter and share. 4. The implement, when taking the form of the dimensions required, should stand upright, and glide onwards in the line of progression, without swerving in any particular way. 5. The ploughman should walk with his body upright, and without using his force to one point, or showing appearance of inclination. 6. The untamed and liveliest, or most forward horse, should be put in the furrow, and only bound back to the right or off theet of the land-horse, or at near the place where the back-band joins it, at such length, when stretched at the width required, as to prevent his end of the beam or double-tree from being before the other. And further, the heads of the two should be connected together by a small rope or chain, at the distance wanted, giving the furrow-horse power over the other—that is to say, if tender-mouthed, it must be fixed well up on his head, and in the rings of the bit or curb of the other, so that he may have the power of the head over that of the mouth of the land-horse.'

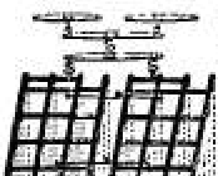
Let the draught of the horses go in a direct line to the plough or swingle-trees; for if the line be in any way bent, a portion of the power will be lost. Sometimes in England as many as five horses are yoked to a plough, two and two, with one in front; and in most cases of this kind the power of the foremost horses is partially thrown away, or probably distresses the hind pair of animals. Two horses will in general do more work yoked abreast to a plough, than four yoked before each other in single file; because some of the power of the foremost horses is always lost in its passage along the sides of the hind horses, and in turning, the whole draught is imposed upon the hindmost in the row. Where four horses must be employed, yoke them two and two abreast, and let the draught of the foremost pair proceed by a chain from their centre swingle-tree to the centre swingle-tree of the hindmost pair, thus passing between the hindmost and going in a direct line to the muzzle of the plough. Never on any account let the power of the foremost pair proceed by two chains along the sides of the hind horses to the outer ends of their swingle-trees, for this would only cause a needless expenditure of draught. In Scotland, where the economising of animal power has been carefully studied, all ploughing whatsoever, be the land light or heavy, except when exerted on the subsoil, is performed with but two horses, and these invariably yoked abreast.

It is a well-known maxim in tillage, that clay or tenacious soils should never be ploughed when either too wet or too dry. In ploughing the first time for fallow or green crops, it is of importance to begin immediately after harvest, or as soon after wheat-sowing as possible, in order that strong tenacious soils may have the full benefit of the frost. On wet stiff soils, frost acts as a most powerful agent in pulverising the earth. It expands the moisture, which, requiring more space, puts the particles of earth out of their place, and renders the soil loose and friable. On such soils there is no rule of husbandry more essential than to open them as early as possible before the winter frosts set in. If left till spring, clay soils may be too wet for ploughing, or if the season be dry, the earth, when turned up, will be in hard clods, very unfit for vegetation. Therefore, on farms having a proportion of clay and of light soils, it is necessary that the strong wet land should be ploughed first, provided the weather will allow.

Subsoil-ploughing is a new feature in husbandry. The object of it is to trench or loosen the soil beneath the ordinary ploughed surface, so as to allow of its gradual assimilation with the mould above, into which it may afterwards be brought. The process of subsoil-ploughing is effected by a powerful instrument, constructed according to the design of Mr Smith of Deanston. As subsoil-ploughing, however, is intimately connected with the 'Culture of Waste Lands,' we postpone any account of it till we treat of that subject in the following sheet. For an account of the proper steps to be taken to drain the land, if in a moist condition, we also refer to the same article.

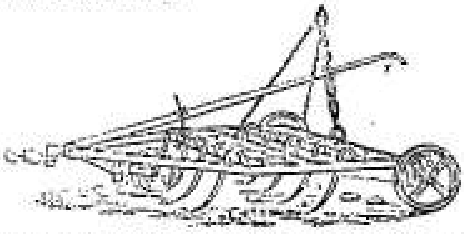
Harrows.—The plough leaves the land cut in longitudinal slices, and is therefore less intended to pulverise the soil than to turn up a fresh surface to the atmosphere. Another kind of instrument is required to break the upturned sward, reduce it to powder, and also to clear it of weeds or other foul substances. The harrow is the implement chiefly employed for this purpose, as well as for covering the seed. According to the diversity of soils, and the particular use to which the harrow is to be applied, its form undergoes considerable modification.

The common harrow is a frame of wood or iron, consisting of at least four bars lengthwise and crosswise, with iron teeth set on one side. Usually a pair of harrows is yoked and drawn together, as here represented.



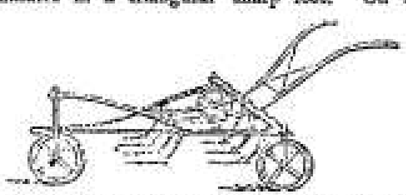
The teeth are set only on the long bars; and the harrows are drawn at such an angle as to preserve the tracks of the teeth in separate lines, and at regular distances from each other. Strong heavy lands require heavier harrows than those of a light nature. In some cases the teeth of the harrow are of different lengths, those forming the front row being half an inch longer than the second, the second a little longer than the third, and so on, diminishing backwards. In drilling crops, an implement called the drill-harrow is employed. A light single harrow is in most instances sufficient for drilling or harrowing over the young wheat in spring.

Where the land is very foul, and calculated to choke the teeth of the harrow, a powerful and effective instrument is now used, called Finlayson's Patent Harrow or Self-cleaning Cultivator. The annexed figure represents its usual construction;—



This instrument is now universally formed of iron, and has, according to the inventor, the following advantages:—1. From the position in which the tines are fixed, their points hanging nearly on a parallel with the surface of the land, the implement is drawn with the least possible waste of power; 2. From the curved form of the tines all stubble, couch, &c. is brought up to the surface and rolled over them—the instrument thus relieving itself in its progress; 3. The readiness with which the cultivator can be adjusted so as to work to any depth renders it of great value, inasmuch as the regulator or lever (*r*) can be moved up and down with the greatest ease, each notch upwards giving the tines an additional depth of 1½ or 2 inches. The axle-tree of the wheels is also capable of being moved up or down by a screw, as represented at *o*, so that the whole implement can be equally adjusted to work at any depth, from 4 to 10 inches; 4. In turning at the headlands, the lever is pressed down to the lowest notch, thereby elevating the front tines out of the soil, and allowing the implement to be easily moved round. There are various modifications of the self-cleaning cultivator in use, according to the taste of the farmer.

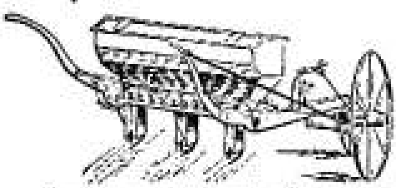
Grubbers, &c.—In certain conditions of the ground, a harrow is incompetent to cut up and clear it of its under-surface weedy matter. In such cases grubbers, eradicators, or scufflers, are used according as circumstances require. The common Scotch grubber resembles a strong harrow frame, running upon four wheels, and guided like a plough. On the lower side of the frame are placed eleven long prongs, each of which terminates in a triangular sharp foot. On being



dragged forward, the prongs scuttle the ground to a depth as great as that of the plough, effectually cutting the roots of weeds, and bringing all loose matter to the surface. The grubber or scarifier, according to the 'Code of Agriculture,' may be used to advantage in the following cases:—'1. Barley and turnip land, after being once ploughed, may be made both clean and fine by its means, and the harrowings and subsequent ploughings thereby rendered unnecessary. 2. Where lands have been ploughed in autumn, the objection to the sowing of spring crops on the winter furrow may be obviated by the use of the scarifier, as not only barley, but oats (if not grain after grass), beans, pease, and tares, may be sown without an additional ploughing. 3. Summer fallows may likewise be advantageously carried on with fewer ploughings, earlier in the season, and at less expense. 4. It may be effectually employed to forward operations in the preparation of land for potatoes or turnips, and afterwards for raising the potato crop; and 5. Its utility in mixing lime or compost with the soil is of the highest importance, as it not only incorporates these manures more effectually than the plough, but never places them beyond the proper depth.'

Sowing.

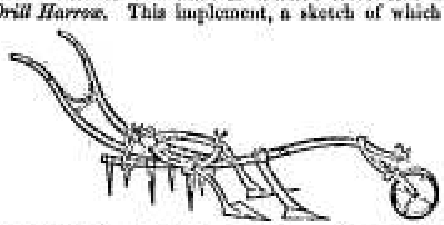
There are various machines for sowing grain, seed for turnips, &c. in drills or rows in the hollow of furrows, on ridges, or on a flat surface, as may be required. For sowing turnip-seed, a barrow on wheels, and pushed along by the hands, is generally used. For sowing grain, one of the best implements in use is *Morton's improved Grain-Drill Machine.*—This ma-



chine, as above represented, consists of a box or hopper supported on a frame with wheels, and is drawn by one horse, and guided behind by one man. The seed escapes from three conductors, the lower points of which act as coulters on the soil, making drills for the seed. In the inside of the box is an axle with projecting teeth, kept in motion by the axle of the machine, and preventing the seed from getting clogged. The seed passes into the conductors through holes, which can be made of any size by means of a sliding board. The width of the coulters admits of being regulated by means of a screw and other apparatus; and five coulters may be used if necessary. A rod projects from the handle half the breadth of the machine (not shown in the cut), to mark the ground, and by this mark the next advance of the machine is regulated.

There are other drill-sowing machines of greater breadth and size, likewise machines for dibbling beans; but they require no particular description. The rollers of wood, stone, or metal, employed to crush or press down the land which has been sown, are so common, that it is also unnecessary to describe them.

Hoes.—The light instrument called the hand-hoe is of use in cleaning turnips and other plants, but is altogether unsuitable for stirring the soil between the rows of extensive crops of turnips, potatoes, beans, &c. This heavy duty requires to be performed by animal labour by means of the horse-hoe. One of the best instruments of this kind is *Wilkie's Horse-Hoe and Drill Harrow.* This implement, a sketch of which is



here presented, is guided and drawn like a plough. As soon as the plants appear above the surface, it is drawn betwixt the rows, thoroughly scuffling or cleaning the land from its numerous weeds. The depth to which its prongs and feathered feet go in the soil, is regulated by elevating or depressing the wheel in front. It likewise answers as a rake, by dragging along with it the heaps of destroyed weeds. Some horse-hoes are fitted with a movable mould-board at each side, by which the earth is heaped up on rows of plants; this is also done by a variety of the plough.

Weeding.

All lands are less or more infested with weeds, which injure the crops by extracting the nourishment from the ground, and greatly impede cultivation by spreading their entangled roots beneath the surface. The manure deposited on the soil is destined exclusively for the support of what is meant to be raised, and every useless plant, therefore, which lives upon it, is so far noxious, and ought to be extirpated.

As prevention is always better than cure, the farmer should begin by preventing the growth of weeds. The seeds from which weeds spring are brought in some manner to the land from somewhere. Try to cut off this vicious produce at its source. Let all banks or natural embankments forming boundaries to fields, be cleared of every species of weeds, such as thistles, docks, ragweed, rank grasses, &c., and let all roadsides near the fields be similarly cleared of their gay but unprofitable vegetation. If this were done generally over the country, a fertile source of foulness in land would be in a great measure destroyed. It is also desirable to sow clean seed for grain or other crops, and to use, if possible, those manures only which are free of the seeds of noxious vegetables.

Notwithstanding all ordinary precautions, lands, it is acknowledged, will develop a crop of weeds, because some weeds will lie uninjured for centuries in the soil, and the winds will waft others from great distances; such, in fact, is one of nature's provisions for covering the earth with vegetation. It has been ascertained that upwards of fifty different weeds infest arable lands, some of which are annuals, others biennials, but the principal part perennials, whose seeds will lie for a long period in the soil. The more common of these various weeds are the wild-oat, the common thistle, dock, coltsfoot, ragweed, dent-de-leon, and charlock or wild mustard, the latter particularly. To these is to be added that most tormenting weed, couch-grass or quick, which spreads its long cord-like roots beneath the surface, weaving the soil into a kind of matting. Annuals and biennials may be partially extirpated by a well-wrought summer fallow, or if the soil be light, by the culture of potatoes or turnips, for the land in that case is well cleaned and dressed in spring, as well as hoed in summer. Hand-hoeing for this purpose is sometimes necessary. If, however, no ordinary process of teasing and cleaning the land extirpate the weeds, the more tedious and expensive operation of hand-pulling by women or children must be resorted to.

This process of weeding may be expensive, but it generally cleans the land, and repays itself by the increase of grain crop. According to experiments adduced by Sir John Sinclair, the increase of a wheat crop on a weeded over an unweeded land was four and a half bushels per acre, and of other crops much more. 'A six-acre field was sown with barley, in fine tilth, and well manured. The weeding, owing to a great abundance of charlock, cost twelve shillings per acre. The produce of an unweeded acre was only thirteen bushels; of the weeded twenty-eight bushels: difference in favour of weeding, fifteen bushels per acre, besides the land being so much cleaner for succeeding crops.' With regard to oats:—'Six acres were sown with oats; one acre ploughed but once, and unmanured, produced only seventeen bushels. Other six acres, ploughed three times, manured, and weeded, produced thirty-seven bushels. Ten bushels may be fairly attributed to the weeding, and the other ten to the manure.' It is justly observed by the same authority, that however anxious farmers may be to have their lands *tithe-free*, it is of greater importance to have them *weed-free.*

Fallowing.

Fallowing signifies leaving the land for a certain time in a bare unproductive condition, during which it receives a rest from the labour of cropping, and is subjected to various processes of ploughing and harrowing, to pulverise the soil, and destroy its noxious weeds, The value of fallowing for these purposes is a subject of considerable controversy; some ascribing to it numerous virtues, and others altogether condemning it, where green crops and good husbandry prevail. The truth seems to be, that fallowing is extremely useful for the purpose of pulverising, cleaning, and otherwise improving lands of a poor quality, after their first subjection to tillage; and that there its value rests.

The operations necessary for a well-wrought naked summer fallow commence after harvest. The first winter fallow ploughing is begun as soon as the hurry of harvest and wheat-sowing is over. If deferred till an advanced period of the season, and the weather sets in wet, the land becomes unfit for the operation. To prevent the bad consequences of too much rain at this period, that manner of ploughing and laying the ridges should be adopted which will best keep the land dry during the winter months, this being a most essential point. Strong retentive soils, to which a summer-fallow is more particularly applicable, should get an end-long ploughing, so deep as completely to turn up the soil from where it mingles with the subsoil or till.

When thoroughly pulverised, and freed from roots and weeds by the process just described, the fallow is ploughed end-long into gathered ridges, which are usually from fifteen to twenty feet broad. When the land is gathered into a furrow as deep as the soil will permit, the manure may be laid on. The manure is carted along the crown of the ridges, and is thrown out into heaps, of a size and at distances proportioned to the quantity intended to be applied; experienced workmen can generally measure both ground and manure accurately with the eye. People are now employed spreading the manure, and the plough immediately follows, in order that the dung may lie exposed as short a time as possible. The dung being covered, and the ridges raised, so as to admit the rain to run freely into the furrows, the land should remain untouched for a few weeks, that the manure may become thoroughly decomposed.

The land may now be considered as ready to receive the seed furrow, which is generally given to it previous to the sowing. The ridge is again gathered; but as this ploughing is very slight, it does not raise the ridge much higher. Lime is frequently applied to fallow as well as dung, sometimes before the dung is laid, and sometimes after. In the first case, the lime is laid on just before the land is formed into ridges, and, if possible, a calm dry day should be selected for the purpose. After the lime is laid, the land should be immediately harrowed, to incorporate it with the soil. The second mode is to lay the lime on just before the seed furrow is made; and if the ground be dry, and the dung decomposed, this will be found advantageous.

The system we have described is referable to the heavier soils; when those of a lighter nature are to be fallowed, the cleaning process is not so difficult, and there is not the same risk from wet weather. If summer fallowing be judiciously conducted in the manner described, strong soils may carry repeated alternate crops of grain and pulse, without any intervening naked fallow, for perhaps six or eight years. But to preserve the beneficial effects of fallow on ordinary farm land, which is manured alone from its own produce, it is certainly the best and most economical plan to lay it down to grass with the crop immediately succeeding the fallow. Afterwards, successive crops of grain and pulse may be taken as its condition will allow, when broken up from lea previous to next fallow. Sir John Sinclair says—'It may be foretold of every farmer on a strong soil, in such a climate as Scotland, that his affluence and prosperity will always be in proportion to the excellent state of his fallows, everything else being equally well conducted.' Indeed, if fallowing is negligently or imperfectly performed, no land, however cheaply rented, can yield much profit.

Carts and Miscellaneous Implements.

Two kinds of machines are in use for conveying produce to market and other purposes in husbandry—wagons and carts—and of these there are several varieties. Wagons with four wheels, and drawn by two or more horses, are acknowledged to be best adapted for conveying great loads to a great distance, and that is their principal merit. For all ordinary purposes connected with husbandry, the one-horse cart with two wheels is preferable.

The Scotch cart, as it is called, is a most convenient and useful machine; and to add to its uses it may be rendered serviceable for carting hay or straw by placing a moveable frame on its sides, as represented here.

The Scotch cart (without the frame) is suited for conveying any kind of material—dung, turnips, grain in sacks, &c.—and usually carries from eighteen to twenty-two hundredweight, when drawn by only one horse; with a horse in trace, the weight may be augmented. In Scotland, all grain for market is carried in these one-horse carts, and to any distance. On such occasions, one driver can take charge of two carts.

The following advantages of one-horse carts are well enumerated by Lord R. Seymour. 'A horse, when he acts singly, will do half as much more work as when he acts in conjunction with another; that is to say, that two horses will, separately, do as much work as three conjunctively: this arises, in the first place, from the single horse being so near the load he draws; and in the next place, from the point or line of draught being so much below his breast, it being usual to make the wheels of single-horse carts low. A horse harnessed singly has nothing but his load to contend with; whereas, when he draws in conjunction with another, he is generally embarrassed by some difference of rate, the horse behind or before him moving quicker or slower than himself; he is likewise frequently inconvenienced by the greater or less height of his neighbour: these considerations give a decided advantage to the single-horse cart. The very great ease with which a low cart is filled may be added; as a man may load it, with the help of a long-handled shovel or fork, by means of his hands only; whereas, in order to fill a higher cart, not only the man's back, but his arms and whole person, must be exerted.' To these just observations it need only be added, that in many parts of England there is a wasteful expenditure in horse power, a couple of horses being often set to draw a clumsy wagon to market, containing a load which could with the greatest ease be drawn by one horse in a less ponderous machine.

Every well-conducted farm establishment is now, or ought to be, provided with a variety of small but useful machines—for slicing turnips or potatoes, chopping hay or peas straw, bruising beans, peas, or oats, weighing-machine, &c.—all which, of the newest construction, are to be seen at the establishments of agricultural implement makers. Utensils for cooking food for cattle, dairy utensils, and tools for manual labour, need not here be particularised.

MANURES.

By repeated cropping, the best soils become exhausted of their fertile properties, while naturally indifferent soils require the administration of certain qualities, before they will yield a due return to the labours of the husbandman. There are, no doubt, soils so naturally rich in some parts of the world, that, though used for twenty or more years in growing successive grain crops, they show no indications of impoverishment; yet even these must in time be exhausted, and therefore, in all circumstances, manures, or artificial fertilisers, require the consideration of the husbandman.

Manures are of two classes, both of which have distinctive characters, and perform different offices in the economy of vegetation. The first of these comprehends all animal and vegetable decomposing matter, and is principally employed in feeding the plant, augmenting its size, and sustaining the vital energy. The second operates more on the soil and decomposing matter, and in this manner contributes to the support of the vegetable. The first kind has been called animal and vegetable, and the second fossil or mineral manures. Under this second class are ranked not only lime, marl, gypsum, sand, and clay, but the so-called *special* manures—nitrate of soda, sulphate of ammonia, phosphate of lime, &c.—which have recently come into use.

The animal and vegetable manures, which are putrescent in their nature, are foremost in importance and dignity. They consist of certain elementary parts of animal and vegetable substances, elaborated by a natural chemical process in the course of the decomposition or decay of the bodies. The excrementitious matter, or dung of all animals, is no other than the remains of the vegetable or animal food which has been received into the stomach, undergone there a partial dissolution, and been thrown out as unserviceable for the further nutrition of the system. From this universal decay of organised matter, and its conversion into fluids and gases, it would seem that animal and vegetable substances, and excrementitious matter, are resolvable into each other, and are only different parts of the same original principles. The essential elements of them all are hydrogen, carbon, and oxygen, either alone, or in some cases united with nitrogen. Conveyed by liquids or moist substances into the ground, these elements are sought for as nourishment by the roots of plants, and so form the constituent principles of a new vegetation. Inasmuch as flesh consists of a greater concentration of these original elements than vegetables, the manure produced by carnivorous animals (man included) is always more strong in proportion to its bulk than that discharged by animals who live only on herbage.

Whatever be the value of the elementary principles of manures, practically they are of no use as manure till they are disengaged by putrefaction. It may be further observed, that putrefaction is in every instance produced by the elementary principles being set at liberty either in a fluid or volatile state. If a quantity of stable dung be piled into a heap, and freely exposed to all varieties of weather, it soon heats and emits a stream of vapour, which is often visible as a cloud over it. These vapours, and also the odours sent forth, are gases escaping, and the heap is constantly diminishing in weight and volume; at the end of six months, if there have been alternate moisture and warmth, not above a fourth of the original essential material remains to be spread on the field; there may be in appearance nearly as much substance, but the fertilising principle is gone, and what remains is little better than a mass of worthless rubbish.

It may be safely averred, that no principle connected with agriculture is so little understood or thought of as that which has been now mentioned. Generally speaking, the excrementitious matters thrown to the dunghill are treated with perfect indifference as to the effects of exposure and drainage away in the form of liquids. It cannot be too strongly stated that this is a gross abuse in farming. The putrescent stream contains the very essence of the manure, and should either be scrupulously confined within the limits of the dunghill, or conveyed to fresh vegetable or earthy matter, that it may impart its nutritive qualities. A knowledge of this important truth has led to the practice of making compost dung-heaps, in which the valuable liquids and gases of different kinds of manure are absorbed by earth, or some other substance, and the whole brought into the condition of an active manure for the fields. Hitherto it has been customary to speak of dunghills, but there ought to be no such objects. The collection of manure from a farm-yard and offices should form a dung-*pit*, not a dung-*hill*; and the manner of managing the contents of this pit on the best method is well worthy of consideration.

Farm-yard Manure.—The situation of the dung-pit should be near the stables and cow-houses, and placed so low, that all streams of urine from them should flow at once into it, but no discharge of rain or spring water should be permitted to enter. It may be three or four feet deep, and of a size proportionate to the stock of cattle usually kept by the farmer. It is not necessary that it should be built round with a wall, or have a perpendicular descent, as it may slope gently inwards, and deepen gradually towards the centre. It may be covered with alternate layers of common soil or peat-moss, so that these may receive the evaporating principles from below, and also prevent the hurtful action of the sun and frosts. If the bottom be found firm, impervious, and capable of containing the juices, no further trouble is requisite, and the work is complete; in many instances, however, it will be necessary first to puddle with clay, and then line the bottom with flagstones. Into this pit earth, with refuse straw, should be brought, and strewed over the bottom and sloping sides, to the thickness of from nine to twelve inches, and this will form an inferior layer to absorb all that portion of the liquid manure which naturally runs to the bottom. The pit is now prepared to receive all kinds of animal and vegetable manure, which, when brought, should be always laid evenly over the surface. On well-conducted farms, such dung-pits are common, and in the course of accumulation, a young or wintering stock of cattle is allowed to go at large upon the whole; the animals being at the same time fed on a proper allowance of straw. Care is also taken to mix, in laying on, the dung brought from the cow-house, stable, and piggeries, so that the rich excrement of the well-fed animals may be incorporated with that of a poorer description. It is likewise of importance, though too frequently neglected, to convey to the pit the entire liquid refuse of the farm-yard, provided the quantity be not so great as to render it advisable to have a separate tank for its reception.

It is customary to cart away the material of the dung-pit at convenient opportunities (usually during the frosts in winter) to a place in the fields, near where it is to be used, and there pile it up in a quadrangular heap of about four feet in height. Dung, carted out in this manner, is ready for the turnip husbandry in June, and the practice is otherwise convenient. It may, however, be stated, that for want of attention to principles already explained, such dung-heaps, by exposure for months to the weather, must lose some of their valuable properties. In every instance, the dung heap in the fields should be placed in a hollow situation, with a substratum of earth, and should have a scattering of a few inches of earth over it, and around the sides, to keep in the volatile gases. When the dung-pit has been thus emptied, it may again be progressively filled as before; and when it is carted out in any of the spring months, it will be found necessary to turn it once, or oftener, for the purpose of accelerating the decomposition of the strawy part of the mass. It may be of use to know, however, that the dung required for fallows for wheat in autumn, may be less putrefied than that for turnip or potato crops.

Liquid Manure, Bone Dust, Guano, &c.—The urine of cattle is of great value as a manure; and this is so well known to the farmers of Belgium, that they use tanks for collecting the liquid from the cow-houses, and thence they pump it up, and pour it over the land at the proper season. When mixed with vegetable refuse, moss, or earth, it forms an excellent compost. It is deeply to be regretted that so little is known on this subject; and such is the carelessness of farmers and cottagers, that the urine from their cattle-stalls is in most cases suffered to go completely to waste. The value of night-soil and human urine as manures is equally great, but both are much neglected in British agriculture. Without entering minutely into details on this point, it may be stated that the offensive odour of all excrementitious matter may be neutralised by an intermixture of gypsum, or of lime and earth, and in this state be used as most valuable manure.—*Bone-dust* is now used as a highly nutritious manure on light soils; and it is reckoned that 100 bushels are equal to forty cart-loads of farm-yard manure. Common sea salt, when judiciously administered in moderate quantities on arable land at the time of fallowing, has been found of great value for its manuring and cleaning properties. It promotes fertility, is a remedy against smut and rust, preserves the seed from vermin, and is particularly useful in increasing the produce of grass lands. The sterile soils of South America are manured with a substance called *guano*, consisting of urate of ammonia and other ammoniacal salts, by the use of which a luxuriant vegetation and the richest crops are obtained. Guano is the excrement of sea-fowl, accumulated for centuries on the islets and rocky shores of arid climates. It is now imported from Peru, Africa, and other tropical regions, into Britain by merchants for the use of agriculturists. The increase of crops obtained by its application to land is said to be very remarkable. According to one authority, the crop of potatoes is increased forty times by it, and maize thirty times. This may be an exaggeration; but it is certain that guano contains ammoniacal salts in abundance, and other inorganic constituents which are indispensable for the development of plants.

Quicklime possesses the power of decomposing animal and vegetable matter, and enters as an element into the fabric of plants; in certain cases it only alters the constitution of the soil. Though occasionally of value on well-cultured soils, the great use of lime is to prepare newly broken-up land for successful cultivation; and on this account we shall reserve consideration of its efficacy for the subsequent number.

CROPPING—ROTATIONS.

Difference of crops successively on the same piece of land is essentially necessary in a right system of husbandry. Crops of the same kind have an exhausting effect, and experience proves that there must be a regular round or rotation, involving in particular a change from grain to green crops. Referring the reader to the article VEGETABLE PHYSIOLOGY for the theory of rotations, we shall merely transcribe the following practical synopsis, as given by Yvard and Pielet:—1. That every plant has a natural tendency to exhaust the soil; 2. That all plants do not exhaust the soil equally; 3. That all plants of different kinds do not exhaust the soil in the same manner; 4. That all plants do not restore to the soil the same quantity nor the same quality of manure; 5. That all plants differently affect the growth of weeds. From these fundamental principles the following conclusions are drawn:—1. However well a soil may be prepared, it cannot long nourish crops of the same kind in succession without becoming exhausted; 2. Every crop impoverishes a soil, in proportion as more or less nutritious matter is restored by the plant cultivated; 3. Perpendicular rooting plants, and such as shoot horizontally, ought to succeed each other; 4. Plants of the same kind should not return too frequently in a circle of cropping; 5. Two plants equally favourable to the growth of weeds ought not to succeed each other; 6. Such plants as greatly exhaust the soil, as grains, should only be sown when the land is in good heart; 7. In proportion as a soil is found to exhaust itself by successive crops, plants that are least exhausting should be cultivated. It may be added, that a change of crops has a tendency to destroy noxious insects, as those which are produced by one crop cannot, in most cases, be supported by another.

Special Rotations.

On Clay Soils.—These soils are of various depths and fertility, and, like all others, differ materially according to the climate in which they are situated. All other circumstances being favourable, good clay soils are particularly adapted for the production of wheat and beans, and may be continued under these crops alternately, as long as the land can be kept free from weeds by drilling the bean crops. This is the most profitable course of cropping that can be followed, providing a sufficiency of manure be procured, and the drilled beans be alternately horse and hand hoed. The nature of the soil or other circumstances may render a crop of clover or rye-grass necessary occasionally for one year, and this can be succeeded by oats. This course may continue for six or eight years, or even longer, and will run thus:—1. Fallow; 2. Wheat; 3. Clover and rye-grass; 4. Oats; 5. Drilled beans; 6. Wheat. In this rotation, to procure full fertility and luxuriant crops, the soil ought to be recruited with manure every third or fourth year, the dung being first applied in the fallow year, and next to the bean crop. Whenever the soil gets foul with root weeds, which it will sooner or later do, another naked fallow must in most cases be resorted to; and this begins a new rotation.

Where circumstances are not favourable to the above rotation, the following may be advantageously substituted. It contains a variety of the crops usually cultivated, and by dividing the labour more equally throughout the year, may be carried on with a smaller number of horses, and consequently at less expense:—1. Fallow; 2. Wheat; 3. Drilled beans; 4. Barley; 5. Clover and rye-grass; 6. Oats; 7. Drilled beans; 8. Wheat; after which a new fallow begins a new rotation. In this rotation, it is absolutely necessary that the land should have dung twice or thrice if possible, to insure abundant crops throughout the course; and the proper periods of its application are—on the fallow before the first crop of wheat, on the clover stubble in the fifth year, and to the beans the seventh year.

A favourite rotation on the strong lands of Essex is —1. Summer fallow, limed; 2. Barley; 3. Clover, first fed and afterwards kept for seed; 4. Wheat; 5. Beans, dunged; 6. Wheat; 7. Oats. It is a rule in Essex never to put in wheat in a fallow. Although two successive crops of white corn are justly objected to, on the best principles of cultivation, yet upon land of this nature both wheat and oats are frequently taken either before or after each other, without doing material injury to the soil. On the strong soils in the neighbourhood of Edinburgh, clover is found not to succeed when sown along with wheat, on which account barley is taken after wheat, and the grass sown along with it succeeds well. In the colder parts of Scotland, beans will not ripen in some seasons, and in these districts the clay soils are uniformly thin and sterile. On such soils and situations, the following rotation may be found to answer:—1. Fallow, with dung; 2. Barley, beans, or oats; 3. Clover, cut in the first year, and depastured for two or three years; 4. Oats; and a new rotation begins. By this method, the rotation is kept up for six or seven years—a period quite long enough, as the pasture on these cold and meagre soils, after the second or third year, will be found of little value; and after this, the soil will rather fall back than improve in fertility. But, as already mentioned, from the practice of furrow-draining, to which, even in exposed situations, these soils are subjected, a fallow crop of turnips is now superseding the naked fallow.

In the south of England, the farmers consider that a clover ley is the best preparation for a crop of wheat; while in the north of England, and in Scotland, clover is more commonly sown with wheat or barley, and followed by oats, both because the oats are almost invariably found to produce a large return after clover, and from the wheat being better placed in the succession immediately after the fallow.

On Loams.—Clayey loam, and loamy soils, in the rotation of crops, may be ranked as clay soils, and cropped exactly in the manner already explained, even though they should approach to the nature of light lands, from which they only differ in degrees of quality. The mode of managing rich loam depends upon the nature of the subsoil. If this be retentive, and not furrow-drained, the soil will require to be subjected to a naked summer fallow every six or eight years, to free it from root weeds; and in this case, the steps of the rotation will be similar to those already described as suitable for the best clay soils. When completely furrow-drained, or if the soil lies on a porous bottom, a fallow crop of drilled turnips or potatoes will be found an effectual cleaning; and from the great value of these roots, they are in every way preferable to naked fallow. The rotation may then be as follows:—1. Turnip fallow; 2. Wheat, on such parts of the land as are freed from the turnips in time for that crop, and barley or oats on the rest: 3. Clover and rye-grass; 4. Oats after grass; 5. Drilled beans; 6. Barley; 7. Clover and rye-grass; 8. Oats; and this to be succeeded by turnips, or other green crop, to begin a new rotation. Some stop at the sixth crop, and make it wheat instead of barley, and then commence with turnips. Where beans are not wished to be grown, the following have been found to be advantageous rotations:—1. Potatoes, with manure; 2. Wheat; 3. Turnips, with manure; 4. Barley; 5. Clover and rye-grass for hay: or, 1. Potatoes, with manure; 2. Turnips, with manure; 3. Wheat; 4. Barley; 5. Clover and rye-grass for hay and pasture: or, lastly, 1. Potatoes, with manure; 2. Turnips, with manure; 3. Wheat; 4. Barley; 5. Clover and rye-grass for hay; 6. Oats. Comparing the returns of these three rotations, they stand in relative value to the farmer as 21, 23½ and 16.

On Light Lands.—The general principles of management for this description of soil are precisely the same as those already described, and every rotation should be established on a well-wrought and well-dunged turnip fallow. The course of crops best suited for these light soils is—1. Turnips in drills; 2. Wheat or barley; 3. Clover and rye-grass; 4. Oats; and round again to a new rotation. On good turnip soils this rotation may be repeated indefinitely, providing the turnip crop be eaten on the ground, that the grass crop be pastured, or that the manure derived from the hay be returned to the ground. It will be necessary, however, to introduce occasionally the alternate system of pasturage; for without this, even with the most liberal treatment, it will scarcely be possible to keep up the fertility of the soil.

On good turnip soils, when what is produced on the farm is the only manure used, the following rotation may be found advisable:—1. Turnips; 2. Wheat or barley; 3. Clover and rye-grass; 4. 5. and, if necessary, 6. Pasture; 7. Oats; and round again. When manure is within reach, alternate white and green crops may be followed for a number of years, in this rotation:—1. Potatoes or turnips; 2. Wheat; 3. Drilled beans or peas; 4. Wheat or barley; 5. Potatoes or turnips; 6. Wheat or barley; 7. Clover and rye-grass; 8. Oats. The advantage of this course is, that it secures a good crop of clover; but wheat occurs too often.

In the vicinity of London, Edinburgh, and Glasgow, the rotations are frequently:—1. Potatoes; 2. Wheat; 3. Clover and rye-grass. By some, the clover is followed by oats, and the rotation again begins; others end the rotation with clover. Even with the manure which these short rotations secure to the soil, occasional pasturage must be had recourse to, if the soil appear in any way exhausted.

On Sandy Soils.—These soils require the most liberal cultivation to produce either grain or green crops; for in the event of dry weather they become so parched as to be unfit for the growth of almost any species of plant. When well manured, sandy soils produce good crops of potatoes or turnips; if possible the latter should be consumed on the ground by sheep or cattle. It is difficult to make these soils too rich, and from their nature, all the manure given them is soon consumed. Wheat, beans, or peas, do not succeed; barley, oats, and rye, are the only grain crops which yield a profitable return on these soils; and pasturage for a term of years is absolutely necessary. The following six years' rotation has been recommended for these soils:—1. Turnips, with dung, which are to be consumed on the ground by sheep; 2. Barley or oats; 3. 4. 5. Grass pastured by sheep; 5. Rye or oats.

On land situated in exposed and remote districts, the only grains which are cultivated are early varieties of oats, bere or bigg, and potatoes, as a change of seed for the more genial and fertile grounds. The following course of crops, proportioning the quantity sown to the manure supplied to the turnips and potatoes, may be followed in such situations:—1. Oats from old ley; 2. Turnips and potatoes; 3. Oats, barley, or bigg, sown with clover or grass seeds; 4. Hay; and then restored to pasture. The rotations *on peat and moorish soils* will be treated in the subsequent number.

White Crops.

By white crops are meant those which, like wheat, barley, oats, and rye, assume a whitish appearance as they approach to maturity. They are called *white* in contradistinction to clover, rye-grass, turnips, &c. which are made use of in a green state, and therefore known as *green crops*. Wheat, barley, oats, rye, and other bread corns, are also known by the name of *cereals*, from the Latin *ceres*, corn; and this term is used to distinguish them from beans, peas, vetches, and the like, which rank under the appellation *leguminous*.

Seed-Sowing.—In choosing seeds, there are three rules which should be attended to:—1. That the variety to be sown is suited to the soil and climate; 2. The propriety of occasionally changing the seed; 3. That the seed has the appearance of being sound. All seed should be allowed to arrive at full maturity before being sown, for the nourishment which the seed must yield to the plant in the first stage of growth can never be so great when this is not the case. The best cultivators choose the finest qualities of each species for seed; sowing them on the land best adapted for their growth. Some varieties are remarkably attached to particular soils, and certain degrees of fertility and moisture seem to suit them best. Others require a greater degree and duration of heat, and frequently take four or five weeks longer to ripen. Early sowing of these sorts ought to be resorted to. Too sudden a change in climate and situation is hurtful; hence Yorkshire seed has been found to answer better in Scotland than that brought from Essex. Many varieties may be introduced gradually, which would not answer if their habits were not a little consulted.

The oldest established mode of sowing is by *broadcast*, or scattering the grain from the hand over the land which has been prepared for it. But this plan is not so economical, or otherwise so valuable, as sowing in drills by machines. In Scotland, the usual method of sowing broadcast consists in the sower walking along the ridges, and at very regular intervals, so as to keep time with his steps, throwing a handful of grain before him by a wide sweep of the arm. He carries the grain in a sheet, which is slung round his neck, and is open to the hand in front. A servant attends, to afford fresh supplies at the end of the ridges.

Wheat is the most important of all the grains, and its varieties are numerous. Among those now in cultivation, the following may be enumerated:—The bearded, the Dunglass, the golden ear, the velvet ear, the egg-shell, the hedge-wheat, the Essex dun, the Kentish yellow, the white and red Essex, the Mungoswell's, the Burwell red, the Hunter's, and the Georgian. A general division of wheats is made into white and red, with several shades between, and summer and winter. Winter wheat may be brought into the nature of summer, by altering the time of sowing. If winter wheat be sown at the period for putting summer wheat into the ground, in the course of two seasons the winter will become of a similar habit as the summer, and the same process will bring a summer wheat to be a winter one. In general, the fine white wheats are preferred to the brown and red; but the latter is most profitable for wet adhesive soils and unfavourable climates, on account of its hardiness and ripening early. The variety of wheat most profitable to be produced must depend upon the nature of the soil, as land which has produced an indifferent crop of one may yield an abundant crop of another kind; and land is frequently found to yield better crops if the varieties be alternately changed. The richer description of clays and strong loams are the best adapted for the production of wheat; but if properly cultivated and well manured, any variety of these two soils will produce excellent crops of this grain. Good wheat land ought always to possess a large quantity of clay, and little sand; for although light soils may be made to produce good crops, yet the strong clay lands in general yield the heaviest grain.

'The season for sowing wheat'—we quote the General Report of Scotland—' is necessarily regulated by the state of the land, as well as of the season; on which account it is not always in the farmer's power to choose the moment he would prefer. After fallow, as the season allows, it may be sown from the end of August till the middle of November. On wet clays, it is proper to sow as early as possible, as such soils, when thoroughly drenched with moisture in autumn, are seldom in a proper state for harrowing till the succeeding spring. In the opinion of many experienced husbandmen, the best season for sowing wheat, whether on fallow, rag-fallow, or ploughed clover stubble, is from the beginning of September to the 20th of October; but this must depend upon the state of the soil and weather. On dry gravelly loams, in good condition, after a clover crop, and well prepared, wheat may be sown till the end of November. After turnips, when the crop is consumed or led off, and the ground can be properly ploughed, wheat may be sown any time betwixt the 1st of February and the middle of March; and it is customary to plough and sow the land in successive portions as fast as the turnips are consumed. It is only on turnip soil of a good quality, verging towards loam, and in high condition, that winter wheat, sown in spring, can be cultivated with success. When circumstances are favourable, however, it will generally happen that such lands, when wheat is not too often repeated, will nearly produce as many bushels of wheat as of barley. The wheat crops, therefore, on an average of seasons, will exceed the value of the barley crop considerably; hence its culture is an object which ought not to be neglected.'

Wheat is liable to certain fungous diseases, as, for example, smut, mildew, or rust, &c. With the view of preserving the grain from these most injurious disorders, it is customary to prepare the seed by steeping or pickling it in a kind of saline brine, or diluted urine. Steeping or pickling is performed after the seed has been washed, by allowing it to lie for a time amongst stale urine, diluted with water, or salt brine, of sufficient strength to float an egg. The seed is put into tubs, containing as much liquid as will cover the grain a few inches, and allow it to be well stirred, so as to bring all the light grains to the surface, which are skimmed off as long as they continue to rise. Another way is to put the seed into baskets, which are immersed in the water, are easily taken out, and can be conveniently placed over an empty tub to drain. The seed is left for three or four hours in the chamber lye, or full six hours in the pickle, after which the liquor is drawn off, and the wheat spread thinly on the floor of the granary, where it is well sprinkled over with quicklime slaked in the liquid. About half a peck of lime is sufficient for a bushel of wheat, and it should be well stirred, so that every grain may get a portion. If the seed is to be drilled, it should be passed through a coarse sieve after being limed, which will facilitate its progress through the machine. The grain will thus be quickly dried; and it should not lie more than six hours in the heap, then be spread out, and sown on the following day.

Some caution should be used in having the lime properly slaked, for if this is not done, too great a heat may be raised, which will destroy the vegetative principle. Doubts have been expressed of the efficacy of lime, and a solution of copperas is used on the Continent instead. Dry powdered lime would certainly have no effect, but when newly slaked it is very efficacious, as has been proved from experiment. It was found that a steep of lime-water alone, in which wheat was immersed for four-and-twenty hours, proved a powerful preventive of disease, while the good effects of unmixed brine were very inconsiderable.

Of the two kinds of steeps mentioned, urine is thought the most efficient, and it should be used neither too fresh nor too stale, as in the first state it is ineffectual, and in the second injurious. The seed should be sown as soon as dry; for if allowed to lie in sacks or heaps beyond a day or two, the lime may be very hurtful. Another steep, which is recommended by Sir John Sinclair, and is much used in Flanders, France, and Switzerland, is a weak solution of the sulphate of copper, or blue vitriol. The modes of using it are as follow:—Into eight quarts of boiling water put one pound of blue vitriol, and while quite hot, three bushels of wheat are wetted with five quarts of the liquid; in three hours the remaining three quarts are added, and the wheat is suffered to remain three hours longer in the solution. The whole should be stirred three or four times during the six hours, and the light grains skimmed off. After the wheat is drained, slaked lime is thrown on it to facilitate the drying.

Rye is usually sown on light soils, and does not require so much care as wheat; it suffers less by being sown on the stubble of another corn crop, or upon its own, and it is not unusual to grow it on the same land two years in succession. This grain is frequently sown to be cut for soiling instead of winter tares, and in England it is frequently used for early sheep-feeding, cut green, without obtaining a grain crop from it. It is extremely useful to breeding flocks, as it comes forward earlier than tares, and affords good food when other sustenance is scarce.

Barley is a much hardier grain than either wheat or rye. There are six varieties of this grain, distinguished by the number of rows in the ear, four of which are cultivated in Britain. The kinds which have been recently introduced into Scotland are the Chevalier, Annat, and other sorts; but the two-rowed and four-rowed, called *berè* or *bigg*, have been most extensively cultivated. In its culture, barley requires a clean, rich, mellow loam, moderately retentive; and on clays, tempered with sandy mould, or containing a certain portion of chalk and sand, it is found to succeed well. On poor wet soils it is never successful; and every kind of land on which it is cultivated should be well wrought and thoroughly pulverised. If the preceding crop has been wheat, the land should undergo three ploughings before barley is put into the soil. Barley usually follows turnips in the rotation, but it is found to grow very well after potatoes. It is thought best to have the turnips eaten on the ground when this can be accomplished; and if the preceding crop has been potatoes, the land should be well ridged up, in order to have it as dry as possible. The application of lime and earth, earth and dung, or urine, is thought of great advantage to the barley crop, and even to plough in the turnip leaves is beneficial. If the plough is not sufficient to pulverise the land properly, the harrow and roller ought to be used to accomplish this. In most cases, more than one ploughing is given, but after a winter furrow the grubber may be used instead. When turnips have been consumed on the ground, it is much trodden down, and will require two ploughings; if this is not given, the soil should be well harrowed and rolled. Barley should be sown as soon after ploughing as possible, when the land is fresh and moist, in order to obtain equal and speedy vegetation. The best season for sowing barley is from the beginning of April to the middle of May; but it has been sown a month after this with success. The bere or bigg sort is sometimes sown in October, and called winter barley.

In Scotland, clover and rye-grass are sown immediately after barley, and the seeds are covered by the last harrowing; a light grass harrow being sometimes used for the purpose. Rolling is practised by some immediately after, while others prefer allowing the plants to come above ground; the small clods in this case act as a shelter to the plants, which is of great service in frosty weather.

The oat is suited to climates which are too cold for wheat or other grain crops, and therefore thrives in high regions better than in low-lying countries. When land is broken up, either from a state of nature or from pasture, oats form the first crop, as they may be repeated for a series of years without injuring the soil. They are also the best crop to follow clover, and are sometimes sown with clover and grass seeds. They often follow potatoes and green crops, and in either of these cases, the land should be well ridged up in the winter. When the seed is sown, the land should be completely harrowed, and then rolled across the ridges. A mixture of oats is generally sown along with tares, to prevent them from falling and rotting on the ground. In this state they are cut green, and form an excellent food for cattle and horses. A change of seed from hot to cold, and cold to hot, is always to be recommended; and the quantity of seed must depend on the nature of the soil and the variety to be sown. On poor soils, from the plants not spreading, oats should be sown thick. The Hopetoun, and many other varieties, do not tiller out, and therefore require more seed to be sown. The quantity of seed necessary varies from four to seven bushels per imperial acre, and broadcast sowing is that generally practised.

The usual time of sowing is from the beginning of March to the end of April; early sowing is to be preferred, as the grain is of better quality; but late sowing produces the greatest bulk of straw. The produce differs materially according to the soil, climate, and the fitness of the particular variety for the land. The maximum quantity, soil and climate being favourable, may be estimated at seventy bushels, and the minimum twenty bushels per acre; the average being about four quarters. Oat straw is preferred to any other as fodder for cattle, as it is considered more nutritive.

Green Crops.

No farming can be said to be perfect unless it involves a due alternation of *green* with *white* crops. The more foul the land is with weeds, green crops of the drill kind are the more necessary, because, in the course of cultivating green crops, we have an opportunity of hoeing and trenching the land, not only once, but repeatedly, and of thus exhausting the seeds of weeds lodged in the soil. By administering manure, and this mode of cleansing, the necessity for *fallowing* is in a great measure obviated. But green crops also fulfil the important purpose of feeding live-stock and producing manure. The constant exhaustion of the soil, be it even very fertile, demands a periodical nourishment, and this is best done by means of live animals. It is customary on the well-organised farms of Norfolk, East-Lothian, &c. to manufacture manure on a large scale by means of *soiling*; that is, feeding cattle in houses or an open yard with turnips, the cattle at the same time treading on the waste straw of the farm, and thus using up a material which would be otherwise lost. Sheep are also turned into pens on turnip-fields, to eat up the turnips from the drills, and the droppings greatly enrich the spot. It is customary in Scotland for low-country farmers to buy cattle lean at the end of autumn, and sell them fatted to a certain extent in spring; and all this trouble is taken principally for the sake of their manure.

Beans require the same sort of soil as wheat—namely, heavy clays—and should be sown in drills. Some suppose that beans exhaust the soil; but this is scarcely probable, from wheat always yielding a good crop after them. In preparing the ground for beans, it ought to be ploughed after harvest, or early in winter, that the soil may be mellowed with the winter frosts. The furrow should be deep, but before sowing the land should be drained of its superabundant moisture. Sow as soon as winter is over, or never later than the end of March in Scotland. Four bushels of seed to the acre are sufficient; but it is common, for the sake of improving the fodder, to mix peas with the beans, to the extent of one bushel of peas to six of beans. Beans require frequent weeding with the horse-hoe. The crop, if late, should be carried to another field to dry, and thus make way for the wheat crop.

Peas grow best when mixed with beans, as they by that means gain a support for their slender trailing stalks. They, however, grow on a poorer soil than beans, such as a sandy loam, and neither too moist nor too dry. They are improved by lime and marl manures. Drilling, as in the case of beans, is greatly preferable to broadcast; and from four to five bushels of seed per acre is reckoned a proper allowance. The early kind of peas may be sown at any time till the end of May, but the late must be sown in February or March.

Tares or vetch are a valuable crop, both for soiling and feeding cattle. Tares are of two sorts—winter and summer. The seed of the summer tares should be put into the ground at intervals, from the end of March to the end of May, so as to furnish successive cuttings. The winter tare requires to be sown in September or October; and in early spring it is a very valuable food for cattle and sheep.

Clover and *Rye-grass* are the most valuable artificial grasses that can be grown by the farmer. They should never be sown except when the land is in the best condition; if possible, with the crop immediately following a summer fallow, or after turnips or potatoes. Thus in all well-manured and well-dressed land, clover and rye-grass are mixed with the crop of grain, being either sown at the same time or at a suitable period after. When the grain crop is cut in harvest, the tops of the young clover are perhaps cut at the same time, but this is of little consequence; the great bulk of the grass crop comes into maturity among the remaining stubble, and is then either scythed for hay or for feeding animals in a green state. When sown on land on which grain has been sown, it is customary to roll the ground, to assist in covering the light seeds. Great care requires to be employed in choosing proper kinds of clover and grass seeds, as there are always many worthless sorts in the market.

Many farmers, on purpose to prolong the rotations, and prevent the too frequent repetitions of the clover crop, substitute a crop of peas or tares after the barley, sowing the clover after the wheat or barley in the next rotation, which makes the time between the two clover crops to be seven instead of four years. The crop of peas they consider as by no means remunerative, yet, from the additional crop of clover reaped in the second rotation, they find themselves compensated for the deficiency in the peas. Surface applications are now administered on an extensive scale in improved districts, for the sole purpose of procuring an abundant crop of clover and rye-grass. Soot is one of the ingredients which is applied, and has uniformly the effect of strengthening and forwarding the crop. Liquid manures are also extensively used, and are much more lasting in their effects, and seem better adapted for clover, than soot. Saltpetre is likewise much employed, and forms an excellent top-dressing for seedling grasses. It is by such means as these that the agriculturists of the Netherlands have been able to keep up the fertility of their lands, in the cultivation of clover, through time immemorial. The whole of the agriculture of the Netherlands rests upon the cultivation of clover, which not unfrequently yields a heavy crop the first year; two and even three abundant crops the second; and, if allowed to stand another year, will yield a good crop, and afterwards be excellent pasture for cattle, till ploughed up to receive wheat seed.

Turnips yield a most profitable crop for the maintenance of live-stock; and they are also useful as a green crop, by permitting an effectual cleansing of the land from weeds. The leaves being large and spreading, they afford a shade, which retains the moisture, and tends to decompose any vegetable matter in the ground. Turnips are divided into various classes, in each of which there are several varieties. The more common classes are the round or globe-shaped; the depressed or Norfolk; and the fusiform or oblong, the latter being better known by the name of Swedish. They are also sometimes known by their colour—as the white, the yellow (including the Swedish), and the purple-topped. The white, with the purple-topped, is early, particularly suited to those light soils where sheep are fed, and requires less manure. It must be consumed, however, as soon as possible, or is apt to run to seed, or to be injured by frost. Upon the whole, the Swedish is now preferred to most others, and yields the heaviest crop. It requires to be sown early, or from the beginning of April to the end of May; the seed should be given liberally, or at the rate of about three pounds per acre. In all cases the sowing ought to be in drills, to permit an effective hoeing when the crop is getting up. After being sown on a well-ploughed field, the roller must be employed to press all smooth on the ridges. The plants will in general make their appearance about ten days or a fortnight after they are sown, according to the quality of the soil and the state of the weather. When the leaves are about two inches high, a horse-hoeing is given between the ridgelets, to cut up the weeds close to the plants. The hand-hoe is then introduced to thin the crop, leaving plants standing at intervals of from eight to ten inches apart, the Swedish kind being somewhat wider. This distance is thought quite sufficient to insure plants neither too large nor too small in size. The soft turnip, when allowed too great a distance, is apt to become very large, and its nutritive juices are found to be quite lost. The Swedish and other hard turnips should be allowed sufficient room to become as large as possible, for their nature is such that there is no fear of their ever being over-bulky. The hand-hoeing and thinning are generally performed by women and boys, and three expert hoers will go over an acre a day. A few days after the hoeing, a small swing-plough is used to make small ridgelets between the rows; and when weeds are still in abundance, it will be necessary again to horse or hand-hoe the ground, which levels the intermediate ridgelet. After all weeds are thoroughly destroyed, and the thinning is accomplished, the earth is sometimes gathered up about the plants by means of a small plough with two mould-boards. This operation, however, is objected to, on the plea that the earth prevents the bulbs from growing, and also when the produce is to be consumed on the ground, the sheep may be injured by falling into the hollows between the rows. On wet soils, the earthing-up is very beneficial, as it allows the free discharge of superabundant moisture; and when the weather is frosty, the earth is an excellent protection to the plants.

Turnips may either be consumed on the fields where they grow, in grass fields, in fold-yards, or in feeding-houses; and in the vicinity of large towns they are sold to cowfeeders. *Mangel-wurzel* or field beet and carrots are both now introduced with advantage as a variety in green husbandry, and either in a raw or dressed state, afford a highly nutritive food for cattle and horses.

Potatoes usually enter into a course of husbandry, particularly in the neighbourhood of populous towns, where a ready market can be obtained. The usual period of planting in the British islands is the end of April or beginning of May, for the late and more common sorts. The early kinds, which are not kept for permanent stock, are planted in March. The potato harvest is in October or beginning of November. It has been customary to plant by sets or cut pieces of the potato, each having an eye or point of germination; but the numerous failures of the crops have introduced the practice of setting the whole tuber. In the large farms of Scotland, they are set in drill furrows (previously well manured), at a distance of eighteen inches apart, and six inches of earth is turned over upon them by the horse-hoe. When the plants appear above the surface, they are repeatedly earthed as may be required; this, with the weeding of them, is done by hand-hoeing. Potatoes are very susceptible of diseases, which cause failures of crop; but there is reason to believe that this arises from some kind of mismanagement or accident—as, for example, producing again and again without change of seed, lifting of seed after frost, rot from wet seasons, heating of heaps after lifting, &c. The preventives of disease, likely to be most successful, are—frequent changes of seed, bringing seed from quite a different soil, not too frequent cropping from the same land, spreading out to dry after lifting, and careful protection from frost during winter. They are best preserved in pits, a layer of potatoes and earth alternately to a height of four feet, and finally covered with earth on the top and sides.

Haymaking.—When the grass has arrived at or near its full growth, but before the seed is perfected, it should be cut down by the scythe for hay. A short time after being mown, it should be turned over in full swathes, without being scattered. If not in a fit state to be cocked the first day after cutting, it should be put into small handcocks as soon as its state of dryness will allow; from these it should be gathered into larger ones, and when its condition permits, put into tramp ricks. The gathering of the hay is generally performed by women and boys, some carrying, and others raking up what may remain. Let it be remembered that the less the hay is exposed to the sun, the better is its flavour and strength. In wet seasons, the utmost care will be required not to stack the hay while moist; for then, like moist sheaves of grain, it will heat, and either burst into a flame, or be seriously damaged in quality. The criterion for good hay is, that it should be greenish in colour, be perfectly dry, and possess a sweet odour and saccharine taste.

REAPING—HARVESTING.

The ripeness of grain is shown by the straw assuming a golden colour from the bottom of the stem nearly to the ear; or when the ear begins to droop gently, the corn may be cut. Although the straw may be green from the ear for some distance down the stem, yet if it be quite yellow at the bottom, and for some distance upwards, the grain requires no farther nourishment from the earth, and if properly harvested, will not shrink. These indications of ripeness may suffice for wheat, barley, and oats.

Reaping.—It was formerly the practice to cut grain with a saw-edged sickle; but this has given place to a larger instrument, with a smooth edge like a scythe. The reapers are usually divided into bands of six or seven, with a binder to each band. When the ridges are less than eighteen feet broad, three reapers are usually placed upon each ridge, the middle reaper making the bands with which the sheaves are bound up. When four reapers are placed upon one ridge, as is usually the case when the ridge is eighteen feet broad, two bands are laid upon one ridge; and two are enabled in this way to manage twelve reapers, placed on three ridges, stooking the corn all in one row upon the middle ridge. When the crop is very strong, however, it is often found necessary that each binder should stook by himself. In harvesting oats and barley, each shock or stook is formed of ten sheaves placed in two rows, the head of each sheaf leaning upon the opposite one, and a sheaf on the top at each end. They stand usually due north and south, so that each side may receive equal benefit from the sun. The straw of wheat being longer than that of oats and barley, the stooks of the former are made larger, having six sheaves in each row, and one on the top at each end. When the crop is thin, half stooks are frequently set up; and to forward the drying process, the end sheaves are now generally omitted when the weather is good; but this should never be done where the climate is uncertain, as it exposes the corn to rain.

Oats and barley are now frequently cut with a scythe, which is either plain or furnished with a bow or cradle, in order to lay the grain evenly in one direction. Wheat is almost universally cut with the sickle; and if the weather keep good after this operation is performed, it will be ready for stacking in the course of five or six days. Barley is frequently cut with the scythe in England, but the sickle is generally used in Scotland. Barley and oats require to lie ten or twelve days, as they are more or less mixed with clover, before being ready for stacking. The clover ought to be completely withered before the corn is stacked; and indeed it requires the greatest caution on the part of the farmer in ascertaining whether his crops are in a proper state for being carried to the stack-yard. The best way for judging of this is to take out a handful from the centre of the middle sheaf on the lee side of the stook, repeating this on several parts of the field; and if the knots or joints of this are dry and shrivelled, the crop may be led home in safety. All corn crops should be cut as low as possible, for by this a great addition is made to the straw, and consequently to the future manure.

Stacking.—When the crop is thoroughly dry, it is led home to the stack-yard on open spar-built carts, and built into stacks so constructed as to afford complete shelter from the weather. The stool or bottom upon which the stack stands was formerly made of loose straw or brushwood; but in the best-managed farms, it is now the practice to construct the stacks on stands made of stone or brick, or upon pillars made of stone or cast-iron, spurred across with wood or iron.

These stands are formed so as to prevent the access of vermin, which is calculated to effect a saving of two bolls in thirty; and many have funnels from the top to the bottom of stacks, to admit a free current of air. In Scotland, the stacks being mostly round, a sheaf is first placed on its butt-end, in the centre of the bottom or stand; around this others are placed, also upright, but with a slight inclination of the head inwards, until the stand is nearly filled. The stacker then places a layer of sheaves horizontally on the outside of these, lying on their sides, the ear-ends inwards; and pressing them together with considerable force, he continues to lay on rows until the outside sheaves are as high as those standing on end. The whole stack is filled up in nearly the same manner, the ear-ends of the sheaves being always inwards, with a regular inclination downwards and outwards to their butts, and the centre of the rick being higher, and not so compressed as the outside. Proper attention to the sloping of the sheaves is necessary from the foundation of the stack, but particularly so at the intake of the inner layers, that part being always left more open. When this is done, the stacker sets up an outside circular row of sheaves, having their butt-ends projecting a few inches beyond the body of the rick, after which the outside layers come gradually inwards, until the roof is drawn to a narrow circle, when two or three sheaves placed upright completely fill up the stack. The topmost sheaves are then firmly bound with a few turns from the middle of the straw rope, the two ends of which are fastened on opposite sides of the stack. When carefully built and thatched, a stack will completely keep out rain, and be quite secure from high winds. Materials for thatching, and straw ropes, should always be made before harvest, so that no delay may arise from this in the event of wet weather. The thatcher stands upon a ladder, placed on the sloping roof of the stack, and lays on the straw in handfuls from a quantity placed within his reach. One end of the straw he thrusts into the butt of a sheaf, and the other end hangs over the stack. He thus progresses upwards, making each handful overlap the other; and having drawn the top to a point, he binds the whole covering securely down with a series of tough oat-straw ropes.

Stacks are sometimes constructed in England on a timber platform raised upon stones, and over the stack the framework of a perfect barn is placed, which can be either tiled or thatched. This is said to afford greater security to the crop, and to be less expensive than annually thatching. The price of erection is said to be comparatively trifling, when the convenience of such buildings is considered; and they have been known, when well put up, to last for thirty years.

Thrashing is either performed with the flail or the thrashing-mill. The use of the latter we by all means recommend in preference on arable farms of above one hundred acres in extent. The machine may be driven by water, horse, or steam power, according to circumstances. Several improvements have been made on thrashing-mills since their first invention. The unthrashed corn is now made to pass through two revolving rollers, while it is acted on by beaters placed lengthwise upon a large cylinder or drum, which moves at the speed of 2500 feet in a minute. The great essential in thrashing is to have regularity of motion, and the grain to be equally fed into the rollers. One man should be employed to feed in the corn, one man, or two boys, to carry the sheaves, and a woman to untie and place them on a table near the feeder. Other persons are employed in raking and carrying the thrashed straw to the straw-house, where it is built. When the machine is driven by steam or water, it is generally the case that one or two winnowing-machines, according to the power employed, are attached to the thrashing-mill, and thus the expense of preparing the grain for market is considerably lessened. A powerful machine will thrash from two to three hundred bushels in nine hours; and allowing for wages and wear of machinery, the expense of thus preparing grain for the market is under one penny per bushel.

Winnowing is a process performed by the aid of wind, by which the chaff of corn is separated from the grain. Winnowing-machines, or fanners, as stated before, are sometimes attached to thrashing-mills, and they are a necessary appendage to every farm, either in conjunction with the thrashing-mill, or separately. Some farmers winnow their grain by hand-fanners, which are thought to be steadier in the motion than when driven by machinery, and consequently the grain is more thoroughly cleansed. After thrashing, the grain is regularly dressed in the clean corn room by means of fanners, riddles, and sieves; and this final dressing is regulated according to the state in which the grain comes from the thrashing-mill. By the process of winnowing, chaff, bits of straw, the seeds of weeds, and other refuse, are separated from the grain; and it is a wise precaution to boil the latter before putting them on the dunghill, which will effectually destroy their vegetative powers. The different qualities of grain are also separated from each other, by which it is rendered more valuable than when the good and bad are mixed together. The thorough cleaning and dressing of grain are of great importance to the farmer, and he will find it to add to his profit in the end to have this effectually done.

Barley undergoes a process called hummelling, by which the awns are broken off from the grain. The machine is composed of a vertical spindle enclosed in a cylinder, and furnished with arms which act upon the grain. It is sometimes attached to the thrashing-mill, and sometimes driven by a separate power. The grain is put in at the top of the cylinder, and as it passes through, the awns are broken off by being struck by the arms attached to the spindle. A more simple process is, after the barley is thrashed, to take off the head of the drum and put on another cover of tin, perforated with small holes about three-sixteenths of an inch wide. The barley is passed through the rollers, and by this the awns are rubbed off.

After being dressed and made ready for market, grain should be kept very dry, in a granary free from damp, and which is impervious to the incursions of vermin. It is, however, the best plan not to thrash grain till it be required for market, because it loses in weight, or shrivels in bulk, by keeping. It also loses in weight, though to a much less extent, by being kept long in ear in stacks; and therefore the sooner grain is thrashed and carried to market, the greater will be the return, supposing there be no rise in price.

CULTURE OF WASTE LANDS—SPADE HUSBANDRY.

According to the best authorities on the subject, it appears that the British islands contain about thirty millions of acres of waste lands. Much of this large proportion of our territory is situated at an altitude which places it beyond the possibility of improvement; but at least one-half is believed to be improvable, and capable of being rendered suitable, if not for tillage and grain crops, at least for the pasturage of cattle. The question as to the propriety of reclaiming the really improvable waste lands of the country is, in any particular case, to be satisfactorily answered by ascertaining at what expense, in relation to the probable profit, the process may be performed. A barren rocky desert may be rendered productive by covering it with soil and manures brought from a distance of miles, aided by years of skilful tillage; but will the cost of these operations be fairly returned by the profits of the produce? Gold itself may be purchased too highly, and so may agricultural improvements. We do not throw out this idea for the purpose of discouraging, but of cautioning proprietors and farmers of lands. In all projected improvements, they will require to ascertain in the first place what will be the probable return, within a moderate length of time, for their outlay—always keeping in view the prospective prices of rural produce during the period. Such at least is the principle of calculation which ought naturally to guide all owners of extensive tracts of waste ground, the outlay on which is to be strictly pecuniary. With reference to those who propose to reclaim wastes chiefly by an expenditure of time and personal labour, the calculation will take a similar turn; and the question will be, whether that time and labour could not have been employed more profitably in another line of pursuit. Leaving this, however, for further discussion in the sequel, we proceed to point out, *first*, to those whose situation in life and inclinations lead them that way, the means to be adopted, according to the best principles of science and lights of experience, for improving large or small portions of waste lands, and the results which may be expected to reward their enterprise; and *second*, the best plans which may be followed for improving patches of ground by spade husbandry, and establishing thereupon small cottage farms, suitable for the support of a comparatively humble class of families. In the treatment of these certainly not unimportant subjects, we shall of course refer chiefly to the condition of waste lands in the United Kingdom.

MORASS OR MOSS LANDS.

The greater proportion of what are usually called waste lands are stretches of peat-bog or moss, covered by a thin benty grass and tufts of heath. This remarkable species of land, though occurring in all parts of the country, is found to the greatest extent in Ireland and Scotland, often in the midst of productive tracts of country, but generally in high-lying districts, which are somewhat defective in point of climate.

Peat-mosses are supposed to be occasioned by the destruction of ancient forests, either by the hatchet or from natural decay. The trees found at the outskirts of these mosses appear to have been cut down, while those in the interior seem to have decayed by the gradual process of time. It is believed that the trees thus left upon the ground would soon become covered with moss, lichens, &c.; and the free drainage of the land being obstructed, aquatic plants, such as reeds, rushes, horsetail, and marsh trefoil, springing up and decaying, would leave a stratum of soft vegetable matter, which every succeeding year would increase. These plants grow in greater or less abundance, according to the quantity of moisture on the ground; and this may account for morasses being deeper in some parts than in others. The hollows would naturally retain moisture in larger quantities than the level ground, and here the aquatic plants would be most prolific, and the hollow gradually become filled up. The peat, which has been in this manner formed, is therefore a compound vegetable substance, which, although it has undergone a change, has not been entirely decomposed; probably the cellular tissue or transparent vegetable matter has decayed, while the woody fibre still remains. Water is indispensable to the formation of moss; and according as the ground is very wet, or only so to a certain extent, different plants will be produced. On ground completely saturated with water, various species of moss grow, to the almost total exclusion of other plants; but if the land should in any way become drier, reeds, rushes, marsh trefoil, horsetail, and the like, spring up in place of the moss. The quality of the peat may be judged of from the plants which grow upon it; all the moss tribe, the horsetail and the marsh trefoil, are fibrous, and difficult to decompose, while reeds, rushes, and sedge are comparatively easy of decomposition. Peat-moss possesses an astringent quality, which has the power of preserving bodies immersed in it, and even keeps itself from entirely decaying. This power is supposed to arise from the carbonic and gallic acids which issue from decayed wood; and vegetable gums and resins will also have the same effect. The tannin principle exists, as is well known, in the oak; and the pine contains much both of resinous and astringent matter. Many mosses are formed upon decayed trees, and the wood most commonly found is either pine, birch, hazel, or oak; and in these cases the presence of the tannin principle is easily accounted for. It is also highly probable that the plants themselves, by the action of natural agents, may have acquired an antiseptic or antiputrefactive quality. In some cases, lakes and pools of water have been filled up by the accumulation of moss; and it has been observed that fermentation occurs where this has taken place. Gaseous exhalations are evolved, and the neighbourhood of such a morass is generally unhealthy; but true peat soils are always salubrious.

The reasonable question has sometimes occurred to inquiring minds—Whence the substance of peat-mosses? for stagnant water alone could not have produced many feet deep of solid matter. This question is answered by chemistry. The vegetation which springs up in the form of aquatic plants, absorbs carbonic acid gas from the atmosphere, and a carbonaceous deposit is made in the condition of vegetable fibre, or dead vegetables in the state of mould. Mr Johnston, in his 'Lectures on Agricultural Chemistry,' makes the following observations on this subject:—'When lands are impoverished, you lay them down to grass, and the longer they lie undisturbed, the richer in vegetable matter does the soil become. When broken up, you find a black fertile mould where little trace of organic matter had previously existed. The same observation applies to lands long under wood. The vegetable matter increases, the soil improves, and when cleared and ploughed, it yields abundant crops of corn. Do grasses and trees derive their carbon from the soil? Then how, by their growth, do they increase the quantity of carbonaceous matter which the soil contains? It is obvious that, taken as a whole, they must draw from the air not only as much as is contained in their own substance, but an excess also, which they impart to the soil. But on this point the rapid growth of peat may be considered absolutely conclusive. A tree falls across a little running stream, dams up the water, and produces a marshy spot: rushes and reeds spring up, mosses take root and grow: year after year new shoots are sent forth, and the old plants die: vegetable matter accumulates; a bog, and finally a thick bed of peat, is formed. Nor does this peat form and accumulate at the expense of one species or genus of plants only. Latitude and local situation are the circumstances which chiefly affect this accumulation of vegetable matter on the soil. In our own country, the lowest layers of peat are formed of aquatic plants, the next of mosses, and the highest of heath. "In Terra del Fuego," says Darwin, "nearly every patch of level ground is covered by two species of plants, which, by their joint decay, compose a thick bed of elastic peat. In the Falkland Islands, almost every kind of plant, even the coarse grass which covers the whole surface of the islands, becomes converted into this substance." Whence have all these plants derived their carbon? The quantity originally contained in the soil is, after a lapse of years, increased ten thousand fold. Has the dead matter the power of reproducing itself? You will answer at once, that all these plants must have grown at the expense of the air—must have lived on the carbon it was capable of affording them—and as they died, must have left this carbon in a state unfit to nourish the succeeding race.' In other words, the substance of peat-mosses is a deposit from the atmosphere, which, as explained under VEGETABLE PHYSIOLOGY, p. 65, is a universal source of subsistence to vegetable life.

Though thus composed of a deposit of dead vegetable matter, which is a basis of fertility to new vegetation, peat-mosses are not in a condition to be actively useful till freed of superabundant moisture, and compounded with siliceous (sandy) materials. Where the subsoil, however, is composed of gravel or sand, it is necessary that the peat and these bodies should be mixed together, so as to form a soil. The first of these methods was planned by the late Lord Kames, and performed with distinguished success on his estate of Blair-Drummond, in the county of Perth. The first process performed by Lord Kames was to construct a ditch through the centre of the moss, through which a stream from the river Teith was directed. Branch ditches were cut in all directions from the main one, the water from which poured itself into the river Forth. The whole estate was divided into portions, and let to small occupiers of land, who received the most favourable terms from the proprietor, as an inducement to carry out his views. The peat earth was cut into small pieces, and cast into the running waters, by which they were carried into the Forth, and thence to the sea. After the moss was cleared away, the trees of the ancient forest appeared, and presented new difficulties to the workmen, which were only overcome with great labour and expense. The roots of these trees were firmly fixed in the earth, and the tanning process which they had undergone in the moss seemed to have added greater strength to their root-branches. They were completely eradicated, however; and in the year 1782, no fewer than 336 acres of ground were reclaimed and brought into cultivation. His son, who inherited his father's spirit of enterprise, pursued the same plan; and in ten years more, the population on the estate had increased to 764 persons, who cultivated 444 acres of land. In 1805, by survey, 577 acres were cleared; and in 1814, between 800 and 900 acres were under cultivation. Lately (1842), the whole has been cleared. Thus an extensive tract of country, which at one time was entirely useless, has been brought, by labour and perseverance, to bear rich crops; and the land is now worth from £3 to £5 per acre of annual rent. In this case the subsoil was good earth, and the operation necessary was the removal of the peat-moss, so that the subsoil might become the culturable surface soil.

Where the subsoil is gravel or sand, a very different operation must be performed; and this perhaps is the most common species of moss ground. Of whatever nature moss ground be, it is evident that, so long as the stagnant water remains, no useful crop can be cultivated; and to remove the superabundant moisture, by means of draining, must be the first operation of the improver. In some cases, where the moss is not too wet, a road may be run through the land, which will greatly facilitate the after-operations. Should such a road be cut, and a deep ditch on each side of it formed, the next operation is to open drains leading to some main channel, by which the water can be carried away. The moss land should be sounded in different places, to ascertain where the greatest depth lies; and when this is found, the main drain should be drawn as nearly in that tract as possible. Where there are beds of great depth, it does not appear expedient that the drain should be cut to the bottom at first; and indeed a difference of opinion exists as to whether moss land should be thoroughly drained at first, so as to render it perfectly dry. Mr Boroughs, the author of a treatise on waste land, is of opinion that the surface water only should be drained off at first; while Mr Blackadder of Stirling asserts that there is no danger of over-drying moss by draining. This may depend upon whether or not the moss be in a decomposed state. When moss is rendered too dry, it becomes a fibrous inert matter; and as is the case with all other lands, it will be easier to work afterwards when moderately moist. With regard to the size and form of drains, it was formerly the practice to make these wide and deep, and at about fifty yards apart. The lateral pressure of the water upon the sides of these drains, however, pressed them so much together, that in the course of years they were scarcely traceable. The depth of the main drain will depend in some measure upon the depth of the moss; and if the average depth of this be twelve feet, the drain may be seven or eight feet deep, and about the same width at the top. The sides should be made sloping, so that the bottom of the drain will not be above two or three feet wide; and this difference between the top and bottom will gradually diminish, in consequence of the lateral pressure. It may in some cases be necessary to perforate the main drain with holes, if any water appear to be coming up from below. The next operation is to form smaller drains leading into the main channel. Experience has shown that the most effectual way of draining deep moss is to insert drains at small distances from each other, and as deep as the nature of the moss will allow. They may be either of tile or stone, and guarded from choking by overlaying turf. Moss ground drained in this effectual way, will be, first, surrounded with the main drain which carries the water entirely away from the field; second, cut into divisions with open drains, at from forty to sixty yards apart, leading into the main drain; third, these divisions will be again divided into smaller portions by the covered drains at five yards' distance from each other.

In this manner the moss will be effectually relieved from its superabundant moisture, and the next operation is to level the surface with the spade. In cases of dry moss, of course the draining is needless, and may be omitted. The land being either naturally, or rendered artificially dry, should now be ploughed with a peculiar kind of plough, made of wood, and covered with sheet-iron, which can be freely used if the ground is free from rushes, heath, &c. If these plants be growing in profusion, however, it is thought better to burn them down to the surface before ploughing. After the ground is ploughed, some prefer rolling, and others burning, as the next operation. If a roller is used, it should be made of iron, with thin plates of iron six inches deep, five inches from each other, and placed at right angles to the cylinder. Repeated rollings from this will cut the sod fine enough to allow the mixing of it with sand or gravel. Instead of rolling, it has been found advantageous to burn the turf turned up, as a more effectual way of decomposing the roots of such plants as the cotton-grass, mat-grass, marsh, trefoil, &c. If the land is burned, it should be ploughed immediately after, preparatory to being mixed with other substances, The next step in the process is to cart sand or small gravel to the field, and spread it over the whole to the depth of three inches. Now plough all down, as the first regular dressing and culture. Thus prepared, the land is ready for cropping, and it is generally allowed that the best plan is to sow with grass seeds; the kinds recommended for this purpose are the timothy grass, cocksfoot-grass, and ribwort. Wheat, however, has been taken from newly-reclaimed moss land; and potatoes, if the moss is in the neighbourhood of cultivated ground, will be found a very valuable crop to be disposed of for seed. Italian rye-grass and rape have both been highly recommended for a virgin crop on bog land, to be followed by oats or barley.

One of the most remarkable experiments ever made in reclaiming peat land was performed some years ago in the neighbourhood of Edinburgh, and is mentioned at length in 'Jackson's Agriculture.' It was as follows:—'On the high and bleak grounds which lie on the boundaries of Mid-Lothian and Tweeddale, at the distance of twelve or thirteen miles south from Edinburgh, there existed, from time immemorial, an extensive tract of moss, which was dug for its fuel, and exhibited the appearance of precipices of peat rising from sour pools of water, the whole broken and disorderly, and of little or no value whatever for pasture. A portion of this dismal-looking land, which lies about 800 feet above the level of the sea, being purchased by Mr John Carstairs, a gentleman in Edinburgh, he commenced operations for reclaiming it. The purchase was made twenty-five years ago, at which time there was neither tree, house, nor road upon the whole moor; and a more hopeless attempt, to all appearance, than that of bringing such a tract of utterly waste land into cultivation could not well be conceived.

The first effort of Mr Carstairs was to gain access to the ground, by forming a road to it from the great road between Edinburgh and Dumfries. He extended the road at a great expense through the centre of the moss, and built a handsome suite of farm offices at the western extremity. The moss was then subdivided into fields of various sizes, by running stripes of plantation in squares, protected by ditches and turf dikes; and the fortunate formation of a new line of road between Edinburgh and Peebles, going through a corner of his property, gave energy to his exertions. Well-formed macadamised roads, made at his own expense, now intersect and cross each other all over the property, affording easy access to every part of it.

The extent of the land to be improved was from 500 to 600 acres; and this he partitioned into fields, protected by plantations and turf walls, as we have just described. The land was also effectually furrow-drained, and levelled on the surface by manual operations. The remainder of the process of reclamation consisted in the application of lime and sandy materials, and tillage. Year after year the land gradually assumed a better appearance, and yielded a better crop. At first, the oats which grew upon it were scanty in the extreme, but now the land is in heart, and yields good crops, and also excellent pasturage. To quote the words of Mr Carstairs himself upon the state of this moss when he got possession of it—"It was mostly composed of white foggy stuff, standing from two to twelve inches deep of water, and not worth sixpence an acre of rent, as it would carry neither man nor beast." In 1834, he commenced cutting sheep drains twelve inches wide and twelve inches deep across the whole moss, dividing it into regular riggs of from twelve to fourteen feet broad each, which has had the desired effect of drying the moss completely, the hollows being filled up with the sods taken from the drains. This drainage cost him £43, 11s. In the summer of 1836 and 1837, a great extent of it was top-dressed with earth and lime; and now it bears the horses and carts over its surface freely, although the moss is from ten to forty feet in depth.

The application of gravel and sand effects perhaps more improvement, in consolidating and decomposing the moss, than either lime or dung. This is shown to be the case from the circumstance, that moss land, when overflowed, is rendered fertile by the deposit of earthy matter from the water. In imitation of this operation, Mr Carstairs is in the habit, at every breaking up of the reclaimed moss land from pasturage, of giving a liberal application of clay, gravel, or sand. This he effects in an easy manner, by means of a portable railway. The application of the gravel, and the committing of the land to pasturage, or irrigated meadow, for a given number of years, have the effect of consolidating it so much, as in most cases to render it capable of being ploughed by horses; but when rather soft, broad wooden pattens are put upon their feet to prevent them from sinking.

By the means detailed, some very large fields of the moss ground have been so reduced in depth as to allow the subsoil, formed from the application of clay, gravel, &c. to be brought up by the plough, and incorporated with the moss. Complete furrow-drainage keeps the soil and subsoil always dry; and now this ground presents fields of as fine and as fertile vegetable loam as can be seen in the whole county, which nothing but their great elevation prevents from being equally valuable. The chick, the sorrel, the nettle, and other weeds, which usually infest moss land when first brought into cultivation, have entirely disappeared—a sure indication that in the above instance a complete melioration of the land has been effected.

When the depth of the moss is considerable, the under stratum, from being more decomposed and consolidated, is uniformly of a much better quality for agricultural purposes than that on or immediately below the surface. To get rid of this inferior soil, Mr Carstairs has frequently resorted to burning; and even in this operation the effects of lime and other earthy applications, some years previously put on, is singularly valuable. They not only make the moss burn more freely, and at a more uniform degree of depth, but the ashes are rendered highly valuable as a manure to the succeeding crops by being mixed with the lime. Thus by frequent applications of any earth or lime, but particularly clay, and occasional burning, the worthless moss soil becomes progressively reduced in depth, and fertilised.' One point in the process of burning requires especial attention—namely, that the moss do not burn unequally, thereby producing pits and hollows for the reception of water beneath the common drainage level. The safer mode is to collect the turf, &c. into heaps, which can be reduced to ashes without any risk, and then spread over the surface, along with the composts of clay and sand.

Mr Roscoe, in his extensive improvements on Chat Moss in Lancashire, used marl instead of gravel or sand. After the land had been burned and ploughed, the marl was laid on at the rate of 200 cubic yards to the acre. From the influence of the atmosphere, the marl soon crumbled down, and was spread over the land with as much exactness as possible. The moss and marl were then mixed together, either with the plough or scarifier, and a crop taken with or without manure, according to the nature of the plant sown. Mr Roscoe is of opinion that lime or marl are equally useful as an application to moss; and although he prefers the latter, he recommends the former as easier of carriage, when these substances are at a distance from the bog. He says, 'Both lime and marl are generally to be found within a reasonable distance, and the preference given to either of them will much depend upon the facility of obtaining it. The quantity of lime necessary for the purpose is so small in proportion to that of marl, that where the distance is great, and the carriage high, it is more advisable to make use of it; but where marl is upon the spot, or can be obtained at a reasonable expense, it appears to be preferable.' Sir Humphry Davy, on the other hand, holds that lime is the most useful dressing for moss. It neutralises the acids, dissolves the vegetable fibre, and converts the moss into friable mould. Lime, he says, slaked with salt water, has been found to be universally beneficial. Mr Aiton, in his Treatise on Moss, observes—' If lime or other calcareous substances are laid on the sward, though the land be neither laboured nor any seed sown, such are the effects of hot lime, that the moss plants will instantly disappear, and a rich and beautiful sward of clover, daisies, and the richest poa or meadow-grasses, will rise spontaneously.' The best application seems to be sand or gravel in the first instance, which will destroy the growth of the moss; and after this lime, to dissolve the vegetable matter.

The expense of draining and preparing moss land depends on many local circumstances. The usual cost is from £12 to £15 per acre; but much has been done at £7 or £8 per acre. The expense in either case is for the most part repaid in a very few years; and then good land, which may be let for £2 or £3 an acre per annum, may be said to have been absolutely conquered from the wilderness, and added to the available productive soil of the country.

DRAINING.

Draining is the operation of drawing off the water from over-wet lands, by open or covered channels, and thereby reducing the soil to that degree of dryness which renders it available for productive tillage. In some countries the ground is naturally so dry, and the climate possesses so little moisture, that instead of drainage, the land may require to be irrigated profusely with water at certain seasons of the year. The lands, generally speaking, of the British islands, are of a very different character. There are few parts of the country where drainage, from superabundant moisture, is not requisite; and therefore the operation of draining, in its most approved modes, should be thoroughly comprehended by every practical agriculturist.

The necessity for draining arises either from the water rising to the surface from springs beneath, or from the subsoil being of a retentive quality, by which water falling upon the surface, or absorbed in the upper stratum, cannot escape. According as either of these causes predominate, or are associated with each other, so must the process of drainage be regulated and conducted. All soils—those of a very sandy or gravelly nature in some situations excepted—are more or less liable to over-wetness, either from their own nature or the nature of the subsoil on which they rest. Clay, whether on the surface or beneath, is, from its adhesive nature, very retentive of moisture. A mixture of clay, sand, and sometimes iron, is also found very impervious; and even loams, although they absorb water freely, generally retain too much. Rich black loams usually lie on a clay subsoil, of different colours and textures, according to which the land will be in various degrees wet. The wetness in these loams is not so apparent as on other soils, but it is in every case as injurious, and as great a necessity exists for its removal. Land subject to springs is usually very varied in its surface, and may require a number of drains or conduits before water is effectually removed.

Many moist lands, though undrained, will produce crops of grain, and the crops will be the heavier the drier and finer the season; but taking these lands on a common average of seasons, it will be found that they often greatly fail in yielding even moderate crops, and that, at the very best, their crops are inferior in bulk and weight to those of grounds which have been subjected to a process of thorough drainage, and the kind of tillage consequent upon such an improvement. The outward mark of all undrained arable land is, that little or no grain grows in the furrows. The crop is seen to run along the centre of the ridges, dwarfing gradually off to the sides, where it disappears, thus leaving a large portion of every field with no crop at all. Wherever land is observed in this condition—and apparently the greater part of that in England is so—there is a want of drainage. The practice of making narrow heaped-up ridges, and deep furrows at their sides, is a proof of the land being badly drained. With a right method of drainage beneath, no portion of the surface is lost for cropping; the crop is at liberty to grow all over the field, and the furrow is little else than a slight indentation to mark off the divisions for the reapers in harvest.

Drains are of several kinds, according to the nature and situation of the land. Some drains are conduits built with stone, others are conduits filled entirely with loose stones, between which the water percolates and escapes, and others are constructed with tiles of a particular form. Of whatever description, main and tributary drains are required. We shall describe a main and a service drain in the language of one of the most experienced writers on the subject, Mr Smith of Deanston:—' The main drain should be directed along the bottom of the chief hollow or valley of the grounds, where the whole or greater portion of the drains can be led into it. If any lesser hollows occur in the field, they must also have their proportional mains or leaders. The bottom of the main drain should be at least three feet, and, if possible, three and a half or four feet under the surface where it passes along; and it should have throughout as uniform a fall or descent as the nature of the ground will admit.

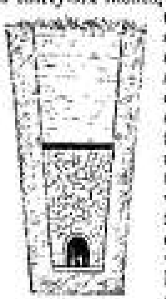
It should be flagged in the bottom, or where flagstones are expensive, built as an inverted arch, to prevent the possibility of washing away under the side building. The dimensions necessary will depend on the fall or declivity, and the area of land from which it has to receive water. With a fall in no place less than one foot in 100 yards, a drain ten inches wide and eighteen inches deep will void the rain water from 100 acres. It is of great importance to make the open area of such drains narrow and high, as smaller bottoms and covers will suit, and be less liable to give way; and the current of water being more confined, mud and sand will be less apt to settle in the bottom. (See Construction of SEWERS, No. 30.) Let the sides be smoothly and securely built with flat stones, either with or without mortar; and let strong flat covers be placed over, or where such are not to be found, rough simple arches may be built with thin stones and mortar, for the bottom and cover, packing the haunches of the arch well up to the sides of the cut. Where lesser hollows occur crossing the fields, it is necessary to cut submains along their bottoms, about three or three and a half feet deep, and having openings of suitable dimensions formed by inverted stone couples, or with drain tiles; or where a very large flow of water has to be provided for, with an inverted tile, and a covering tile placed above the bottom one, or with larger tiles made for the purpose.

There should be a cross submain at the bottom of every field or stretch of drains to receive the water from all the parallel drains; and such drain should always be cut six inches deeper than the drains running into it, that the water may have a free drop, which will prevent the lodgment of mud or sand at their junctions or mouths. Open cuts or ditches, either as mains or submains, should never, except from necessity, be adopted, being apt to get filled with mud and grass, by which water is thrown back into the drains, which often chokes them; besides, the loss of land, annoyance in ploughing, constant expense of cleaning, the propagation of weeds, danger to young cattle, and the like, are serious objections.

Having thus provided a main drain, with submains flowing into it, matters are prepared for setting off and executing the parallel frequent drains in the body of the field. The drains can be executed at any season, when the weather will permit; but the spring and summer are most suitable for the work. It is best to execute the drains when the field is in grass, as it can then be done in all weathers in a more cleanly and more expeditious manner.

In laying off the drains, the first object for consideration is the nature of the subsoil. If it consist of a stiff strong till, or a dead sandy clay, then the distance from drain to drain should not exceed from ten to fifteen feet; if a lighter and more porous subsoil, a distance of from eighteen to twenty-four feet will be close enough; and in very open subsoils, forty feet distance may be sufficient. When the ridges of the field have been formerly much raised, it suits very well to run a drain up every furrow, which saves some depth of cutting. The furrow being thereafter made over the drains, the hollow is filled up, and the general surface ultimately becomes level. When the field is again ridged, the drains may be kept in the crowns or middle of the ridges; but if it is intended to work the field, so as to alternate the crowns and furrows, then the ridges should be of a breadth equal to *double* the distance from drain to drain; and by setting off the furrows in the middle betwixt two drains, the crowns will be in a similar position; so that when the furrows take the place of the crowns, they will still be in the middle betwixt two drains, which will prevent the risk of surface water getting access to the drain from the water furrows by any direct opening.'

Small tributary drains, made with broken stones, and covered with turf, to prevent the earth from filling them up (called *rumble drains* in Scotland), are in most places falling into disuse, and are superseded by drains made with tiles. Tile-drains are peculiarly available over the greater part of England, where there is a scarcity of stone; and both there and elsewhere they will soon constitute the only kind of field-drainage in use. The tiles for these drains are made at most brick-fields, and are simple in construction. There is a flat for the bottom, and a semicircular tile to place upon it, with the concavity undermost. In hard-bottomed land, the sole is sometimes disused. The tiles measure from twelve to fourteen inches in length; and being placed neatly in a row, close to each other, a channel of four inches wide and six inches deep is formed; the water is admitted by the seams or interstices, so as readily to flow away. A little straw, stubble, or loose furze, is placed immediately over the upper tile, by which the chance of stoppage by the intrusion of earth is removed. The depth at which the tile-drain is laid is twenty-four or thirty-six inches, as above, which, being covered with



ten or twelve inches of gravel or stones, allows a sufficient depth of soil above for the operations of subsoil-ploughing. When the depth of the drain is three feet, and the soil a retentive clay, it is frequently filled up for about a foot with stones above the tile, and turf laid above the stones, the rest being made up with surface earth. The annexed figure represents a section of a tile-drain of the proper construction. It will be observed that the bent tile laid on a flat sole is advantageously placed for carrying off all the water that may trickle through the earth and stones above, and cannot be easily choked up with soil.

In cutting drains, three kinds of spades will be required—a common working spade, one a little narrower, and the third the breadth of the bottom of the drain. The cuttings should be done smoothly and neatly, preserving a descent throughout; and the tiles should not be laid till the cuttings have been carefully inspected. The terminations of the tile-drains may be led into subterranean mains, or into the shelving banks of open rivulets or sunk ditches; but in the latter case their mouths will probably require to be protected from the intrusion of vermin, or from external injury. In planning the lines of drains, the straightest side of the field should be selected, the first being laid off as parallel as possible, and the others formed at the distances thought necessary. In some places, from the extreme levelness of the land, or from obstructions in the subsoil, it will be found difficult to carry off moisture by drainage in the regular manner, and the leading of converging drains to a pit in a low part of the field will be the only course open for adoption.

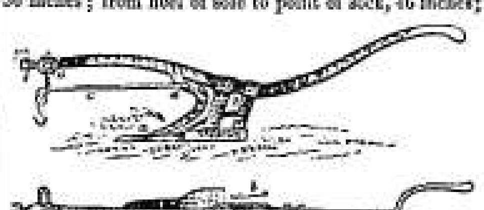
The drainage of sheep pastures is often not less necessary than land for tillage: it improves the grass, and, by drying the surface, renders the ground more salubrious—dry pasturage being indispensable for sheep. The mode of draining adopted for hilly sheep-walks is very simple: on the sides of hills, open drains a foot in depth, and from eighteen inches to two feet broad at the top, are cut, with a gentle slope towards a rivulet, into which they are to discharge themselves. They are made to slope in different directions, and thus form so many furrows, which draw off the trickling moisture of land springs, and superabundant rains.

SUBSOIL-PLOUGHING.

It has been seen, in treating of moss lands, that soils chiefly composed of inert vegetable matter, or peat, may be greatly improved by supplying a due proportion of sand or gravelly material, carted from a distance, or raised from the subsoil. The same thing may be said of all lands which have been deteriorated by repeated cropping. A time comes when the silica and other earthy bases are found to have been abstracted in the crops, and fresh materials must be added.

The process of earthy restoration may be accomplished by scattering new materials upon the fields; and this might be easily accomplished in many parts of the country, so far as silica or fine sand is concerned; but the readiest and cheapest process in most situations will consist in trenching the subsoil, and gradually assimilating it to the mould above. The subsoil, or that portion of the under stratum which lies out of reach of the ordinary plough, may already be so good as to be available for bringing towards the surface, and in such cases it admits of easy and profitable management; but in most instances in our country the subsoil is hard and stony, and will require to be trenched, and lie for a time in its underground position, before it is ready for admixture with the upper or culturable mould.

The most efficient instrument for trenching the subsoil on a large scale is the subsoil-plough, invented by Mr Smith of Deanston, whose account of it we here transcribe:—' In the design, two essential points were kept in view:—1. The construction of an instrument that would effectually open up the subsoil without throwing any of it to the surface, or mixing it with the active or surface soil; 2. To have an implement of the easiest possible draught for the horses, while it was of sufficient strength and weight to penetrate the firmest ground, and resist the shocks on the largest stones. The extreme length of the plough is about 15 feet. From the socket at the point of the beam to the first stile or upright, 6 feet; from thence to the back of second stile, 19 inches; from thence to the outer end of holding handles, 7 feet; from the sole to the bottom of beam at stiles, 19 inches; length of head or sole-bar, 30 inches; from heel of sole to point of sock, 46 inches;



broadest part of sock, 8 inches. The coulter is curved, and in order to prevent its point being driven from its place by stones, it is inserted to the depth of an inch in a socket (*a*). The lateral dimensions of the sole-piece are 2 inches square. This is covered on the bottom and land side with a cast-iron sole-piece, to prevent wear. The sock goes on the head in the usual way, and from its feather rises the spur-piece (*b*), for the purpose of breaking the subsoil furrow. When the subsoil consists of very firm clay, or other hard and compact earth, the feather and spur-piece may be dispensed with, and a plain wedge or spear-pointed sock, such as those of the old Scotch plough, may be used. The draft-bar (*c*), of 1¼ inch round iron, is attached to the beam at the strong eye (*d*), and passing through an eye in the upright needle (*e*), is adjustable to any height or lateral direction, being movable in the socket (*f*), at the point of the beam, and can be made fast at any point by a pinching-screw wrought by the lever (*g*). By the proper setting of the draught-rod, the direction of the power of the horses is so regulated as to render the guiding of the plough easy at any depth or width of furrow. The beam is about 5 inches deep in the middle, and 1¾ inch in thickness—towards the draught end it tapers to 3 inches deep, and 1 inch thick—at the holding end, where the handles branch off, it is 2 inches by 1. The whole weighs 440 lbs. imperial. This appears an enormous weight, and most people are alarmed at the strength and weight of the implement; but after repeated trials with lighter ploughs, those of the dimensions and weight now described have been found to be at once the most efficient, the most easy of draught, and the easiest for the ploughman to manage.'

When a field is to be trenched, a common plough, drawn by two horses, goes before, throwing out a large open furrow of the active soil. The subsoil-plough follows in the wake of the common plough, stirs up thoroughly and breaks the bottom, and the next furrow of active soil is thrown over it. This large subsoil-plough is a kind of *horse-pick*, breaking up without raising the under stratum to the surface. The atmospheric air being by this means freely admitted to the subsoil, the most sterile and obdurate till becomes gradually meliorated, and the common plough may ever after be wrought to a depth of from ten to twelve inches without obstruction. For this heavy ploughing most likely three horses yoked abreast will be required. The charge for subsoil-ploughing may be estimated at twenty-four to twenty shillings per statute acre, being one-fifth of what a similar depth with the spade would cost, and upon the whole, be as effectually done. The expense of subsoil-ploughing is no doubt considerable, but its advantages are incalculable. 'All who have ever studied or experienced the most common gardening, must be aware of the important advantages of deep working; and when it can be attained in the broad field of farming at so small a cost, they may easily believe that the whole will be more than doubly repaid in every succeeding crop, and abundantly even in pasture. When land has been thoroughly drained, deeply wrought, and well manured, the most unpromising sterile soil becomes a deep rich loam, rivalling in fertility the best natural land of the country, and from being fitted for raising only scanty crops of common oats, will bear good crops of from thirty-two to forty-eight bushels of wheat, thirty to forty bushels of beans, forty to sixty-six bushels of barley, and from forty-eight to seventy bushels of early oats per statute acre, besides potatoes, turnips, mangel-wurzel, and carrots, as green crops, and which all good agriculturists know are the abundant producers of the best manure.'

It would be easy to produce further evidence of the value of subsoil-ploughing for all the purposes to which we have adverted; but such testimony, we should think, can hardly be required. We conclude with the following valuable observations by the Marquis of Tweeddale:—'The system I have adopted for the treatment of the lands of my own farm, where the soil and subsoil are of the weakest, is as follows:—A great proportion of the land is valued at five or ten shillings per acre. After it is drained in grass, the land is trench-ploughed, making the furrow from fourteen to sixteen inches, the soil being turned into the bottom of the furrow. The ploughing is done by two ploughs, each having a pair of horses. As the work is harder upon the horses that turn up the till or clayey subsoil, they every hour change with the plough that turns over the sod. The till remains exposed to the frost during the winter; in the spring the land is cross-ploughed, the sod is found quite rotten, and mixes with the till. Oats are sown, and the crop is found considerably better than before the land was drained. After the crop is cut, the land is ridged up with a winter furrow, turnips being sown in spring. In ridging up the land for turnips, there is little or no appearance of till. The best crop of turnips to be found in the same district of the country is not superior to that grown after this management of the land. The land, after the turnips are eaten off by sheep, is ploughed for barley; there is an excellent crop, and the grass seeds are always well planted during the two years of grass that follow the barley, the fields having the earliest grass crop in the district. The largest number of sheep are fed on them, and are the fattest animals. The grass that formerly grew on these fields was of the worst quality, and sheep would scarcely eat it. No extra manure or lime has been applied to these fields, except on a part of one of them, which remained six years without growing anything an animal would eat, consequently it was left without stock. In the third year since it was in that state, it is grown as good a crop of turnips as can be seen in the country; and no stranger who saw the land in fallow would believe it to have been what the people of the country knew it to be previous to its improvement. It is evident that the only extra work in following out this system is trench-ploughing once; this, however, is done with the ordinary plough used for working the land, and the horses are never oppressed. It will be satisfactory to state that I have an equal dread with other farmers to bring till, before the land is drained, to the surface: it is only after that operation is effectually executed that I consider the till, when properly pulverised, forms a new soil the most valuable and easy to work of any I know.'

LIMING—TOP-DRESSING.

Lime is the most important mineral substance which is usually applied to land. It is found in the form of rocky material, in which condition it is in combination with carbonic acid gas. On being burnt, this gas is expelled, and it assumes the form of a whitish brittle mass called *quick-lime*, easily reducible to a powder by the application of water. On being exposed to the atmosphere in its soft powdery condition, it has a strong tendency to imbibe moisture from the air, and soon becomes as heavy as it was previous to burning. It also recombines with carbonic acid from the air.

The use of this artificially-prepared earth in agriculture is well known; but certain peculiarities in its action have never been satisfactorily ascertained. It possesses the power of decomposing animal and vegetable matter, and enters as an element into the fabric of plants; in certain cases it only alters the constitution of the soil, and in some instances its application would be positively injurious. Speaking of this remarkable fossil, Sir Humphry Davy observes—'When lime, whether freshly burned or slaked, is mixed with any moist fibrous vegetable matter, there is a strong action between the lime and the vegetable matter, and they form a kind of compost together, of which a part is usually soluble in water. By this kind of operation, lime renders matter which was before comparatively inert, nutritive; and as charcoal and oxygen abound in all vegetable matters, it becomes at the same time converted into a carbonate of lime. Mild lime, powdered limestone, marls, or chalks, have no action of this kind upon vegetable matter; by their action they prevent the too rapid decomposition of substances already dissolved, but they have no tendency to form soluble matters. It is obvious, from these circumstances, that the operation of quick-lime, and marl or chalk, depends upon principles altogether different. Quick-lime, on being applied to land, tends to bring any hard vegetable matter that it contains into a state of more rapid decomposition and solution, so as to render it a proper food for plants. Chalk and marl, or carbonate of lime, will only improve the texture of the soil, or its relation to absorption; it acts merely as one of its earthy ingredients. Quick-lime, when it becomes mild, operates in the same manner as chalk; but in the act of becoming mild, it prepares soluble out of insoluble matter. The solution of the question, whether quick-lime ought to be applied to a soil, depends upon the quantity of inert vegetable matters that it contains. The solution of the question, whether marl, mild lime, or powdered limestone, ought to be applied, depends upon the quantity of calcareous matter already in the soil. All soils are improved by mild lime, and ultimately by quick-lime, which do not effervesce with acids, and sands more than clays.'

Let us now proceed to the practical application of this valuable stimulant, commencing with its use in the reclaiming of waste lands. If moorish or waste soil is much infested with the tenacious roots of rushes, heaths, and other weeds which resist the mechanical action of the harrow, and yield slowly to putrefaction, the best mode is to till the ground, and allow it to lie in this state for twelve or eighteen months, or even two years, before applying the lime. It is then generally applied in autumn, and tilled in as soon as possible; but if not immediately tilled in, the soil with the lime on it should be harrowed, so that its decomposing effects may act as powerfully as possible upon the vegetable matter. After these operations, the land is sown two successive years with oats, without any fallowing; and along with the second crop of oats, some persons sow it out in grass seeds for pasture. Others, after the first or second crop of oats, give the land a summer fallow for one season, or a green crop with manure. On the following season another crop of oats is taken, along with which grass seeds are sown, and in this state it is committed to pasture. In some cases, after tillage, the soil is allowed to lie for one, two, or more years, according to its nature, after which it is reduced to a complete state of pulverisation by a well-wrought naked summer fallow. On the spring following it is limed, and the lime is well harrowed in along with grass seeds alone, and in the following season the land is committed to pasture. This, however, is a very expensive mode, and cannot be recommended to tenants whose lease is of a moderate length. It is decidedly the most enriching mode of laying down waste land with lime only for pasturage, as the energy which the lime communicates to the soil is not intermediately exhausted by grain crops.

It will now be observed that lime is a most important engine of improvement for waste lands; for it decomposes and brings into active use the inert vegetable matter, and also serves as an elementary earth for the growth of plants. For peat lands, after being drained, and generally all rough lands reclaimed from a state of nature, lime is invaluable, and equally so for either tillage or pasture. In connection with turnip husbandry, it has been the grand reclaimer in many parts of Scotland, and will effect similar ends in any district of country not possessing a sharp and active soil; in such places it is not required, and its application may do harm. Laid on merely as a top-dressing—that is, thinly powdered over the land—lime is found to have very extraordinary effects; producing a beautiful close sward of white clover, daisies, and nutritious meadow grasses, where formerly nothing but heath or the coarsest herbage prevailed.

From the result of experiments in many different situations, it seems satisfactorily proved that the proprietors of waste lands within reach of lime have themselves to blame for the grounds continuing in sterility. Their complete melioration, however, is not to be expected at once; but upon proper arrangements being entered into between the landlords and the tenants, a great proportion of the high pastoral grounds, now lying in a state of waste, might by these means be progressively improved.

It seems to be a general wish of farmers to use lime rather in tillage than by top-dressing, which is much to be regretted, as the lime, when used in tillage, conjoined with over-cropping, eventually exhausts the soil; whereas, by applying it in top-dressing, it will prove highly beneficial. Therefore, in a climate rising six hundred feet above the level of the sea, top-dressing is the most effectual way in which lime can be applied for improving barren pasture-grounds. The land is never in this way exhausted by any species of cropping; it is put in a state of being benefited by the dung of the animals grazing upon it; and by due attention being paid to keeping the land free from wetness, by draining, it will be progressively fertilised. In the application of lime, it is a rule which should invariably be attended to, always to give abundance, and in a newly-slaked condition, in order that it may have its full effect. If slaked a considerable length of time before it is applied, it does not act so powerfully either in reducing the natural herbage or neutralising the acids, as when applied in a hot powdery state. There are very thin moorish soils, however, where lime by itself will not improve the herbage, these requiring a nourishing before a stimulating manure; and on such lands a dressing of good earth will be found to have the same effects as lime has on a strong soil. Top-dressing with clay or sand may also be performed with advantage in mossy moorish tracts where lime cannot easily be obtained. These earthy materials have a wonderful effect in improving the pasturage; they entirely destroy the growth of moss plants; and if applied to the depth of an inch or so, will generate a sweet herbage, rendering the ground capable of being benefited by the droppings of the animals it supports.

IRRIGATION.

While some lands can be reclaimed only by draining, others, which are naturally dry, may be rendered equally serviceable by artificial water. *Irrigation*, as this process is termed, is of great antiquity, especially in tropical countries, and seems to have been practised from the earliest periods of their history. In Egypt, the periodic overflowings of the Nile rendered the sandy desert a land of plenty; and in ancient Persia, Ceylon, and the East generally, the superintendence of the dams and water-courses was one of the most important offices in the state. In Lombardy, the best irrigated country in Europe, it has converted a land of stagnant marshes into meadows of exuberant fertility; and in the arid region of Peru it would be impossible to reap a single average harvest without such an application. In our own country, irrigation has as yet been attempted upon a comparatively limited scale; but where experiments have been judiciously made, they have always been attended with success. Though generally applied to dry grounds, it may happen that lands naturally marshy are as much the better for irrigation as dry deserts; but in all such cases the lands must in the first place be drained. This leads to an explanation of the principle of irrigation.

When water lies in or upon the land, it stagnates, and produces a marsh, which is alike insalubrious and unproductive. The extensive Pontine marshes in the neighbourhood of Rome present a remarkable example of both these conditions. In order that water may not be injurious, it must be kept flowing, always running amongst and from the blades of herbage. Regarding the theory of irrigation, Sir Humphry Davy says, 'Water is absolutely essential to vegetation; and when land has been covered with water in the winter, or in the beginning of spring, the moisture, which has penetrated deep into the soil, and even the subsoil, becomes a sort of nourishment to the roots of plants in the summer, and prevents those bad effects which often happen in lands in their natural state, from a long continuance of dry weather. When the water used in irrigation has flowed over a calcareous country, it is generally found impregnated with carbonate of lime, and in this state it tends in many instances to ameliorate the soil. Common river water, also, generally contains a certain portion of organisable matter, which is much greater after rains than at other times, and which exists in the largest quantity when the stream rises in a cultivated country. Even in cases where the water used for flooding is pure, and free from animal and vegetable substances, it acts by causing the more equable diffusion of nutritive matter existing in the land; and in very cold seasons, it preserves the tender roots and leaves of the grass from being injured by frost. In general, those waters which breed the best fish are the best fitted for watering meadows; but most of the benefits of irrigation may be derived from any kind of water. It is, however, a general principle, that waters containing ferruginous impregnations, though possessed of fertilising effects when applied to a calcareous soil, are injurious to soils that do not effervesce with acids; and that calcareous waters, which are known by the earthy deposit they afford when boiled, are of most use on siliceous soils, or other soils containing no remarkable quantity of carbonate of lime.' Whatever be the actual properties communicated by the water, it is certain that the general effect of meadow irrigation is greatly to increase the quantity of natural herbage, and render it more sweet and nourishing for cattle.

In order to irrigate a field, there must be a difference of levels, the water being made to run in a main channel along the highest side, and thence sending small rills all over the lower parts of the ground. The principle of adjustment is by sluices. When the slope is considerable, the water requires to be sent diagonally across the field, and being catched in mains at intervals, is again distributed, if need be, in new directions. This is called catchwork irrigation, and on favourable situations may be executed so low sometimes as ten shillings an acre. The following observations on the subject occur in Stephens's Practical Irrigator and Drainer:—'In the formation of an irrigated meadow, there are two rules of the greatest weight: one is, that no part of the works be made on a dead level; and the other, that every drop of water be kept in constant motion; but to give exact directions for the formation, is beyond the ingenuity of man; for no two pieces of land are precisely alike, which renders it impossible for the irrigator to follow the same plan in one field that he has done in another. Each meadow, therefore, requires a different design, the construction to be varied according to the nature of the ground and the quality and quantity of water. Inclined planes are absolutely necessary for the purpose of irrigation; and the benefit of irrigation depends so much upon the good management and patient perseverance of those who have the superintendence of it, that I do not wonder it has so often proved unsuccessful. However simple the construction of a water meadow may appear to be on a superficial view, those who enter minutely into the detail will find it much more difficult than is commonly imagined. It is not an easy task to give an irregular surface the equal slope requisite for the overflowing of water. It is very necessary for the irrigator to have just ideas of levels; a knowledge of superficial forms will not be sufficient. Few people unacquainted with the art of irrigation, and the regularity of form which the adjustment of water requires, have any idea of the expense of modelling the surface of a field. Where land is very uneven, it is sometimes advisable to break it up with the plough, and take a crop of oats before the formation; by which means the land can be properly cleaned and pulverised before levelling it into form with the levelling plough and spade the following year—an operation which may be executed at half the expense of doing the whole with the spade and wheelbarrow. But there is one advantage by doing the whole work with spade and barrow, especially where the turf is strong, which is, that the water can be applied as soon as the beds are formed; but by breaking up, and taking a crop of oats, it will require two or three years after the grass seeds are sown before the water can be used, which some proprietors think too long to wait, therefore will rather be at an additional expense to have the turf lifted and laid down again; by so doing, the whole operations may be performed in one season. The grass seeds generally used for laying down land for water meadow are, vernal grass, crested dogstail, soft meadow grass, rough-stalked meadow grass, foxtail, fiorin grass (*Agrostis stolonifera*), which last is one of the prevailing grasses in all good meadows; and the best way of planting it is to cut the whole into short pieces, the same way as cutting straw into chaff, and sow it with other seeds. It is not always that these grasses give a good crop the first year; therefore, to obviate this evil, some perennial rye-grass seed should be sown along with the others, to produce a crop of hay before the watering commence.'

It must be understood that the irrigation of any meadow is not to be incessant. There are times when the water must be altogether turned off, and the ground left to dry; it is at these times that the herbage is to be cut and removed. In large meadows, it is customary to turn off the water from different parts at different times, by which a constant succession of crops is obtained. Speaking on this part of the management, the same authority observes:—'One of the greatest defects in the management of irrigated meadows in this country is the not paying proper attention to freeing the ground from subterraneous and stagnant water; for experience shows that, wherever there is too much moisture beneath the surface, or if the water lodges too long upon it, the crop will always be coarse and scanty. Another great error generally committed is, allowing the water to run too long at a time, without properly drying the ground. I know some instances in this neighbourhood where the ground is not attempted to be dried from the time the water is put on the meadows, in the autumn, till eight or ten days before the cutting of the hay; the consequence is, that the grass is of the coarsest quality, and the ground has become so very boggy, that the whole crop of grass is obliged to be carried by people to some other place to be made into hay. Another inconvenience arises from bad management, which, I am sorry to say, is too prevalent in this country—that is, permitting the grass to stand too long before cutting; the consequence is, coarse hay, badly made, and in many instances half rotten before being put into the stack; and, moreover, owing to the lateness of the season, the aftermath is entirely lost; so that the proprietor has not received half the value from his meadow which he might have received, if the hay had been made at the proper season.

The first operation of the irrigator is to adjust the water in the conductor, or if the meadow is in more parts than one, the water in each conductor must be first regulated; then he commences anew by regulating the stops in the first feeder; but should there not be sufficient water in the feeder, a little more must be let in, by making the aperture wider or deeper, till the water flows regularly over the sides from one end to the other; from the first he proceeds to the second feeder, and so on, until the water in all the feeders is adjusted. Let the beds of a water-meadow be ever so well formed, yet by some places sinking more than others, or by the ice raising the surface of the ground, although the water along the banks of the feeders have been ever so nicely adjusted, it often happens that there may be some places between the feeders and drains with too little water, when it will be advisable for the manager to make a third round, redressing inequalities of the surface, so as to give every spot an inch deep of water. Every part of the works being regulated, the water should be allowed to run through the whole of October, November, December, and January, from fifteen to twenty days at a time, without intermission. At the expiration of these periods, the ground should be made completely dry for five or six days, to give it air; for there are few species of grasses, which form the most nutritious part of the herbage of water meadows, that will long exist under an entire immersion of water. Moreover, if the frost should be severe, and the water begin to freeze, the watering must be discontinued, otherwise the whole surface will become one sheet of ice; and wherever the ice takes hold of the ground, it will undoubtedly draw it into heaps, which is very injurious to the plants. The object of this early preparation of the meadows is to take advantage of the autumnal floods, which bring along with them a variety of putrescent matter, which is found very enriching to land.' At the most convenient period of the year, the various channels will require to be cleaned out, and the sluices and works repaired.

It is not, however, dry pasture lands and meadows alone that may be improved by irrigation; even bogs and morasses may be totally altered in their constitution by the same process. After drainage, the vegetable soil of these morasses is loose and pulverulent, and wants consistency and the necessary admixture of other earths to render it fertile. If, therefore, such a drained moss lies in the vicinity of a river, whose waters can be allowed to overflow it at pleasure, the rich silt of these waters will not only give a temporary fertility, but in time add a new superstratum of the most productive soil. It is by this double process of adding new compounds, and facilitating the decay of the humus already existing, that moss-irrigation becomes so advantageous where there are facilities for its execution.

PROTECTION OF RIVER BANKS—WARPING.

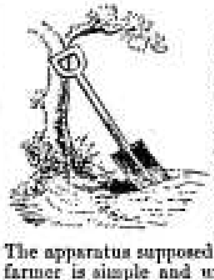
Much valuable land on the banks of rivers and rivulets is often laid waste by the encroachments of floods. A few words on this important subject seem to be necessary:—It may be laid down as a principle in natural science, that water is irresistible, and therefore it must not be resisted—it must be humoured. All windings in streams are caused by resistance. The water, in rushing onward, dashes against a projecting stone or hard part on one of its banks; this sends it in an opposite direction, and it strikes against whatever obstacle is presented. This process of interruption soon causes a mouldering of the banks in opposite directions, so that at length the water runs in a zig-zag or serpentine course. All this might have been avoided by allowing the water a perfectly free course.

The damage done to lands by flooding has led to numerous experiments for keeping the water in its channel, but seldom with any degree of success; because the attempts have been to hem in the current by sheer force. In all cases in which it is desirable to keep out tides or high floods from lands, the only secure method consists in giving the banks such a slope, that they will present no resistance whatever, but allow the water to rise and subside with equal ease and tranquillity. As a general truth, the greater the slope, the better; and it should never be less than a foot and a half for every foot in the height. Employ no stones or stakes, or anything else, for the current to catch upon; but cover the slopes with smooth turf, at a season which will allow of its growth before the floods set in. If any patches get broken, let them be annually mended. To keep out high floods, the banks must be made correspondingly high. Artificial embankments, in a flat country, should assume the form of a long mound, sloping gradually on both sides.

Notwithstanding the obvious utility of this simple and unexpensive mode of protecting river banks, instances of damage are constantly occurring from projects of an opposite kind. Mr Stephens mentions the following as one of many within his knowledge:—'An embankment was thrown round the small island Mugdrum, in the river Tay, to protect the land from being overflowed by the tide; but it was made so steep, that the first spring tides levelled the greater part of it to the ground. A second attempt was made, with the additional expense of a stone wall facing the water, which shared the same fate with the former bank. Since these failures, a third embankment has been erected with nothing but the natural soil of the land, and the whole covered with thin turf. The length of the present slope next the sea is five times the perpendicular height of the bank, and the inner slope three times; the water meeting no resistance, rolls down the long slope without doing any injury.' To prevent high tides and freshets from entering the cross drains and ditches, and thus flooding the reclaimed land, it is often found necessary to fit all water-courses passing through the embankments with sluices and self-acting valves; and where the new land is exceedingly flat and low, even steam-power is sometimes indispensable to carry off the stagnant waters. In every case, these expensive adjuncts must be regulated either by the immediate or prospective value of the newly-acquired ground. We refer to Mr Stephens's useful treatise (Blackwood, Edinburgh) for further information on this subject, as well as on irrigation and draining.

In connection with the protection of river banks, we may say a few words on the method of gaining land from rivers and tidal estuaries. This may be done if the river appears to straggle over an unnecessarily wide space, and brings down quantities of mud so as to produce impediments to navigation. The process usually followed with most advantage is that of *warping*, which consists in running out at intervals short rows of stakes, matted with twigs, calculated to catch the confluent particles of mud, but to allow the water to pass through. A sediment is thus gradually formed between the rows; in time, it rises above the water, and ultimately forms a green productive surface. When the water is affected by the tides, a row of loose stones laid between high and low water mark will similarly catch mud and sand, and while forming new land, will, by narrowing the channel, give greater impetus to the stream, and help to deepen its bed. When done on a great scale, the bed of the river is scooped by mechanism, and the rubbish brought up may afterwards assist in elevating the newly-formed banks. In point of justice to all parties, any of these processes of river-bank improvement should be done on both sides of the river at the same time; for if effected only on one side, the water may be driven to the opposite shore, to the serious damage of the land in that quarter.

SPADE HUSBANDRY.



The reclaiming and culture of small pieces of land by means of the spade and other instruments of manual labour, is usually spoken of under the name of spade husbandry; but is also sometimes called cottage-farming, or field-gardening—the operations of the culturist bearing an intimate resemblance to those applied in ordinary kinds of gardening. The apparatus supposed to be employed by the cottage farmer is simple and unexpensive. It consists of two or three spades of different sizes, a pickaxe, three-pronged digging-fork, hoes, rake, light harrow which he can draw, scythe, reaping-hooks, hay-forks, flail, wheelbarrow, &c. according to means. It is of great importance for the cottage farmer to be able to sharpen or mend his tools, and for this purpose he should have a grinding-stone and small forge, also some carpenters' tools. No horse or paid servant is kept. All the work is done by the manual labour of the farmer and his family. The only live stock is a cow or cows, pigs, and poultry. The homestead consists of a cottage with several apartments—a cow-house, pigsty, and barn. The size of the farm is supposed to vary from four to six or eight acres, and to be laid out in six or eight distinct field-plots, properly fenced.

Trenching.

The basis of cottage-farming is deep trenching with the spade; but before regular trenching can commence, the land, if in a rough state, must be cleared and drained. We have already shown how these preliminary operations are performed on a large scale, and they may very easily be modified for manual labour. Suppose the patch of land is part of a moss, dig open drains round it to draw off the water; scarify the surface with the spade, and burn the heaps of turf; scatter the ashes on the land along with any sandy material or lime which can be procured, and then delve all from one end to the other. This process will cause a large portion of the mossy fibre to decay, and the exposure to the atmosphere and draining will be found to meliorate the soil. In twelve months, the face of the land will be more like *earth* and less like peat than it was at the time of delving.

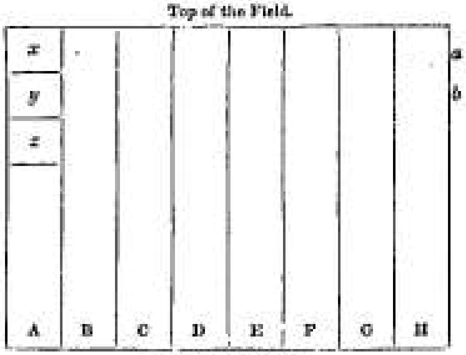
If the land be choked with stones or roots, all these incumbrances should be removed to the depth to which you design your trenching should go; and the sooner you get rid of them the better. The whole ground should be free of everything which can present the slightest impediment to the spade. Where sub-draining is required, the stones may be employed to lay in the drains. With respect to the first crops taken from the delved field, it will depend on the natural fertility of the ground and other circumstances. If the land be comparatively dry and fertile—as, for instance, the forest land of North America—a good meliorating and opening crop is potatoes; but in the case of poorer soils, manuring will be required, and the first crop may be grass. If the land can be conveniently partitioned into separate fields, a different crop may be taken from each, thus commencing a regular rotation. In proportion as the upper layer of earth is meliorated and exhausted, it will be necessary to go the deeper down. On large farms, certain fields are occasionally left fallow—that is, doing nothing, unless it be gathering what strength can be procured from the atmosphere. (See p. 488.) In cottage-farming, this practice must be unknown. Instead of trying to recruit the land by giving it a rest, you must recruit it by turning up the layer of mould immediately below that which has been affording nourishment to your crops. This stratum, which we shall call layer No. 2, extends from nine to eighteen inches below the surface, supposing you to have been employing a nine or ten-inch spade. It is, generally speaking, neither soil nor subsoil, but partakes of the qualities of both; and after two or three years' cropping, will be found to have imbibed a share of the manure delved in for the crops. The art, then, consists of raising up this layer No. 2, and turning down No. 1 in its stead. By doing so, perhaps manuring may be omitted for a year, and at anyrate a light manuring will suffice.

In some districts the depth of available soil may not be so much as eighteen inches, the layer beneath being rock or chalk, in which case the stirring of the soil cannot be carried deeper, unless at an immense cost of labour; but in the greater number of instances, the soil rests on a till of a hardish clayey substance, usually called subsoil; and this, which we may call layer No. 3, must be stirred and gradually brought up in aid of the upper soils. As mentioned under the head *Subsoil-Ploughing*, the proper method of nourishment consists of first stirring or breaking up the hard subsoil. Get down to it, and go over it with a pickaxe. Next year it may be incorporated with layer No. 2, and in two or three years the whole three layers may be indiscriminately mingled or made to change places. Such is the principle of trenching, by which three layers of soil are alternately, or at proper intervals, compelled to do duty; and thus a farm of six acres, by being, as it were, three storey deep, is practically as extensive as one of eighteen acres, but one storey deep. When we add, that while the plough leaves lumps of earth unbroken, and comparatively useless to the crop, the spade dashes and pulverises the whole soil, bringing all into effective play on the roots, the value of spade over plough husbandry will be at once apparent. Another important advantage of deep-trenching with the spade, is the turning down and destroying the larvæ of insects and seeds of weeds which may be about the surface; and it will be found that the first crops of trenched ground are always remarkably free of these nuisances.

The process of trenching to effect these important advantages is no doubt very toilsome; this, indeed, is a fact not to be concealed; but without almost constant labour, and labour in which a pleasure is taken, cottage-farming will generally come to nought; and he who is disinclined to undergo the trouble, should not commence the undertaking. To render the work as easy as possible, it should be strictly methodic, and bit by bit, and always the more the ground is tilled, the less difficult will the trenching be.

Trenching, either for gardening or farming, is usually performed as follows:—Mark off the field in strips of two feet in width, as in the annexed diagram. Commence at *x* and *y* at top of the field, and take from each

Top of the Field.



Bottom of the Field.

the top layer, which wheel across to *a* and *b*, beyond the top of the strip H. Then dig out the lower layer or subsoil from *x*, and wheel it away to a separate heap near where you have laid the top earth. The patch *x* being now empty, fill it two-thirds, first with layer No. 2, and next with layer No. 3 of *y*, and cover it with layer No. 1, or top earth of *z*. Thus go on wheeling and shifting till you come to the bottom of A. You now turn and trench upwards the strip B in the same manner; trench down C and up D, and so on till you have in every patch laid a layer No. 2 undermost, and a layer No. 3 above it. The overplus, wheeled aside, will fill up the strip H. You may vary the process in many different ways; and if you think proper, place layer No. 2 uppermost, and layer No. 1 in the centre; but all this must be left to your own ingenuity, and your ideas of what will be best on the occasion. As a further means of melioration, some trenchers stir the bottom of each strip when it is exposed with a pickaxe, which is a good plan; for the more the subsoil is loosened and prepared for being brought into activity, the more fertile will the fields be.

General Management.

Whether the land of a cottage-farmer be part of a reclaimed bog or waste, or a section of fertile soil, or whether it be his own property, or rented, he must necessarily exert unremitting industry not only in digging and trenching his small fields, but in all the ordinary routine of manuring, cropping, and in attending to the other affairs of his establishment. To procure manure in sufficient abundance, he must keep one or two cows and a pig, and into a pit adjoining the cowhouse all the solid refuse, including all that may be collected from the dwelling-house, must be removed. The urine from the cow-house should be collected in another pit, or in a barrel sunk in the ground, protected from the air. This will be found a most valuable liquid for throwing over the land, to excite a young growing crop. While on the subject of manures, it cannot be out of place to mention that most surprising results have been effected in agriculture and market-gardening by the use of night soil. In some foreign countries, where this is well understood, the night soil is carefully saved, and to destroy its offensive effluvia, is mixed with gypsum or earth; for a few shovelsful of earth thrown over it at once removes all offensiveness in this respect, besides being otherwise useful. So little thought and trouble have hitherto been taken in Britain to preserve this material for manure, that for the use of enterprising agriculturists, quantities are still imported from France in a dried and prepared condition.

There are other means of increasing the quantity of manure. From every piece of ground a quantity of rubbish may be collected—as withered leaves, stalks, clippings of branches, roots, &c. Improvident persons burn much of this refuse, but we strongly advise the cottager or gardener never to burn anything, except it be stumps of trees or pieces of branches as fuel. Collect all the inferior stuff into a heap, to which scrape or carry all the mire that can be gathered from the pathways, and the whole will make a compost dunghill; a pailful of cow urine thrown occasionally over the heap will be a valuable addition, and so likewise will be a shovelful of night soil. A little lime will hasten the rotting of any compost. If properly managed, in twelve months all will be rotted, and then begin taking from one end for manure. To the other extremity you may keep adding new matter that is collected. The treatment of the ordinary dung-pits is to be on the same plan. Do not remove the manure till it has lain a sufficient length of time to decompose, but keep taking from one that is ready while another is collecting.

If a rivulet can be made to run upon a meadow, as previously described under the head *Irrigation*, the cottager will add prodigiously to his stock of grain, fodder, and hay. From a single acre, well irrigated, as much as 200 stones of sweet nourishing hay may be gathered every year, besides a quantity of green stuff. The proper saving of this artificial meadow hay requires considerable tact; if anyway spoiled, the cattle will probably not touch it.

In the scheme of working a cottage farm, it should be an object to make the very most of every day out of doors, when the season and weather permit, and to occupy the dead of winter and days of bad weather at work in the barn or house. There is always some implement or gearing to make or mend; and where the cottager has willows and straw at command, field-baskets, beehives, and the like, might often be made either for his own use or for sale. The Swiss small farmers do much by working at some handicraft employment, particularly weaving and making toys, during those seasons when prevented from labouring out of doors; and in many instances they keep one member of the family at the loom. In short, none must be idle; the grown-up children, when not at school, being made useful as far as their capacities will admit of.

It is calculated that an active spadesman would find little difficulty in bringing half an acre annually into an improved state; for as eighty rods make the half acre, and there being 313 working days in the year, to accomplish this it would require little more than a quarter of a rod to be trenched daily, whereas a moderate day's work, even where the soil is stony and difficult to trench, would considerably exceed a rod. But where there is a boy or two to assist, an acre per year might with perfect ease be brought into an improved condition.

Whether it would be preferable to devote a cottage farm to a mixture of green and grain crops, as in ordinary husbandry, or make it chiefly a dairy farm, in which the raising of green crops for fodder is the principal if not the only object, must depend on local circumstances. If near a city where fresh dairy produce could be profitably disposed of, dairy-farming might be most suitable, although the large rents usually exacted near populous towns would prove an obstacle. Several experiments have been made in order to ascertain the quantity of produce in roots, artificial grasses, &c. that an acre of ground, under this sort of culture, could be made to yield; and the result has been, that even less than eighty rods, or half an acre, will produce food sufficient to maintain a cow. This calculation is founded upon the well-known fact, that 100 pounds weight of green food, a considerable portion of it roots, is a sufficient daily allowance for an ordinary cow. But cows kept upon such produce must not be allowed to pasture on those portions of the ground that are devoted to grass crops, such as clover, lucern, tares, &c.; but for the better health of the animals, they should have an open space to move about in adjoining the shed or out-building, where they find shelter from the storm and cold; for in soiling cattle during the hottest part of summer, an open shed, with a rack for their food, is to be preferred to shutting them up in close stables. Mr Allen, in his 'Colonies at Home,' very properly remarks—'Whenever it is possible to make a rod of ground produce 500 pounds of the artificial grasses, in the several cuttings during the season, I greatly prefer it to anything else, for cows thrive best upon grass and hay.' He afterwards observes, in reference to this sort of food—'As it sometimes suffers much in dry seasons, we must not depend entirely upon it; but I have proved that it is possible to keep a cow all the year round upon the produce of half an acre of land, if it be carefully cultivated.' He then proceeds to give a list of the produce he raised, which consists of lucern, cabbage, tares, mangel-wurzel, potatoes, turnips, parsnips, and carrots; and as a portion of hay is indispensable along with some of the root-crops during the winter season, he did not attempt to grow it, but sold a portion of his potatoes, and laid out the sum he received for them in hay. We need only add, that whatever number of cows be kept, they must be fed entirely within doors, and only suffered to go out in any small enclosure for the sake of air and exercise.

Plan of a Three-Acre Farm.

With the view of keeping up in the country a certain number of peasant families who should be able to assist farmers at particular seasons, the late Sir John Sinclair planned a system of cottage farms of three acres each; these were individually to be cultivated entirely by manual labour, and by the cottager and his family. From the account of the method of managing these cottage farms, which he has given in the second volume of the 'Farmers' Magazine,' we select the following particulars:—

'*Course of Crops.*—The three acres proposed to be cultivated should be divided into four portions, each consisting of three roods, under the subjoined system of management:—

	Roods.
Under potatoes, two roods; under turnips, one, -	3
Under winter tares, two roods; spring tares, one, -	3
Under barley, wheat, or oats, - - - - -	3
Under clover, with a mixture of rye-grass, -	3
Total, - -	12

Other articles besides these might be mentioned; but it seems to me of peculiar importance to restrict the attention of the cottager to as few objects of cultivation as possible. It is proposed that the produce of the two roods of potatoes shall go to the maintenance of the cottager and his family, and that the rood of turnips should be given to the cow in winter and during the spring, in addition to its other fare.

The second portion, sown with tares (the two roods of potatoes of the former year to be successively sown with winter tares, and the turnip rood with spring tares), might partly be cut green, for feeding the cow in summer and autumn; but if the season will permit, the whole ought to be made into hay for the winter and spring food, and three roods of clover cut green for summer food.

The third portion may be sown either with barley, wheat, or oats, according to the soil or climate, and the general custom of the country. The straw of any of these crops would be of essential service for littering the cow, but would be still more useful if cut into chaff for feeding it.

The fourth portion, appropriated to clover and rye-grass, to be cut green, which, with the assistance of the orchard, will produce, on three roods of land, as much food as will maintain a cow and her calf for five months—namely, from the end of May or beginning of June, when it may be first cut, to the 1st of November—besides some assistance to the pigs. It is supposed that an acre of clover and rye-grass, cut green, will produce 20,000 pounds weight of food for cattle. Three roods, therefore, ought to yield 15,000 pounds weight. A large cow requires 110 pounds weight of green food per day; a middling cow, such as a cottager is likely to purchase, not above 90 pounds; consequently, in five months, allowing 1320 pounds weight for the calf and the pigs, there will remain 13,680 pounds for the cow. Were there, however, even a small deficiency, it would be more than compensated by the rood of land proposed to be kept in perpetual pasture as an orchard.

Mode in which the Family may be Maintained.—It is calculated that three roods and eight perches of potatoes will maintain a family of six persons for about nine months in the year, but according to the preceding plan, it is proposed to have but two roods under that article; for however valuable potatoes are justly accounted, yet some change of food would be acceptable; and the cottager will be enabled, from the produce of the cow, and by the income derived from his own labour, and from that of his family, to purchase other wholesome articles of provision.

Manner in which the Stock may be kept.—It appears, from the preceding system of cropping, that ten roods of land, or two acres and a half, are appropriated to the raising of food for the cow in summer and winter, besides the pasture of the orchard; and unless the season should be extremely unfavourable, the produce will be found not only adequate to that purpose, but also to maintain the calf for some time, till it can be sold to advantage. It is indeed extremely material, under the proposed system, to make as much profit of the calves as possible, as the money thus raised will be a resource, enabling the cottager to replace his cow when a new one must be purchased.

For the winter provision of the cow, which is the most material, because the summer food can be more easily procured, there is the produce—1. Of about three roods of tares made into hay; 2. Of three roods of straw, deducting what may be necessary for litter; and if dry earth be put into the cow's hovel, and removed from time to time to the dunghill, little or no litter will be necessary; 3. Of one rood of turnips.

The whole will be sufficient for seven months in the year; namely, from the 1st November to the 1st June; and during the remaining five months, the pasture of the orchard, some of the winter tares, and the produce of three roods of clover and rye-grass, will not only suffice, but will furnish a surplus for the calf, if it is kept for any length of time, and some clover for the pigs. The inferior barley, potatoes, &c. will of course be given to the pigs and poultry.

Value of the Produce.—The land thus managed will certainly produce, by means of the extra industry of the family, and at a small expense, a most important addition to the income which the cottager may derive from his ordinary labour. For instance—

	Per Annum.		
1. The orchard, after the trees become fruitful, will probably yield, - -	£1	10	0
2. Three roods of turnips and potatoes, -	4	0	0
3. Eighteen bushels of barley at 4s., -	3	12	0
4. The cow and calf, - - - -	7	0	0
5. Hogs, - - - - - -	3	0	0
6. Poultry and eggs, - - - - -	2	0	0
Total, - - - -	£21	2	0

Where wheat can be raised instead of barley, the profit would be still more considerable. Opinions will differ much regarding the value put on each article; but that is of little consequence, as the total cannot be accounted too high.

Time required for Cultivating the Land.—The quantity of land intended to be cultivated will not materially interfere with the usual labour of the cottager. It will only require to be dug once, and is then fit to be cropped. It is proposed that only nine roods shall be annually cultivated (the remaining three roods being under clover and rye-grass), and nine roods may be dug in the space of about 558 hours, or at the rate of sixty-two hours per rood. This may be done at by-hours (more especially when the family of the cottager shall be somewhat advanced, and consequently more able to furnish assistance); but supposing that the digging, manuring, harvesting, &c. will require twenty entire days per annum, in addition to the by-hours, and allowing sixty days for Sundays and holidays, there will remain 285 days for the ordinary hand-labour of the cottager, which, at 1s. 6d. per day, would amount to £21, 7s. 6d.; the earnings of the wife and children may, at an average, be worth at least £4 per annum more. This is certainly a low calculation, considering how much may be got during the hay and corn harvests. But even at that moderate estimate the total income of the family will be as follows:—

1. Produce of the farm, - -	£21	2	0
2. Labour of the cottager, - -	21	7	6
3. Earnings of the family, - -	4	0	0
Total, - - -	£46	9	6

Rent and Balance of Income.—The rents of cottages and of land vary so much in different parts of the kingdom, that it is difficult to ascertain an average. But if the cottage shall be stated at £3 per annum, the land at 25s. per acre, and the orchard at 16s., the whole will not exceed £7, 13s. The cottager will also be liable to the payment of some taxes, say to the amount of £1, 5s. more. Hence the total deductions would be about £9, leaving a balance in favour of the cottager of £37, 9s. 6d. Considering the cheap rate at which he is furnished with a quantity of potatoes, equal to several months' consumption, and with milk for his children, surely with that balance he can find no difficulty not only in maintaining himself and family in a style of comfort, but also in placing out his children properly, and laying up a small annual surplus, that will render any parish assistance, either in sickness or old age, unnecessary.

Advantages.—The land possessed by the cottager would be completely cultivated, and rendered as productive as possible. The dung produced by the cow, pigs, &c. would be amply sufficient for the three roods under turnips and potatoes, which would afterwards produce—1. Tares; 2. Barley; and 3. Clover; with a mixture of rye-grass in regular succession, without any additional manure. The barley should yield at least eighteen bushels, besides three bushels for seed; and if wheat is cultivated, in the same proportion. The milk, deducting what may be necessary for the calf and for the cottager's family, might be sold in its original state, if there shall be a market for it; or converted into butter, for the purpose of supplying the neighbouring towns or villages. Such cottagers also might certainly send to market both eggs and poultry.

It is hardly possible to suggest a measure more likely to promote the benefit of a numerous and valuable body of people. The system of keeping cows by cottagers, which has been found so advantageous in the grazing districts, may thus be extended over the whole kingdom; and indeed, if the above plan is found to answer, in place of four or five acres employed in feeding a single cow, it would be much better, even in the grazing counties, to restrict the land to a smaller quantity, under a tillage mode of management.

It is of infinite consequence to establish the practicability of this system, as the means of removing a most unfortunate obstacle to the improvement of the country. It is well known to be the only popular objection to the enclosure of our wastes and commons, that, while unenclosed, a number of cottagers are enabled to keep cows by the means of their common rights, and that their cows disappear when the commons are enclosed. But if so small a portion of land as 3¼ acres, when improved and properly cultivated, can enable a cottager to keep a cow to more advantage than with a right of common, which can hardly be doubted, as he is enabled to provide winter as well as summer food, there is an end to that obstacle to improvement. Indeed, if sufficient attention be paid to the principles above detailed, the situation of the cottager, instead of being deteriorated, would be materially bettered by the enclosure; and his rising family would be early accustomed to habits of industry and order, instead of idleness and vice.

I shall conclude with asking if any one can figure to himself a more delightful spectacle than to see an industrious cottager, his busy wife, and healthy family, living in a comfortable house, rented by himself, cultivating his little territory with his own hands, and enjoying the profits arising from his own labour and industry! Or whether it is possible for a generous landholder to employ his property with more satisfaction, or in a manner more likely to promote not only his own but the public interest, than by endeavouring to increase the number of such cottagers, and encouraging by every means in his power the self-sustaining exertions of so meritorious and so important a class of the community.'

To the article comprehending the above account there is added an appendix, containing a letter from Sir Henry Vavasour, describing the field-gardening on his estate. We extract from it the following passages: —' I have for some years encouraged my cottagers in Yorkshire in this mode of managing their small garths or gardens, which are in general from one to three acres. I have now an opportunity of stating the husbandry of a poor industrious cottager's garth, whose land I visited almost every day during the last harvest. His stock was two cows and two pigs; one of his cows had a summer's gait for twenty weeks with his landlord. The land was partly ploughed and partly dug with the spade, cultivated (the ploughing excepted) by the man, his wife, and a girl of about twelve years of age, in their *spare* hours from their daily *hired* work, seldom a whole day off, except in harvest: made the rent in butter, besides a little used in the family. The man relates that he thinks he clears, one year with another, from the three acres, about £30. The daily wages his family earns nearly keep them. It is very evident that this man clears, from his three acres, more than a farmer can possibly lay by from more than eighty acres of land in the common husbandry of the country—paying for horses, servants, &c.; and it must be obvious to every one how great the advantages must be to society in cultivating land in this manner. It would have taken more than half the quantity of his three acres in pasture for one cow at grass during half the year; whereas (excepting the summer's gait for one of his cows, as mentioned before) his stock of two cows and two pigs is kept and carried on the whole year. The family lives well, and a handsome sum has been yearly saved, to place out two sons, and supply them with clothes, washing, &c.'

Spade Husbandry in Belgium.

As a picture of rural affairs under a well-conducted system of spade husbandry, we present the following from the report of Mr George Nicholls respecting Belgium, laid some years ago before parliament:—

'The extensive manufactures which at no very remote period flourished in Belgium, appear to have congregated a numerous population of artisans in and around the great towns. As the scene of manufacturing industry changed, this population was deprived of its means of handicraft employment, and was compelled to resort to the cultivation of the soil for subsistence. This seems to have been the chief, though possibly not the sole, origin of the system of the small farms which still prevails, and which are cultivated by the holder and his family, generally without other assistance. The farms in Belgium very rarely exceed 100 acres; the number containing fifty acres is not great; those of thirty and twenty acres are more numerous; but the number of holdings of from five to ten and twenty acres is very considerable, especially those of smaller extent; and to these I chiefly confined my inquiries.

The small farms of from five to ten acres, which abound in many parts of Belgium, closely resemble the small holdings in Ireland; but the small Irish cultivator exists in a state of miserable privation of the common comforts and conveniences of a civilised life, while the Belgian peasant-farmer enjoys a large portion of those comforts. The houses of the small cultivators in Belgium are generally substantially built, and in good repair: they have commonly a sleeping-room in the attic, and closets for beds connected with the lower apartment, which is convenient in size; a small cellarage for the dairy, and store for the grain, as well as an oven, and an outhouse for the potatoes, with a roomy cattle-stall, piggery, and poultry-loft. The house generally contains decent furniture; the bedding sufficient in quantity; and although the scrupulous cleanliness of the Dutch may not be everywhere observable, an air of comfort and propriety pervades the whole establishment. In the cow-house the cattle are supplied with straw for bedding; the dung and moisture are carefully collected in the tank; the ditches had been scoured to collect materials for manure; the dry leaves, potato-tops, &c. had been collected in a moist ditch to undergo the process of fermentation, and heaps of compost were in course of preparation. The premises were kept in neat and compact order, and a scrupulous attention to a most rigid economy was everywhere apparent. The family were decently clad, none of them were ragged or slovenly, even when their dress consisted of the coarsest material. The men universally wear the blouse, and wooden shoes are in common use by both sexes. The diet consists, to a large extent, of rye bread and milk; the dinner being usually composed of a mess of potatoes and onions, with the occasional addition of some pounded ham or slices of bacon. The quantity of brown wheaten bread consumed did not appear to be considerable. I need not point out the striking contrast of the mode of living here described with the state of the same class of persons in Ireland; and it appears important to investigate the causes of this difference.

In the greater part of the flat country of Belgium the soil is light and sandy, and easily worked; but its productive powers are certainly inferior to the general soil of Ireland, and the climate does not appear to be superior. To the soil and climate, therefore, the Belgian does not owe his superiority in comfort and position over the Irish cultivator. The difference is rather to be found in the system of cultivation pursued by the small farmers of Belgium, and in the habits of economy and forethought of the people. The cultivation of the small farms in Belgium differs from the Irish—1*st*, In the quantity of stall-fed stock which is kept, and by which a supply of manure is regularly secured; 2*d*, In the strict attention paid to the collecting of manure, which is most skilfully managed; 3*d*, By the adoption of a system of rotation of five, six, or seven successive crops, even on the smallest farms, which is in striking contrast with the plan of cropping and fallowing the land prevalent in Ireland.

In the farms of six acres, we found no plough, horse, or cart; the only agricultural implement, besides the spade, fork, and wheelbarrow, which we observed, was a light wooden harrow, which might be dragged by the hand. The farmer had no assistance besides that of his wife and children, excepting sometimes in harvest, when we found he occasionally obtained the assistance of a neighbour, or hired a labourer at a franc per day. The whole of the land is dug with the spade, and trenched very deep; but as the soil is light, the labour of digging is not great. The stock on the small farms which we examined, consisted of a couple of cows, a calf or two, one or two pigs, sometimes a goat or two, and some poultry. The cows are altogether stall-fed on straw, turnips, clover, rye, vetches, carrots, potatoes, and a kind of soup made by boiling up potatoes, peas, beans, bran, cut hay, &c. into one mess, and which, being given warm, is said to be very wholesome, and to promote the secretion of milk. In some districts the grains of the breweries and distilleries are used for the cattle; and the failure of the Belgian distilleries has been reckoned a calamity to the agriculture of the country, on account of the loss of the supply of manure which was produced by the cattle fed in the stalls of these establishments.

The success of the Belgian farmer depends mainly upon the number of cattle which he can maintain by the produce of his land, the general lightness of the soil rendering the constant application of manure absolutely necessary to the production of a crop. The attention of the cultivator is always, therefore, especially directed to obtain a supply of manure. Some small farmers, with this view, agree with a sheep-dealer to find stall-room and straw for his sheep, to attend to them, and to furnish fodder at the market price, on condition of retaining the dung. The small farmer collects in his stable, in a fosse lined with bricks, the dung and moisture of his cattle. He buys sufficient lime to mingle with the scourings of his ditches, and with the decayed leaves, potato-tops, &c. which he is careful to collect, in order to enrich his compost, which is dug over two or three times in the course of the winter. No portion of the farm is allowed to lie fallow, but it is divided into six or seven small plots, on each of which a system of rotation is adopted; and thus, with the aid of manure, the powers of the soil are maintained unexhausted, in a state of constant activity. The order of succession in the crops is various; but we observed on the six-acre farms which we visited, plots appropriated to potatoes, wheat, barley, clover (which had been sown with the preceding year's barley), flax, carrots, turnips or parsnips, vetches, and rye, for immediate use as green food for cattle. The flax grown is heckled and spun by the farmer's wife, chiefly during the winter; and we were told that three weeks' labour at the loom towards the spring enabled them to weave into cloth all the thread thus prepared. The weavers are generally a distinct class from the small farmers, though the labourers chiefly supported by the loom commonly occupied about an acre of land, sometimes more, their labour upon the land alternating with their work at the loom. In some districts, we were informed, every gradation in the extent of occupancy, from a quarter or half an acre to the six-acre farm, is to be found; and in such cases more work of course is done on the loom by the smaller occupiers.

The labour of the field, the management of the cattle, the preparation of manure, the regulating the rotation of crops, and the necessity of carrying a certain portion of the produce to market, call for the constant exercise of industry, skill, and foresight, among the Belgian peasant-farmers; and to these qualities they add a rigid economy, habitual sobriety, and a contented spirit, which finds its chief gratification beneath the domestic roof, from which the father of the family rarely wanders in search of excitement abroad. It was most gratifying to observe the comfort displayed in the whole economy of the households of these small cultivators, and the respectability in which they lived. As far as I could learn, there was no tendency to the subdivision of the small holdings. I heard of none under five acres held by the class of peasant-farmers; and six, seven, or eight acres is the most common size. The provident habits of these small farmers enables them to maintain a high standard of comfort, and is necessarily opposed to such subdivision. Their marriages are not contracted so early as in Ireland, and the consequent struggle for subsistence among their offspring does not exist. The proprietors of the soil retain the free and unrestricted disposal of their property, whether divided into smaller or larger holdings. The common rent of land is about twenty shillings an acre, and the usual rate of wages for a day labourer is a franc (or 10d.) a day.

A small occupier, whose farm we examined near Ghent, paid 225 francs per annum for about two *bonniers*, or six acres, of land, with a comfortable house, stabling, and other offices attached, all very good of their kind; this makes the rent (reckoning the franc at 10d.) equal to £9, 7s. 6d. sterling per annum; and if we allow £3, 7s. 6d. for the rent of the house, stabling, and other offices, there will be £6, or £1 per acre for the land, which accords with the information we obtained at Antwerp, Brussels, and other places, as to the rent of land in the flat country, the soil of which is generally of the same quality throughout. This farmer had a wife and five children, and appeared to live in much comfort. He owed little or nothing, he said; but he had no capital beyond that employed on his farm. We questioned him respecting his resources in case of sickness. He replied, that if he were ill, and if his illness were severe and of long duration, it would press heavily upon him, because it would interrupt the whole farm-work; and in order to provide for his family, and to pay the doctor, he feared he should be obliged to sell part of his stock. If his wife and family were long ill, and he retained his strength, the doctor would give him credit, and he should be able to pay him by degrees in the course of a year or two. The thought of applying for assistance in any quarter appeared never to have entered his mind. We suggested that the Bureau de Bienfaisance, or charitable individuals, might afford him aid in such a difficulty; but, with evident marks of surprise at the suggestion, he replied cheerfully that he must take care of himself. If a sick club or benefit society were established among these people, so as to enable them by mutual assurance to provide for the casualty of sickness, the chief source of suffering to their families would be obviated, and there would be little left to wish for or amend in their social condition.'

Comparative Value of Spade Husbandry.

It is, we believe, an indisputable fact, that a garden produces heavier crops, space for space, than a field under ordinary culture with the plough. 'In regard to difference of produce'—we quote the Code of Agriculture—'an experiment was tried in the neighbourhood of Hamilton, expressly to ascertain that point. A field was taken, which had been cropped with beans the preceding year, and the previous year with oats. Two ridges were dug, and two ploughed alternately, and the whole was sown on the same day. A part both of the ploughed and dug was drilled with the garden-hoe. The whole was reaped the same day, and being thrashed out, the result was, that the dug land sown broadcast, was to the ploughed sown broadcast as fifty-five bushels to forty-two; while the dug and drilled was as twenty and a quarter bushels to twelve and a quarter upon the ploughed and drilled. The additional grain produced was not the only beneficial result gained by digging; for in this instance there was also a great deal of straw, and the land was much more free of weeds, and more easily cultivated in the following year.'

Some soils, however, are unsuitable for spade husbandry; as, for instance, heavy wet lands liable to inundation; stony, gravelly, or shallow soils, more especially if incumbent on chalk. Manual labour is also inapplicable where the climate is precarious, and it is necessary to be expeditious in tilling the land, and in sowing and harrowing for a crop. On these accounts spade husbandry cannot be universally resorted to with advantage either to the culturist or the community. With respect to its economy, where it is available, there are two questions.

First, Whether the cottage farmer, with his six acres, can raise as much produce, and at as cheap a rate, as the capitalist can from any given six acres on his farm? If he cannot raise so much at so cheap a price, and cannot pay the same proportion of rent, cottage-farming is decidedly injurious to the community; but if he can compete on all these points, there can be no solid objection against the practice. From the foregoing evidence of Sir John Sinclair, and from what is known respecting spade husbandry in Belgium and some other continental states, it is placed beyond a doubt that more produce is raised for human subsistence—space, soil, and climate being equal—by small farmers using only manual labour, than by large farmers with horses and ploughs; and it is certain that the produce is always more accessible to the public than that of large farmers, who, by means of their capital, which is very frequently not their own, but borrowed from banks, can hold themselves indifferent respecting sales, till, by a fortunate contingency, the prices rise, and become highly remunerative.

Second, How far is spade husbandry available in the shape of paid labour to the capitalist farmer? We are unable to answer this question from our own experience, and therefore refer to a paper written by a competent authority on the subject. This is an essay by Mr Archibald Scott of Southfield, near Haddington, who obtained a prize of £100, which the Rev. C. Gardiner, a clergyman of the Church of England, had proposed to grant for the best plan of giving employment to the poor:—

'I am quite convinced,' proceeds Mr Scott, 'there is but one way of employing the surplus population of England and Ireland, and that is by a judicious introduction of spade husbandry.

To show that I am not a mere theorist, but a practical man, I may mention that I rent a farm from the Earl of Wemyss in East Lothian, consisting of 530 Scotch acres; that I have cultivated land to a considerable extent with the spade for the last three years, and that the result has exceeded my most sanguine expectations. In 1831, I determined to ascertain the difference of the expense and produce between trenching land with the spade and summer fallowing with the plough in the usual way; I therefore trenched thirteen acres of my summer fallow-break in the months of June and July; I found the soil about fourteen inches deep, and I turned it completely over, thereby putting up a clean and fresh soil in the room of the foul and exhausted mould, which I was careful to put at the bottom of the trench: this operation I found cost about £1, 10s. per Scotch acre, paying my labourers with 1s. 6d. per day. The rest of the field, which consisted of nine acres, I wrought with the plough in the usual way, giving it six furrows, with the suitable harrowing. I manured the field in August; the trenched got eight cart-loads per acre, the ploughed land sixteen; the field was sown in the middle of September. The whole turned out a bulky crop as to straw, particularly the trenched portion, which was very much lodged. On threshing them out, I found them to stand as under:—

By trenched wheat per acre, 52 bushels at 6s. 9d.,		£17 11 0
To two years' rent at £2, 10s. per acre,	£5 0 0	
Expense of trenching, - - -	4 10 0	
Seed, three bushels at 6s. 9d., - - -	1 0 3	
Eight cart-loads of manure at 4s., -	1 12 0	
Expense of cutting, threshing, and marketing, - - - - - - -	1 10 0	
Profit, - - -	3 18 9	
		£17 11 0

By ploughed wheat per acre, 42 bushels at 6s. 9d.,		£14 3 6
To two years' rent at £2, 10s. per acre,	£5 0 0	
Six furrows and harrowing at 10s., -	3 0 0	
Seed, three bushels at 6s. 9d., - - -	1 0 3	
Sixteen cart-loads of manure at 4s., - -	3 4 0	
Expense of cutting, threshing, and marketing, - - - - - - -	1 10 0	
Profit, - - -	0 9 3	
		£14 3 6

I now saw, that though it might be difficult to trench over my fallow-break during the summer months, it was by no means making the most of the system, as the operation was not only more expensive, owing to the land being hard and dry during the summer, but that it was a useless waste of time to take a whole year to perform an operation that could be as well done in a few weeks, provided labourers could be had; and as in all agricultural operations losing time is losing money, as the rent must be paid whether the land is carrying a crop or not, so that in taking one year to fallow the land, and another to grow the crop, two years' rent must be charged against the crop, or at least there must be a rent charged against the rotation of crops for the year the land was fallow. As I felt satisfied that, by trenching with the spade, the land would derive all the advantages of a summer fallowing, and avoid all the disadvantages attending it, I determined on trenching thirty-four acres of my fallow-break immediately on the crop being removed from the ground, and had it sown with wheat by the middle of November 1832. I may here remark, that I did not apply any manure, as I thought the former crop was injured by being too bulky. As it is now threshed out and disposed of, the crop per acre stands as follows:—

By average of 34 bushels per acre at 7s.,		£15 8 0
To rent of land per acre, - -	£2 10 0	
Expense of trenching, - - -	4 0 0	
Seed, - - - - -	1 1 0	
Cutting, threshing, and marketing, -	1 10 0	
Profit, - - -	6 7 0	
		£15 8 0

The advantages of trenching over summer fallow are, in my opinion, very decided, as it is not only cheaper, but, as far as I can yet judge, much more effectual. I am so satisfied of this, not only from the experiments above noticed, but from the apparent condition of the land after it has carried the crop, that I have this autumn cultivated about a hundred acres with the spade, and the crops at present are very promising. When I first commenced, I was laughed at by my neighbours; but now, when they see me persevering in what they considered a very chimerical project, they are suspending their judgment, and several of them have made considerable experiments this year. I should think there are at least 250 acres under crop cultivated in this way this season in East Lothian; in 1831, the year I commenced, there was not a single acre. I have therefore the satisfaction of knowing that I have been the means of causing £1000 to be spent this year amongst the labouring classes in my immediate neighbourhood; and I feel confident, that should the season turn out favourable for the wheat crop, and fair prices obtained, their employers will be handsomely remunerated for their outlay. I do not say that this system will succeed in every description of soil, as it must necessarily be of some depth to admit of the operation; but there are few districts where such soil will not be found in sufficient abundance to give ample employment to the surplus population of the neighbourhood.

Now this is going on in a county where agricultural labourers *are better employed* than almost any other in Great Britain. The system was not introduced, nor is it persevered in, for the purpose of giving employment to the poor, but entirely for the benefit of the employer. The East Lothian Agricultural Society are now offering premiums for the most satisfactory reports on the subject. I last year received a medal from the Highland Society of Scotland for introducing the system; and what I value still more, I received a piece of plate from the labourers I employed, as a token of their gratitude. The system, I admit, is only in its infancy, but I have this year put it completely to the test; and should it succeed as well as it has done hitherto, it must take root and spread over the kingdom; and the landed interest in those districts of England where the poor-laws are so oppressive, and still more the Irish proprietors, will do well to investigate the system, and have it introduced with the least possible delay, that what is now a burden on their estates may become a source of wealth, and what is now a curse may become a blessing.

This system, if it succeed to my expectation, possesses all the requisites you require: it furnishes employment for the surplus population by substituting manual labour for that of horses—and certainly, if there is a lack of food for both, it is desirable that the one should give place to the other; it will make bread plenty, as the naked summer fallows of Great Britain will be covered with grain instead of lying waste for a season; it will render corn laws unnecessary, as we will be then independent of foreign supplies; farmers will be enriched who are enterprising and industrious, and they only deserve to be so; it will raise rents, by increasing the capabilities of the soil, enabling the farmer to cultivate wheat to double the present extent; it will raise up a home-market for our manufactures, as the paupers, who are at present starving, or living a burden on the parish, will find employment, and thereby be enabled to procure the necessaries and comforts of life; it will check the poor-laws, as there will then be none but the aged and the helpless dependent on parochial aid.'

We might add other testimonies in favour of spade husbandry, all less or more conclusive of its advantages in certain situations and under certain circumstances; but we forbear, leaving consideration of the subject to those who may be personally interested in its adoption. This, however, we may state generally—that on light loams which have been long under croppage, it will be highly advantageous to have the exhausted substratum occasionally turned up, and this cannot be done more effectually than by a spading of fourteen or sixteen inches; that on wet, turfy soils, it is frequently the only system of tillage which can be adopted to shear down the turf, and thoroughly to bury the herbage; that in the case of lands infested with small boulders, nothing save spade-trenching can be applied; and that in the neighbourhood of towns, where manual labour is abundant, it will be found most effectual for the rearing of all species of green cropping, or root-crops. It is true that in remote districts it can never be extensively followed, and its adoption is also rendered less necessary by the invention of the subsoil and trench ploughs; but for those having abundance of hands and capital at their command, and who have soils such as we have above described, or who wish to subsoil thoroughly, spade husbandry has advantages to recommend it over any other known mode of tillage. Without at all entering at length upon the merits of the Allotment System, it is clear that in the present state of agriculture the plough must continue to be the main implement of tillage; and we only, but strongly, recommend the spade where the requisite amount of labour can be easily procured, and where the soils require a thorough upturning and incorporation. The question of cost should scarcely enter into consideration, for a well-executed spade-tillage must be regarded more in the light of a permanent improvement than a temporary expedient. On this point our views are fully corroborated by the following observations of the Rev. Mr Hickey (Martin Doyle)—one of our ablest agricultural authorities:—' However gratifying to the benevolence of an individual farmer it may be to employ a vast number of men to dig his land in preference to the usual course of plough and horse-labour, he must consider that there is a limit beyond which he cannot multiply his labourers without occasional inconvenience and perplexity to himself, and without *unceasing superintendence*. Should any of the numerous causes which may occasion a change of occupiers on a given farm, or a change of *system* occur, what is to become of the numerous families collected by an individual who has largely introduced the practice of manual labour, and confined his operations to that system alone? What is to become of an excessive population of agricultural labourers, if their services be no longer required by the successor of the spade-husbandry farmer? If any one replies, "Oh, let the system be generally introduced, and there can be no danger of their want of employment somewhere," the answer is plain. If you substitute the spade for the plough to such an extent, you raise the price of labourers beyond what you can afford to pay, and you diminish the chances of success in your general farm operations, by giving up too much time to one department of labour. Time is money to a farmer; let him lose a week in a critical season, and the delay may be highly injurious to him in many respects. Promptitude and despatch are essential to his completion of farm labours at the proper times: without the aid which improved machinery affords him, it would be utterly impossible for him to get through his work in due course. Let him abandon the more rapidly-working plough, and take the tedious spade, and he will soon heartily regret his exchange. After what we have premised on this subject, it is almost superfluous to repeat, that if these latter remarks possess any accuracy at all, they are merely true in their application to *large* farmers, and not intended by any means to affect the subject as it is connected with the cotter or small farmer, who has rarely any capital but his labour, and "needs no other if he be suffered to use it freely and fairly." What is the limit, then, to the capital of his labour? What sized farm should he have that will make it the most productive? Why, the exact amount to which he can apply all his capital. Has he a family, he may then have more capital of labour to bestow by their assistance; consequently a larger allotment will be needed to employ all the capital of more extended labour. Is he single, then less will suffice.'

The only point that remains to be settled is one connected with political economy. It is alleged by the leading political economists of England that cottage-farming, while calculated to promote the growth of a population of paupers, is only distracting manual labour from its proper field of employment. If it could be shown that every able-bodied man could make five shillings a day by working as a weaver, at a factory, or any other branch of labour, the assertion would in part be correct; but such is not the case. There are countries in which remunerative employment cannot be permanently had, and in such situations—to which society in England seems advancing—the choice is in a great measure between spade husbandry and starvation, not between spade husbandry and well-paid employment. Besides, the political economist entirely overlooks the fact, that the cottage farmer derives immense advantages from the labour of his wife and children, not one of whom, most likely, would be able to earn a penny at any kind of labour in towns. It is by calling up these engines to assist him that he can outdo the large farmer with all his capital and machinery—a fact distinctly proved, at least as respects the keeping of cows and selling their produce; no joint-stock company of cowkeepers being able to compete with the miscellaneous and unmarketable labour of a humble dairyman and his family. As to the allegation that cottage-farming would cause a deterioration in society, it is also founded on narrow views. In some parts of the canton of Vaud, and elsewhere in Switzerland, where the farms are all small, and mostly wrought by their proprietors, there is no pauperism worthy of the name, no overplus population; and who would compare the orderliness of manners, the sobriety and thriftiness of the people, and the small amount of crime in that country, with the vice, intemperance, and poverty, for which England and Scotland, with all their large and splendid farms, are now becoming unhappily distinguished? It might be difficult to prove that large farms have been, in any material degree, the cause of the social evils now exciting so much attention; but it is clear that they have not prevented those evils. Without going so far as to say that cottage-farming would furnish a universal remedy, we think that, independently of its use in increasing the productive surface of the country, it would at least afford some relief, and add to that section of the population which is still in a healthful moral condition.

THE KITCHEN GARDEN.

THERE are various kinds of gardens—the Italian gardens, with their splendid terraces, vases, and statues; the old French gardens of Le Notre, of which we have a specimen at Versailles, with their long straight walks, clipt hedges, formal parterres, and fountains; English gardens, with their elegant blending of natural with artificial beauty; and so on. But it is to none of these princely kinds of gardens that we intend, in the present series, to direct attention. We propose to treat of the three departments which belong to the greater number of gardens of the middle and humbler classes; those, in short, which, designed on a moderate scale, are intended to afford the three staples of garden culture—*vegetables* for the kitchen, *flowers* to charm the eye, and the more easily attainable kinds of *fruit*. These various articles are for the greater part the production of one garden, a section or scattered part being set aside for each; but for the sake of clearness, we shall confine ourselves in the present sheet chiefly to the economy and products of the kitchen garden.

LAYING OUT OF GARDENS.

A garden of the ordinary mixed description usually extends from the eighth of an acre to a whole acre; but the more common size in country places is about half an acre. Whatever be the dimensions, the garden ought to be enclosed with a wall from ten to twelve feet high, and, if possible, be surrounded by a strip of cultured land, which should be fenced with a hedge and shrubbery, so as to remove the appearance of stiffness from the walled enclosure, and serve for other useful purposes. Besides a wicket or small door for ordinary entrance and exit, there should be a gate that will admit a cart, to take away produce or bring in manure. A much more important circumstance than size or an external appearance is exposure. In a flat country, the garden must of course be level; but if there be a choice as to situation, select by all means a spot which lies with an easy slope—an angle, for instance, of fifteen degrees—towards the sun at his meridian. In the British islands this will be facing the south. The next best exposure is towards the south-west, and after that the west. Avoid a northern or eastern exposure. An exposure towards the morning and mid-day sun, even though at a very small inclination, is as good as being many degrees farther south; hoar-frost on the grass and plants will be melted within an hour after sunrise; whereas if the garden lie in the smallest degree away from the sun, the hoar-frost will remain unchanged perhaps the whole day. Allow no house, wall, or trees, to interrupt the fair action of the morning sun on your garden; for the sun is the main agent in bringing vegetation to perfection, and if you be deprived of it, your operations will be blighted and retarded in every possible way. So important are the sun's rays, that, if your garden be small, rather have no wall on the south and west sides, but only a low fence, than submit to their exclusion. Some gardens are so disposed that they receive the sun in abundance in summer, but only partially the rest of the year. These gardens are imperfect. The garden should be visited all over by the sun daily, except perhaps in the heart of winter, when his rays have comparatively little effect. The exposure should also allow a free admission and currency of air; for this reason a garden is best away from dense old woods, and is most advantageously placed in an open sloping lawn, overlooked by, or near, the house of the proprietor.

The shape of a garden is of little consequence. It may be square, oblong, semicircular, or irregular, according to taste or local circumstances. In the greater number of instances, an oblong, as represented in the following figure, will be found most convenient. It is surrounded by a wall, in which is an entrance marked *e*. Within the wall is a border of several feet wide, and dotted round with flowers or flowering shrubs. Next is a gravel walk; and within is another border containing fruit bushes, or perhaps fruit-trees on espaliers, and in the centre is the body of the garden laid out in three plots, marked *a*, *b*, and *c*. Between these plots and around them are paths (represented by dotted lines) of twelve or fourteen inches in width, not for or-

dinary walking, but for admission to the various plots or sections into which the ground may be divided. These paths are only flattened by the foot or by the spade, and are to be delved up annually in the course of digging. At the opposite side of the garden from the door there may be supposed to be an arbour or summer-house, overhung with climbing plants and honeysuckle, and fitted up according to taste.

The regular walks in all moderately-sized gardens should not be wider than three feet; anything wider is a mere loss of ground. Much care is required to keep walks in order, for they are very liable to show crops of weeds and grass. The best remedy is to bottom the walks well with broken cinders or slag from furnaces; this effectually prevents worms coming up, and also stops the growth of weeds. Over a smooth bed of cinders put a layer of small gravel that will bind, or, failing this, a layer of brayed yellow ashes from a furnace, if they can be procured. Smooth all with the rake, and flatten with a roller. Such walks should be scuffled with the Dutch hoe, raked, and rolled down at least once a year. Many small flowering plants, such as daisies, Virginian stock, and thrift, are used for edgings to walks; but if not constantly attended to, they straggle over the borders. The most effectual and also the prettiest edging is dwarf box. It is easily planted in an even row, grows readily and regularly, requires little trouble in trimming—for it should not be always close shaved—and, summer and winter, is ever fresh and green.

No precise directions can be given respecting garden tools and apparatus; the following are the articles required in moderately-sized gardens of a mixed kind:—Spades of three sizes, a trowel for lifting flowers, Dutch and common hoes, a broad iron rake, a rake with short teeth for the walks, a small rake for flower borders, a strong claspknife for pruning, a pair of strong pruning shears, an axe, a hand-saw, a hammer and nails, a wheelbarrow, a wooden scuttle for carrying a little earth or manure, a roller, a pair of large compasses, a dibble and line, a watering-pot, and a ladder. Flower pots of different sizes, conical earthenware blanching pots, bell-hand glasses, and glazed frames of different sizes. These frames are among the most serviceable parts of a garden apparatus, and may be had either in one piece or with a movable top, as in the following figure. A neat small kind, framed in zinc, useful for protecting early seedlings or flowers, may be had in London for 1s. 6d. each. Other utensils employed by gardeners, such as forcing-pumps to wash wall trees, fumigating bellows, &c. need not be particularised. A person possessing only a small garden will shortly discover by experience what are the articles required in his operations. For gardens in which cucumbers and melons are to be grown, glazed frames and brick-built pits will be necessary. It is a great advantage for every garden to have a command of good fresh water for the purpose of irrigation, and also a small pond in which aquatic plants can be grown. If water is procured from a pump-well, it should be allowed to stand in the open air in a trough for at least a day before being poured on the plants. By this means it not only absorbs carbonic acid gas from, but gradually acquires the temperature of, the atmosphere.

A garden is in all cases laid out according to the taste or fancy of the proprietor; but there are certain general rules which all follow. The wall is reserved for fruit-trees. As fruit-trees require much air and sun, the borders must not be clogged up with bushes, peas, or any other tall vegetables. The borders should contain only small articles which are delved up yearly, because the soil at the roots of the trees requires occasional renewal and loosening, and these operations cannot be done if the ground is encumbered with permanent plants. If a row of gooseberry or other small fruit bushes be placed on the borders, they should be near the outside, and not less than ten feet apart. Let it be observed also that flowering plants should occupy the border most exposed to the sun, while those naturally loving the shade should be placed on the south and west borders, from which the sun's rays are generally less or more excluded.

The body of the garden within the walks is laid out in larger or smaller plots, according to taste. These plots are generally oblong, and are subdivided into sections, rows, or beds for the different kinds of kitchen vegetables. In the corner of one plot are the cucumber and melon pits, partially secluded by bushes. In different corners are plots, and round the edgings are the flower parterres, disposed to meet the eye, and to be easily accessible from the walks. In some gardens much of the ground is overshadowed by fruit-trees. This is seriously detrimental to the growth of the plants beneath, exhausts the soil, and prevents the proper flowering and fructification of every vegetable within reach. Permit no tree to overshadow your ground; the only allowable places for trees are the walls and narrow espaliers running up one side of the central plots. When a garden possesses the addition of an outside strip, enclosed by a hedge, the exterior sides of the walls may be lined with fruit-trees, and the ground laid out for potatoes and other common classes of vegetables; it will also afford the most proper site for compost dung-heaps, forcing-pits, and the like.

SOILS—COMPOSTS—TRENCHING.

The soil of a garden should be deep, rich, and easily penetrable. Whatever it may have been originally, the soil admits of vast improvement, and no trouble can be considered too great to bring it into a good condition. If shallow, trench it according to the plan mentioned in the previous sheet on Spade Husbandry, so as to loosen the subsoil, and gradually bring it into operation above. In many instances the soil is too stiff or clayey. Such a soil may not be unfit for plough husbandry, but it is out of place in a garden. The method of loosening and meliorating a clayey soil is to give it a large volume of sand and vegetable manure, which may be delved in at the winter digging, and at the spring digging the new and old materials will be well mixed. In general, far too little attention is paid to adding sand as a restorative; such is absolutely necessary in all soils but those of a very sandy nature, because every crop actually carries away a certain proportion of the silica lodged in the soil. If the soil be already too sandy, it may be assisted by clay, silt from ditches, vegetable earth, &c. Whatever be the nature of the soil, it should be thoroughly pulverised. Lumps thrown up by digging at the commencement of winter are meliorated by the frost, and have imbibed nutritious gases from the atmosphere. In spring, all should be well delved, cutting and breaking every spadeful as it is turned down, and leaving no hard part impervious to the tender roots of the vegetables. A garden should not contain a single stone the size of a boy's marble. Every particle of soil should be capable of doing duty in feeding the plants. It will save much future trouble in lifting stones by the hand, if every spadeful of mould were at first put through a sieve. Persons owning small gardens ought to pay particular attention to this. A working man having only a small patch for his amusement at leisure hours and on holidays, could not do anything more serviceable than trench his ground bit by bit, and riddle it carefully as he proceeds.

No garden can be conducted with the least advantage without giving it a regular manuring. If you hunger a garden, it will hunger you in return. In connection with every rightly-managed garden, there must either be a compost heap, in which dung is preparing for use, or there must be some means of readily purchasing old manure when it is required. The manures employed are the same as in agriculture (see p. 490); but being required for a more delicate purpose, they must in general be well rotted, and ready to unite with the soil. A compost dung-heap is prepared by putting alternate layers of stable dung, or night-soil, &c. with earth, peat moss, decayed leaves, and general refuse of vegetation, turning the whole occasionally till the mass appears to be sufficiently decomposed for use. A small quantity of this stuff will often be required to place at the roots of plants.

The practice of professional gardeners as respects composts may be learned from the following brief notice in the 'Encyclopædia of Gardening':—'Composts for particular plants may be reduced to light sandy loam from old pastures; strong loam, approaching nearly to brick earth, from the same source; peat earth from the surface of heaths or commons; bog earth from bogs or morasses; vegetable earth from decayed leaves, stalks, cow-dung, &c.; sand, either sea-sand, drift-sand, or powdered stone, so as to be free as possible from iron; lime rubbish; and lastly, common garden earth. There are no known plants that will not grow or thrive in one or other of these earths, alone, or mixed with some other earth, or with rotten dung, or leaves. Nurserymen, whose practice may be considered a safe criterion to judge from, have seldom more than three sorts of earth: loam, approaching to the qualities of brick earth; peat or bog earth from heaths or morasses; and the common soil of their nursery. With these, and the addition of a little sand for striking plants, some sifted lime-rubbish for succulents, and some well-rotted cow-dung for bulbs and some sort of trees, they contrive to grow thousands of different species in as great perfection (taking the difference between plants in pots and plants in the free soil and air) as in their native countries; and many, as the pine, vine, camellia, rose, &c. in a superior manner.' The same author afterwards observes: 'Peat earth, or heath earth, being generally procured in the state of turfs full of the roots and tops of heath, requires two or three years to rot; but after it has lain one year, it may be sifted, and what passes through a small sieve will be found fit for use. Some nurserymen use both these loams and peats as soon as procured, and find them answer perfectly for most plants; but for delicate flowers, and especially bulbs, and all florists' flowers, and for all composts into the composition of which manures enter, not less than one year ought to be allowed for decomposition, and what is technically called sweetening. French gardeners allow for orange-tree composts from three to six years.'

Near large towns, where there is a constant demand for kitchen vegetables, market gardens are established for producing the required articles in variety and abundance. The finest market gardens in the world are near London, where the soil is deep, and any quantity of manure, in the form of night-soil, from the metropolis, is easily obtainable. The plan on which these gardens are conducted might serve as a model for all kitchen gardeners in this country. It is thus briefly described in the article *Gardening* in the 'Penny Cyclopædia':—'The gardeners' year properly begins in autumn, when the land is dug, or rather trenched, and well manured. Various vegetables, which will be required in winter, are now sown, and especially those which are to produce plants to be set out in spring: spinach, onions, radishes, and winter salads are sown, and when the weather is severe, are protected by a slight covering of straw or mats. In February, the cauliflowers, which have been raised in frames or under hand-glasses, are planted out. The cabbage plants are pricked out. The radishes, onions, and salads go to market as soon as they are of sufficient size, and sugar-loaf cabbages succeed them. As the cauliflowers are taken off, they are succeeded by endive and celery, and the same is the case with the cabbages. Thus there is a constant succession of vegetables, without one moment's respite to the ground, which, in consequence of continual stirring and manuring, maintains its productive power. Deep trenching in some degree prevents that peculiar deterioration of the soil which would be the consequence of the frequent repetition of similar plants. This effect is most perceptible when the plants perfect their seed, which is seldom or never allowed to take place in market gardens; but great attention is paid to the species of plants which succeed each other on the same spot. The principle which experience and theory unite in establishing, is that of avoiding the too frequent recurrence of plants which belong to the same natural families. The greater variety cultivated in gardens, in comparison with the common produce on a farm, enables this principle to be fully acted upon. Those gardeners who overlook this, and repeatedly sow or plant the same kind of vegetables in the same spots, are soon aware of their error by the diminution of the produce, both in quantity and quality, and by various diseases which attack the plants, however abundant may be the food supplied to them, or however careful the tillage.

The principle on which the gardens are cultivated is that of forcing vegetation by means of an abundant supply of dung, constant tillage, and occasional watering. The whole surface is converted into a species of hotbed; and crop succeeds crop with a rapidity which is truly astonishing. Those vegetables which arrive at a marketable state in the least time are always the most profitable, and those also for which there is a constant demand at all times of the year. With an abundant supply of manure, the market gardeners have no fear of exhausting the soil; and dissimilar vegetables may grow together on the same ground.

The value of the produce in one year from an acre of garden ground in the most favourable situation, as stated by Mr Middleton, from the account which he received from a market gardener, is almost incredible. It is as follows:—Radishes, £10; cauliflower, £60; cabbages, £30; celery (first crop), £50; (second crop), £40; endive, £30: making a total of £220 for the gross produce of an acre in twelve months. The expenses of cultivation are no doubt great. In inferior situations, the produce is much less, but the expenses are also somewhat less. When it is considered that there are nearly 2000 acres thus cultivated, the gross amount of produce must be very great.'

The domestic gardener will now perceive, that independently of a good soil, he must give his ground plenty of rich manure, and by so doing he need scarcely ever have any part of the surface unoccupied. To attain and keep up fertility is the grand principle of his operations: the delving may be awkward, the lines of beds uneven, the raking may not be neat, but all is of no importance in comparison with keeping the ground in good heart. Although the most available manure be that from the common dung-pit, the kitchen gardener should thoroughly acquaint himself with the peculiar properties of the specific manures—guano, bone dust, phosphate of lime, nitrate of soda, ammoniacal water, and the like—which are now in extensive use and reputation. Many of these act specifically on certain kinds of plants, supplying to their constitution some principle of growth not to be found in the soil, and but sparingly, or not at all, in the ordinary dung-heap. All this he should learn either by direct experiment or from the experience of others. He should likewise maintain a regular connective rotation, leaving no cropping to caprice at the time, or to a system of unintelligent routine.

GENERAL OPERATIONS.

Digging or delving with the spade is the principal means of garden culture. The spade usually employed is ten inches deep in the blade or spit; but as delving is not direct downwards, but sloped, the depth to which the spade goes in digging is seldom more than nine and often not more than eight inches. In commencing to dig a piece of ground, take out a spadeful all along one side, and carry it to the opposite side where you are to leave off. Now begin at one end of the trench just opened; thrust the spade with the foot into the ground, taking about five inches in breadth, lift it up, and turn it over into the open trench, the top undermost, and the fresh earth above. Do the same with the second spadeful, and so on with all the others to the end of the line. Take care to dig always a uniform depth and breadth, so as to keep the line even, and the trench or open furrow one width. If there be any weeds or loose refuse on the surface, put them in the trench, and cover them in—avoiding to bury weeds which have ripened, the seeds of which are sure to be a cause of future annoyance. All such refuse ought to be well rotted in the dung-pit, or, what is better, reduced to ashes, and then spread over the soil. Break or pulverise the mould as you proceed, and keep the fresh surface level. When you have delved row after row to the last, the earth laid aside will fill up the concluding trench. Ordinary digging is performed best in dry weather; but digging to throw up lumps for winter melioration should, if possible, be performed when the soil is somewhat moist. In this kind of digging do not touch the lumps with the spade after throwing them up; for the more rugged and uneven the surface, the more thorough is the exposure to the influence of the frost.

Raking is usually performed after delving. Hold the handle of the rake at an angle of forty-five degrees, and draw it lightly over the surface of the newly-dug ground. The object is not to draw earth along, but to smooth or comb down the irregular surface, and to bring away any loose refuse or stones. Like digging, it should be performed in dry weather.

Marking with the Line.—When there is any difficulty in delving in a straight line by the eye, mark off the ground with a cord, drawn from a reel stuck in the earth at one end to a dibble or pin at the other. This reel cord will be indispensable in marking off the edges of parterres, plots, &c. In such cases, having fixed the line, go along it with the spade, taking out a very small quantity of earth immediately beneath the cord. Then do the same with the opposite side and ends of the plot, and so its dimensions will be fairly marked. The gardener measures and marks off all his figures in the ground with his line and spade. With the line he can draw a circle round a central pin, or make an oval from a union of two circles, or form semicircles, spirals, triangular spaces, or polygons. When he wishes to make a small path between rectangular plots, he sets his line accordingly, and walking along it, with a foot on each side, he tramples down the earth from one end to the other, and then he can smooth it and beat it down with his spade.

Hoeing.—With a common hoe, the earth is cut and drawn towards the operator. The object of hoeing is to draw the earth up the stalks of plants growing in a row, or to destroy weeds. In hoeing weeds, cut off the weed beneath the surface, and do not cover the stalk. If convenient, rake away all the loose stalks, and place them on the dung-heap. Weeds, such as dandelion and groundsel, which become winged when ripe, should be hoed and removed before seeding. As many such weeds which infest gardens are blown into them from adjacent roadsides, it would not be misspent time to clear the neighbourhood periodically.

Animal Annoyances.—All gardens are less or more exposed to the destructive inroads of wild animals. Hares and rabbits gnaw the bark off the stems or lower branches of trees, and also the buds in season. To prevent the encroachments of these quadrupeds, the garden ought to be properly fenced; but if they get in notwithstanding, the trees may be saved by smearing the lower parts with a mixture of cow-dung, soot, and water, reduced to the consistency of thin paint; a smearing of tar will also answer the purpose. Moles, rats, and mice may be caught by trapping; moles also may be got rid of by placing slices of garlic, or onion, in a green state, within their holes, as they have a great antipathy to the odour of these vegetables.

Birds are sometimes an annoyance, particularly when new-sown peas or seeds may be easily scratched up. But though in some instances injurious, it is believed that on the whole their visits are beneficial; for they pick up large quantities of slugs, insects, larvæ, or caterpillars of different kinds. Wall-fruit may be preserved by nets, or by the more simple method of fixing horizontal lines of black worsted in front of the trees; the repeated ineffectual attempts to alight on these lines is said to scare the animals, and cause them to desist. Lines of threads, in which feathers are fastened, are employed in many cases to protect beds of seeds from birds; this preventive can be easily tried.

Insects are the grand pest of gardeners; their appearance is so mysterious, and their devastations so varied, that all schemes to extirpate them are often ineffectual. They are most destructive in their first condition of larvæ or caterpillars. In this state they should be removed by the hand from kitchen vegetables. To destroy the smaller kinds of larvæ, fumigation of tobacco smoke, by means of a fumigating bellows, may be employed with advantage; and the plants may be cleansed with a syringe and water. For the cleansing of fruit-trees from insects, we refer to our article on FRUIT GARDENING, No. 35.

Slugs are another chief annoyance, especially in low-lying situations. A little salt destroys them; but, as in the case of caterpillars, the best plan is to clear them out at their first appearance by the hand. Worms in the ground are not considered injurious; in a properly-trenched garden, however, they exist only in small numbers. Salt kills them.

Sowing.—The greater number of garden vegetables are reared from seeds, which are sown at certain seasons in the ground. Some seeds, such as peas, are sown in drills, the hand deliberately dropping them in a straight shallow trench. Other seeds, such as those of onions, leeks, cress, &c. are sown broadcast, which is a thin and equable scattering over a bed prepared for the purpose. There is no necessity for any species of sowing machine in a common kitchen garden. Most seeds, peas included, require to be pressed down by treading or gentle rolling, and then covered up by the hoe or rake. All seeds should, if possible, be sown and covered up in dry weather.

Planting.—Many vegetables require to be removed while young from the bed in which they were grown from seeds, and planted out in rows. A straight row is made with the line, which is gently treaded on each side. Commence now at one end of the trodden line, and in the central or untrod part pierce the earth with the dibble. Into the hole so made insert the root of the plant, and pierce the earth at its side, so as to press the mould round the root, leaving no vacant space below. The common error in planting is injuring the tap-root and rootlets by careless pulling the young plant from the nursery, by rudely using the dibble, or by pressing the earth too firmly round the collar, and neglecting to do so with the roots. If a plant is carefully transplanted in damp weather, it should never show any symptoms of the change.

Watering.—In dry seasons, artificial irrigation is of great use for giving due liquid aliment to plants, and is indispensable to those newly transplanted, in order to consolidate the roots. Watering, for whatever purpose, is most advantageously performed in the morning or evening. If done during the time the sun is shining, take care not to water the leaves of any plant, for the heat will raise the temperature of the liquid, and the leaves will be scalded. If the day be cloudy and cool, watering the tops of plants can do no harm. The watering, in any case, should resemble as nearly as possible a soft shower, and be performed with a rose watering-pot. The greater number of flowers are injured by watering, if the water touches their petals.

KITCHEN VEGETABLES.

The vegetables usually grown in kitchen gardens belong to various natural classes, which, for convenience, we shall arrange in the following groups:—1. The cabbage kind of vegetables; 2. The pea and bean kind; 3. The root kinds, or those grown only for the sake of their roots and tubers; 4. The onion and leek kinds; 5. The salad kind; 6. The various kinds of sweet herbs; and 7. Miscellaneous kinds, including several of a delicate nature. This grouping, it will be understood, has no reference to botanical arrangement, and has only been adopted in preference to the confusion of common alphabetic lists. For the technical classification of the plants here treated, the reader is referred to the sheets on SYSTEMATIC BOTANY.

The Cabbage Tribe.

This includes some of the most hardy, easiest cultivated, and useful of kitchen vegetables. The following are those which we would recommend to be cultivated: broccoli, Brussels sprouts, common cabbage, red cabbage, cauliflower, savoy cabbage, and Scotch kale.

Broccoli is one of the best kinds of greens, and is valuable for coming at a season when not liable to be affected by caterpillars. There are various kinds of broccoli, but all may be arranged under two heads—those for spring use, and those for use from September to Christmas; the latter are termed 'Cape' or autumn broccolies. The most approved varieties for spring use are Bowles's new sulphur, Moody's dwarf, Grange's cauliflower, and Portsmouth cream or buff colour.

One ounce of seed of broccoli is calculated to sow a bed four feet wide by ten long, broadcast on a prepared bed; but if sown in drills, rather less seed will be sufficient. Each kind should have a place allotted to itself. The soil should be a fresh sandy loam, not manured, and the season for sowing will be comprised between April and July. The Cape plants are finally set out in beds made rather rich with manure, at any time when they have leaves six or eight inches long; two feet distances, plant from plant, will be sufficient. Each plant is to be firmly secured in the soil; and if the weather be dry, every hole should be filled with water. This species will come in season in August, and continue to produce a supply throughout the autumn; in mild seasons, some heads may be cut even so late as the turn of the year.

The spring hardy varieties are treated by most persons in the same way as the Cape—that is, the plants, when they are six or eight inches high, are transplanted as they become ready, between the first week of July and that of September, into beds of richly-manured loam, and set two feet apart, the largest sorts, as the

Portsmouth, at thirty inches, and they are kept perfectly free from weeds. If the seasons be favourable, a successional supply of broccoli is thus obtained from the first week of March to the end of May. It is also customary to lay down plants in September, with the heads turned from the sun, applying earth on the south side over the stems, to protect them from snow and frost. We prefer to plant in six-inch-deep trenches, properly manured, removing the plants to them when not less than a foot high, filling each hole with water, and repeating the watering for two or more successive evenings. This treatment, even in the driest seasons, will secure the plants; and as the winter approaches, by drawing the earth from the ridges on each side, and thus filling up the trenches, the stems will be protected, and the ground levelled and rendered light. We have practised this method during seven or eight winters, and have lost no opportunity to recommend it to others. Broccoli plants do better in trenches than any other members of the Cabbage family.

To save seed, it is only necessary to watch the progress of some very fine plant left late in the spring, to cut out all the weakly and crowding parts of the heads when expanded, and to secure the seed before it be quite ripe, or rather before the seed-vessels shed the seed. But as all these plants pass, by crossing or hybridising, into other varieties, it is generally not desirable to attempt seed-growing.

Brussels sprouts produce tall stems, three or four feet high, which support a head somewhat resembling an open savoy, of little value. This being cut off, the lateral buds down the stem protrude a succession of little green heads, like small savoys, delicate in flavour, very much admired, and yet but seldom seen, inasmuch as the true vegetable is not easily obtained. Our best authority is still that of Professor Van Mons of Brussels. The following is transcribed from the last edition of the 'Domestic Gardener's Manual,' wherein the Brussels practice is noticed, and a few experimental remarks appended:—'The plants are raised from seed sown in March or April, of which an ounce may be requisite for a seed-bed of four feet by ten. Van Mons says, "The seed is sown in spring under a frame, to bring the plants forward; they are then transplanted into an open border with a good aspect. By thus beginning early, and sowing successively till late in the season, we contrive to supply ourselves in Belgium with this delicious vegetable fully ten months in the year; that is, from the end of July to the end of May. The plants need not be placed at more than eighteen inches each way, as the head does not spread wide, and the side leaves drop off." In England, the Brussels sprout is so hardy, that it will stand twenty degrees of frost; and its head about Christmas is a tender and delicate species of greens. Being then cut, the plant will remain nearly torpid till the advancing sun causes it to start into new vegetation; then the spaces between the rows should have a little leaf-soil or good manure lightly forked in; and the young heads, all of which were quiescent, but visible in the winter, will speedily advance from the axils of the leaves, and yield a supply for many weeks, if they be properly pulled or cut off in succession.'

We cannot add much to the above, but may observe that, if any one can procure true seed, it will be advisable to try to ripen some, and to abandon seed-growing of every other kind of the cabbage during that season, for fear of crossing it; also to try Van Mons' repeated sowings, for in truth a more delicate family vegetable cannot be cultivated.

Cabbage.—The cultivated varieties of the common or white-hearting cabbage are very numerous; and as all can intermingle, so no one who aims at raising seed can be confident of what he shall produce. The best varieties in ordinary use are—1. Small and large York; 2. London, variety of York; 3. Sugar-loaf; 4. Knight's Downton; 5. Battersea; 6. Vanack. The cabbage is a biennial plant; it runs a two years' course, bears seed, and dies. Therefore to obtain hearted cabbages throughout the year, two or more sowings must be made; one in the spring, the other in summer. Spring-sowing can be effected at once, or it may be divided into two or three operations; because, from the third week of March to the first week of May, the seed can be successfully sown for the supply of summer and winter. Yet by attentive management, one sowing may be made to produce all that a family can require: we restrict our directions to that simple operation.

Prepare a bed of good sound loam in an open exposure, and let it be very slightly manured, for cabbage seedlings benefit much by strong contrasts, and ought not to be made to run up while tender. Dig the ground for four rows, nine inches asunder, and from fifteen to twenty feet long. Break the earth finely, and leave it to settle for three or four days; then place boards to tread on, while a first drill, one inch deep, is struck by the line; make the bottom of this and every other drill even, and a little solid, either by pressing a long pole into it, or by patting it with the back of a wooden-headed rake. Sow the seeds rather thickly, because it is better to thin out an abundance of plants than to lose the greater part of a thin crop by insects. When sown, cover the drill with fine earth, proceed to make and sow other drills, till the bed be finished, and then either tread the surface over with the feet placed nearly close together, or pat the surface with the spade, and then finish it off smooth with the back of a rake. Always avoid to tread ground into holes, and therefore recede from the work backward; prefer to use the feet in light sandy soil, but rarely with stiff and binding ground. In a very dry season, seeds will not easily vegetate; therefore in such cases strike the drills, and water effectually along them for three successive evenings, covering the plot with mats throughout the day. In the third evening make the drills even, sow, cover with earth, sprinkle again, and lay on the mats by day, till the plants be visible, then dust them once with the finest road sand while the dew is on, and in the evening with air-slacked lime. These precautions need not be repeated. We never saw a set of cabbage, turnip, or celery plants so dusted with road sand that was much infested with the turnip beetle; and as to slugs, lime, or lime with coal-soot, will effectually prevent their ravages, or destroy the vermin.

When the plants begin to produce their true leaves, thin them out, first to an inch asunder, and again to two inches; they will thus gain strength rapidly; and when they have three or four good leaves four inches long, they will be fit to go out, some into nursery beds, and others to the plots where they are to remain. Those set in the former, six inches asunder, will acquire stocky roots, and be prepared for successional beds. The size of the plants will indicate the season during any of the summer months. Those planted permanently will require the ground to be made rich with manure, and the transition from poor to rich earth will make them grow rapidly. The smaller Yorks, &c. should stand twelve or fifteen inches apart, the large varieties twenty to thirty inches. Set each plant as deep as the base of the lower leaves, and observe the directions given for the treatment of broccoli. These seed and nursery beds will supply the table from May to November, and in fine seasons even later.

Cabbage coleworts—a favourite vegetable in London, known by the name of *spring greens*—are raised by sowing the seed of the hardier middle-sized cabbages from the end of June to the middle of July, to be transplanted in August and September in rows twelve or fifteen inches asunder, the plants nine inches from one another; they form pretty little heads—not properly cabbages—at a period when the old stock is exhausted, and the spring cabbage is not come in.

The main summer crops are raised from seeds sown between the 25th of July and the 10th of August: the last week in the former month comprises the most favourable period. The directions previously given will apply in every respect to the treatment of the plants; we need only remark that it is advisable to plant the young cabbages first in nursery beds of simple loam, wherein they will be more secure during the frosts than they would be in rich beds; but being transferred to the latter at the end of February, or early in March, they will make rapid progress, and according to the season, produce hearted cabbages in April, May, and June. All the departments must be kept clean, and free from litter or weeds. Seeds can easily be raised, but the result is always doubtful.

Red cabbage is only used for pickling; it is raised by a two years' course—that is, by sowing in August, and transplanting, as directed above; but this variety requires a little more space. The heads form in the ensuing summer, and are in fine condition in October. If sown in spring, little-hearted cabbages can be obtained, which may supply a loss, or serve as a substitute for the others.

Cauliflower, which is grown only for its rich white head, requires in the open air a warm and moist climate, or it must be grown under glass. In Holland, it grows to great perfection, and like many of our garden vegetables, is most likely imported from that country. One of the chief difficulties attending its open-air culture is its destruction by caterpillars, and therefore great care is in many respects necessary to bring crops of it forward. Under glass, the plants are rendered very expensive.

Spring-sowing, for a first crop, may be made in March, over a temperate hotbed. The seedlings are to be pricked out when the leaves are an inch broad; and from this nursery bed they are moved to the garden bed in May, to stand more than two feet asunder, the ground being made extremely rich. The plants, after they begin to grow, are occasionally watered with the liquid manure collected from the drainage of dunghills. A second spring-sowing is made in the open border in May, to obtain plants from September to November, by a similar mode of treatment. The last sowing occurs in the middle of August. The plants, when about four or five weeks old, are to be thinned out to two or three inches apart, the best to go into nursery beds of rich earth, three or four inches asunder. Here they must grow till November, when the strongest are to be set out in rows, to be preserved under bell or hand-glasses. Dig a bed of rich ground in an open situation, and make it still richer with manure; set three or four plants together, five inches apart, in patches, each patch a yard asunder; give water, and cover close with a hand-glass till the plants begin to grow. When fairly taken with the soil, tilt the glasses on the sunny side with a brick; and thus continue to give air on mild days during the winter, and on some occasions take the glasses quite off, but replace them and cover close every night.

In the spring thin the plants to two under each glass, making good any deficiencies with some of the best plants thus taken up, and plant the surplus in a warm spot of ground two feet apart. Keep the glasses on the other plants, raising them more and more, occasionally exposing them to mild rains till about the beginning of May (unless in the event of intense frost, such as we have experienced within a few years), when the glasses may be finally removed. Cauliflowers will thus be produced in succession from the end of May throughout June.

Other plants should, in November, be placed in frames four inches apart, in a bed of rich dry loam, over a very slight hotbed: give water, close the lights, and be guided as respects the admission of air by the directions for the hand-glass division. The lights should be covered with mats and boards during severe frosty nights. In February, March, and April, the plants are removed in succession to beds richly prepared; and the cauliflowers will come into perfection during July and August. It is customary to form the earth immediately around the stems into the shape of basins, to contain water or the liquid manure: it is a useful practice, and this, with hoeings between the rows, will comprise the general treatment.

The savoy is very hardy, and the most useful of winter cabbages. Its culture is very easy, and admits of four sowings. There are two approved varieties—the *hardy small green* and the large *yellow*; the former is generally preferred. Begin to sow in February, sow a second time in March; a third, and this is for the main crop, in April, about the middle of each month. Let the situation be open, the soil a good natural loam, if possible, and laid out in a bed three or four feet wide, digged, and made fine. Scatter the seeds evenly, and rake them. Repeat, for the fourth time, in August. The plants of this last sowing will attain a large size by the following August and September, if planted out in April. As the plants of all the sowings, after thinning, become four or five inches high, they are transplanted between crops standing widely apart, as in the single-row system of asparagus, or as succession on potato land. Moist weather should be chosen, and the savoys should stand two feet apart. Keep the ground clean, stir it occasionally, and draw a little toward the stems on each side, always, however, leaving a sort of furrow three or four inches wide, to receive the rain, and convey it to the roots. Seed can be sown in the second year, but may be rendered spurious.

Scotch kale and *German kale* are the hardiest among our winter greens. They are raised by sowing the seeds either in beds or single drills late in February or early in March; to be first thinned out to three inches apart, and finally transplanted to beds or rows, wherein the plants are to stand thirty inches asunder. The plants may go out in succession from June to the middle of July. The heads are cut first, and subsequently side-shoots arise, which produce excellent winter greens, till early cabbages come in. The plant runs to flower and seed during the succeeding summer.

Instead of growing kale, cabbage, or any other of these plants from seed, it will save much trouble to the cultivator of a small garden to purchase young plants by the hundred from a nursery of such vegetables.

The Pea and Bean Tribe.

Of the pea there are various sorts, but it is only those of a fine kind which are cultivated in gardens, and called *garden-peas*, that we require to notice. When fresh, they are a bright green, and when dry for seed, most are a buff yellow. Peas are a summer delicacy, and the chief art is to produce them in the open air, by the middle of May, and to keep up a succession of crops till other vegetables supersede them. Skilful gardeners do not consider it a difficult process to effect an early crop, as the plant is very hardy, and sustains violent transitions without much danger. Peas, therefore, may be accelerated in frames and vineries during February, and being transplanted into rows fronting a south and east wall, will continue to advance progressively though the weather be cold. They can also be sown (provided there be no frost) in the open ground at any time. The chief varieties for the earliest and latest crop are the *early Warwick*, *bishop's dwarf*, *Charlton*, *frame*, and some others peculiar to localities. The varieties for the main summer crops are the *blue Prussian*, the *imperial*, *Knight's*, *dwarf* and *tall*, *marrowfats*, and the *scymitar-podded*.

The soil in which this vegetable most luxuriates is a free, light, but rich loam, abounding with vegetable matter, but not manured with recent dung. The situation for crops from June to August should be exposed and open. The times of sowing are very various. Some obtain an excellent yield from seed sown early in November in long drills; and if the winter be open, success is nearly certain. At whatever season persons commence, a better general rule cannot be adopted than to sow for a successional crop as soon as the peas of the preceding sowing are fairly above the surface. The plants, when three inches high, should have earth drawn against their stems on both sides, after which the soil may be superficially opened by passing the hoe lightly through it, and thin branchy sticks, of a height suitable to the habit of the variety, ought to be thrust into the ground, converging a little, so as to meet at top, and interlace each other. Shallow soils over chalk are soon over-cropped by peas, and refuse to bring a healthy plant; and in all kinds of ground the frequent repetition of pea-sowing is to be deprecated. The land must also be purified by a rotation of cabbage and potatoes.

Stakes for peas are indispensable in keeping them from trailing on the ground; and therefore every person who wishes to grow this vegetable in his garden should take care to preserve the stakes from one season to another, as long as they are serviceable. Any kind of branchy twigs, such as those of the beech and the larch, will answer the purpose; and the better if they are open and spreading, and stript of their foliage. When all the pods are taken, remove the haulm or pea-stalks to the compost dung-heap.

Dwarf-beans are planted in rows, and the seeds are generally sown at different periods between the 1st of May and the middle of July. The situation should be open, not crowded by other vegetable crops, or under trees — the soil a free-working loam, moderately manured. The drills should not be nearer to each other than thirty inches, and not more than two inches deep. In these the beans are to be dropped at regular distances, not exceeding three or four inches. Make the ground firm at bottom, but let the covering earth be light, and only slightly raked, not trodden or made hard. The one leading principle of successful growth is to bring the plants up as soon as possible, and this is effected by selecting warm weather, and opening the drill early in the day, that its base and the loose soil about it may be rendered hot by exposure to the hottest sun for two or three hours. A cold, wet, cloddy condition of the land causes decay.

The kidney-bean comprises two species of plants, which, though of one family, are of very different habits. Both, however, are natives of the East, and are very impatient of cold; hence the necessity of deferring the sowings till the weather be nearly settled in the spring, and the ground warmed to the depth of several inches. The two species are, first, the dwarf with its numerous varieties, all bearing the title of *French beans*; and second, the climber,* commonly termed *scarlet beans*, or runners, although there are varieties with white and variegated blossoms: one of the latter, *the painted lady*, is very prolific. There are few of the many varieties of the dwarf which can surpass the buff or dun-coloured bean—it is free of growth, and fertile, either when forced in pots, or planted in the open ground. The black speckled dwarf is also an excellent bearer; the white-seeded is the true *haricot* of the French; in Kent it is called *caracansera*.

Runner-beans are planted with similar precautions, or if sown early in pots and boxes, will transplant very well. When the plants attain the height of three or four inches, they should have a little earth drawn about the stem, and be staked; that is, somewhat tall branchy sticks should be placed on each side, converging towards each other at the top; these props ought to be eight feet high; and when the plants reach their summits, they should be nipped off and kept stopped, to cause them to produce fruit-bearing laterals. 'Gather beans, and have beans;' that is, never leave any pods to ripen; if redundant, let them be given away, or go to the pig-stye, for a maturing pod arrests the fertility of the plant by tasking all its powers. Keep all the crops clean, and the surface of the ground about them rather open. The roots of the members belonging to this section are accounted narcotic and poisonous.

The garden-bean is known to every one, and it has been in use from time immemorial, as appears by the allusion made to it by ancient classical authors. Though a native of the East, it is, in all its cultivated varieties, very hardy; these varieties are numerous: some of the more approved are, the early *mazagan* for the first crops, which may be sown from October to February; *early long-pod*, an excellent fertile bean for general use, not highly flavoured; *broad Windsor*, the best of all beans for flavour, but not a prolific bearer, a hybrid between the two last, combining the fertility of the one with much of the high flavour of the other.

Beans prefer a sound and rather firm loam, retentive of moisture. They suffer much in a very dry season and soil, particularly if attacked by the black blight (*aphis*), which covers the tops, preys upon the fluids of the plant, and often almost entirely destroys whole fields in a very short time. *Topping*, when the insects are first seen, appears to be the only remedy. The seeds should always be sown in rows, and one pint is considered enough for eighty feet. The beans ought to be sown in one long row, three inches deep and four inches apart, returning the soil and treading along the course of the row; after which the rake should be employed to level the surface. Beans transplant extremely well, and therefore may be sown thickly in autumn, covering the plants with hoops and mats, or with a garden frame and lights.

When the plants rise in the rows, or begin to grow after being transplanted, loosen the earth by pushing the Dutch hoe along the surface, and draw three inches of it to each side of the stems; or rather shovel up two or three inches of the earth, and lay it flat a foot wide on each side of the row of beans, shelving rather towards the stems than from them, for then the rains would find their way directly to the roots. The seasons of sowing are autumn for the mazagan, January and February for long-pods, and from March to June for the Windsor. Sow succession crops one after the other, according to the demand, as soon as the plants of the preceding sowing shall be quite above ground. To cross the variety, sow Windsor and long-pods alternately in the row, and save the beans, introducing in future sowings an occasional Windsor bean, till the desired rich flavour be attained.

As the beans ripen and turn black, draw them up, and place them to dry in an airy situation, guarding the pods from mice, which are rather partial to the bean, and thus, as we have found, deprive the gardener of a choice variety, which he had been at considerable pains to procure.

Esculent or Root Vegetables.

The vegetables grown for the sake of their roots are of two kinds:—1. Those in which the roots are round or lumpy, including the Jerusalem artichoke, the potato, and the turnip; and 2. Those which are tap or taper-rooted, including the carrot, the beet-root, the radish, and the horse-radish. Strictly speaking, the tubers of potatoes, &c. are not *roots* (see VEGETABLE PHYSIOLOGY), but merely concentrated stems of the vegetable below ground, the real roots being small fibres which shoot out from the tubers, and bring nourishment to the whole. All require depth of soil to penetrate, and also looseness and breadth of mould to allow of expansion.

The Jerusalem artichoke is a root which may be said to combine, in point of flavour, the turnip with the potato. Its name is an absurdity, for the plant has no resemblance to an artichoke; and the word *Jerusalem* is a corruption of the Italian name *Girasol*. The plant is a native of Brazil, and botanically belongs to the same family as the sunflower, but it rarely produces flowers in the British islands. The tubers, which alone are eaten, are produced abundantly under the surface, close to the base of the main stem. The plant is set like the potato, by either whole roots or cuts with one or more eyes to each. The pieces or cuts should be prepared at the time of planting, and set by depositing in shallow trenches two feet apart, and one foot asunder in the row; and being covered with earth, nothing more will be required but to keep the ground clean by the hoe. The season for planting is in the first dry weather of March; and half a peck of tubers, according to Abercrombie, will plant a row 120 feet long. A good mellow loam is the proper soil, and the spot for planting should be apart from the vegetable garden, otherwise this prolific plant may intrude, and become a complete nuisance. Being set in March, the plant is perfected about October or November; the crop is ready for use when the stems are quite dry. Dig only when wanted, if that be convenient; but if there be a danger of frost, as will most likely be the case, lift the crop, and store away for winter use in moist sand or any kind of light soil through which the frost cannot penetrate.

The potato, like the Jerusalem artichoke and some other plants, is a naturalised exotic in English gardens from the wilds of America, and has been greatly improved by culture within the last hundred years. There are now many varieties, individually distinguished by colour and flavour; and as some are better than others, it is very important that proper sorts should alone be cultivated. There are two distinct kinds—*early* and *late*. Early potatoes are a premature and transient kind; they soon come to perfection, and cannot be stored for future use. On this account no cottager should have anything to do with early potatoes, which are never grown but as a luxury; and after all, they are in general poor waxy stuff. The true potato is the late kind, which will store for winter and spring use. Of this there are hundreds of sorts, every district apparently having one which is best adapted to its soil and climate. The sorts to be preferred are those possessing the quality of mealiness, and which will not degenerate or fail in cropping. The kinds we recommend, as far as they may be found suitable as to climate, &c. are kidney-shaped, or long and flattish; red roughs, a round reddish-coloured potato; and those white kinds which are smooth-skinned. Of early potatoes, the ash-leaved kidney is among the best for open-garden culture.

The potato may be cultivated either from seed procured from the apple on the stalk, or from the tuber itself. If from the seed, the first crops of tubers are only a little larger than peas, and several seasons are required to bring the plant to an edible size. The common method of cultivation is by pieces or cuts, each having at least one well-defined eye; cuts with two eyes are generally preferred. These are set in trenches, the ground being in good heart with previous manuring, or good old manure placed along with the sets. The season for planting is late in April. Dig and plant sets, fresh cut as the work proceeds, placing the sets from nine to twelve inches apart, and the rows being about twenty inches asunder. Heap six inches of soil loosely over the sets, and when the shoots have risen sufficiently above ground, keep earthing them up with a hoe. When the stalks begin to decay in October, the crop is ready for lifting. (For further information on potato culture, see AGRICULTURE.)

Of the turnip there are many varieties, but three only are grown in gardens: these are the *early Dutch*, which is white; the *yellow Dutch*; and the *Swede*, also a yellow kind. The white is the most delicate while young, but the yellow Swede is preferable as a keeping or late turnip. The yellow Dutch has also an excellent flavour. Turnips are cultivated from seed in drills one foot apart, and thinned when they come into leaf, to afford room for their expansion. For the two Dutch varieties, the best soil is sandy, enriched with bone-dust, guano, or good old stable-dung. One ounce of seed will go over a great space—Abercrombie says as much as 200 square feet of surface. Small sowings should be made in succession from March till July, and then the main crop for winter should be sown. Swedes, as directed under AGRICULTURE, should be sown in April and May. Deeply hoe the ridges after thinning, and keep the surface clear of weeds.

Of the carrot, the favourite varieties are the *early horn*, the *Altringham*, the *long orange* or *Sandwich*, and the *long red Surrey*. All require a deep light soil. The early horn is sown in February for the spring crop, and in July for a late crop; the other kinds are sown in March, April, and May. All are sown broadcast in beds, and on a calm day, if possible, as the seeds are very light: they should also be rubbed between the hands, and mixed with some dry sand or wood-ashes, to separate them, and so facilitate an equable sowing. The seed may be saved by planting a few of the best carrots to stand the winter; seed will not retain its growing principle above a year, and therefore requires to be purchased with caution. Carrots may be stored like potatoes in winter; and it adds materially to their preservation in a sound and sweet condition to riddle over the layers a few barrowfuls of dry mould or sand.

The parsnip is a taper-rooted vegetable resembling the carrot in shape, and in England is a favourite vegetable with salt fish and salted meats. It is also used in the preparation of soup, of a species of marmalade, and in the manufacture of a wine which is said to approach nearest the malmsey of Madeira and the Canaries than any other. It is also an excellent agricultural as well as horticultural vegetable, and is extensively grown for cattle on the continent. It requires a rich deep soil, trenched and manured as if for a crop of carrots. The seed is sown in drills a foot asunder. The period of sowing is comprised between the last week of February and the first week of May. On thinning out, let the remaining plants be nine inches apart in the row. Parsnips are not liable, like carrots, to be injured by severe weather; but if taken up before Christmas, and properly protected, they will continue good till May in the following spring.

Of the radish there are two distinct kinds, which comprise all the numerous varieties now so generally cultivated. According to Lindley's catalogue, these are—The *taper-rooted spring radish*, of which the varieties are—1. The long white; 2. Purple or salad radish; 3. Salmon or rose-coloured; 4. Scarlet; 5. White Russian radish.—The *round turnip-rooted spring radish*.—6. Crimson turnip-rooted; 7. Yearly white; 8. Purple turnip; 9. White turnip; 10. Yellow turnip.—*Winter radish*.—11. Black Spanish; 12. Brown oblong; 13. Large purple; 14. Round brown; 15. White Spanish, a large bulb, which in good soil grows to the size of a small stubble turnip.

Numbers 2 and 3 are the best of the spindle-rooted radishes; numbers 6 and 7 of the early turnip-rooted. The winter black radishes are rarely seen in gardens; but the large white (15) is very mild, if the soil and season be favourable, and its texture is tender.

Sown in February and March, the spring radishes come into use in April and May; if required earlier, they must be protected by frames or mats. The market gardeners obtain them early by gentle forcing, covering the beds every severe night. The sowings of all the early varieties may be repeated monthly till August. The winter radishes are sown in July and August, and come into use from September till the spring. A rich and light soil suits the radish, with occasional copious supplies of water; and rapidity of growth is required, otherwise the roots will not be tender, nor will the flavour be mild.

Horse-radish is a vegetable which in certain soils is of extremely difficult culture, in others of uncontrollably luxuriant growth: it is a most pernicious weed where it intrudes, because of the multitude of vital germs with which its root-stock abounds, and by which it is rendered a sort of vegetative polypus, every inch of it being capable of developing a growing bud.

Such being the difficulty of artificial propagation, it may be questioned whether much trouble is not expended uselessly to effect that which nature produces by the most simple means. However, horse-radish can be procured by trenching two feet deep a plot of free loam, removing all stones as the work proceeds. One trench being well cleared, a layer of manure two inches thick should be laid at the bottom (for none must be mixed with the soil), and upon that three inches of the fine loam. Some fine straight roots being in readiness, they are to be cut into two-inch lengths, and piece after piece pressed into the soil eight inches asunder, in a row, to the whole length of the trench, and exactly in the middle. The soil is then to be dug out another two feet space, turning it into the open trench, clearing away the stones and other rough substances. Thus alternately trenching and planting, a bed will be formed of any extent that may be required. The work should be performed either in October and November, or in February; and the driest weather of the season should be selected.

Abercrombie, one of the best practical writers on gardening, made the following judicious remarks, which will, if duly considered, throw light upon those habits of the plant which have led to the deep method of culture just described:—'The root,' he says, 'being durable, forms itself into a thick knotty stool at a certain depth, sending up several erect, straight root-shoots, in length proportionate to the depth of the stool or main root, which, if planted fifteen or eighteen inches below the surface, the shoots or sticks of horse-radish will rise to that length. They will rise in May, increasing all summer till October, when in rich ground they will be sometimes large enough to dig up for use, being an inch thick; if not, they must have another year's growth, taking them up clean to the bottom by cutting them off close to the old stool, which remaining, sends up a fresh supply annually.' These habits indicate two important facts. First, that the crown or stool must enjoy all the benefit of the manure, to enable it to send up a straight stem, and to nourish that stem by its own power; therefore no manure must be placed in the upper soil, since it might excite lateral growth. Second, it points out the method of taking up the roots, which should always be that of trenching, beginning at one end of the bed and clearing away the soil to the full depth of the original trench. Thus a row can be taken without disturbing the crowns, by cutting off the upright shoots close to the head of each stool or stock; and what is surplus of each digging can be preserved in sand till more be required.

Beet-root or *red beet* is one of the most valuable of the spindle-rooted vegetables; it has heretofore been wasted by most persons, who, overlooking the really useful purposes to which a root so salubrious can be applied, have considered it as little more than a garnish to salads. Beet-roots should be boiled or baked till they become perfectly tender, when they may be eaten warm as a dinner vegetable. When cold, they should be cut into slices, and covered with vinegar. The plant is a biennial—that is, it grows and perfects its roots in one season; in the following spring it sends up its flower-stalk, ripens its seeds, and dies. Seed, therefore, can thus be procured; but it is better to purchase or exchange than to grow it. Of the two varieties of red beet, the smaller deep-purple variety is greatly preferable to the larger, which approaches to, and is little better than, mangel-wurzel. We select two varieties. 1. The short-rooted deep-purple beet, for its root. 2. The *beta cycla*, or silver beet, the leaves of which only are used in lieu of spinach.

To grow the red beet well, the ground ought to be light and pulverisable, otherwise the spindle-root will be diverted if it meet with obstacles, and become forked and distorted. Trench the plot to the depth of eighteen inches, removing large stones, roots, and hard clods of earth; lay a stratum of manure at the bottom of the trench, in order to attract the root downward; then return the fine earth. Let the work be completed before frost set in, and mark out the beds according to the number of rows required. At the middle or latter end of March the seeds are to be sown. These are contained in a curious seed-vessel of rude shape, and cannot conveniently be separated from it. In sowing, stretch the line, and draw an even drill about an inch or an inch and a half deep, and drop the seed-vessels at even distances, two or three inches asunder; for although these spaces are much too small for final growth, it is in all cases wise to be liberal of seed, because insects and other enemies destroy many plants, and thus a season may be lost. Cover with light fine earth, and either tread or beat the covering earth with the spade till it lie firm on the seeds. If the plants rise equally, thin them gradually, till they stand from nine to twelve inches apart every way, or even eighteen inches for the large rooted variety. Beet will transplant, but the operation dwarfs the plants; and at best it is attended with some risk. Keep the rows or beds entirely free from weeds by hand-weeding or flat-hoeing. Some roots will be ready in September, and thence throughout winter. In using them, or prior to storing up during winter, cut off the straggling leaves, being careful not to wound the roots; they keep well in dry and well-washed sand, but become tainted if wet straw or decomposable vegetable substances are present.

To collect seed, either reserve two or three of the best roots in the spot where they grow, or transplant them in autumn to a convenient situation. The flower-stems will be produced in the following spring, and should be secured by stakes till the seeds ripen. Then cut them in stalks, and dry them on a cloth under an airy shed; separate the seed-vessels, and preserve them in paper bags in a dry and cool situation; the seeds will retain vegetative power for several years.

Remark applicable to Beet, Carrot, and Parsnip.—In stiff clayey or cloddy land these spindle-root vegetables succeed very indifferently, carrot especially; therefore, to avoid repetition, it is thought right to observe that at the time of sowing the land having been previously trenched, and left exposed to frost in ridges), the soil is to be levelled, and holes made along the course of a garden line with a strong pointed crowbar about four inches asunder and twelve inches deep. Fill them with very light sandy earth sifted, and make a little cavity in the centres, into which drop four or five seeds; cover them with the same light earth, and beat the surface level with the flat of the spade; the roots so treated will tap downward, and be preserved as in a sort of sheath by the binding earth around them. Thus carrots, which always fail in certain soils, as we have often observed, may be produced of handsome figure and good quality, and beet-root may be grown without a fork in it—a circumstance of considerable importance with a root which is so liable to be injured by the loss of its saccharine juice whenever it is wounded by the knife.

The Onion Tribe.

This savoury class of kitchen vegetables comprises the onion, leek, garlic, and shallot, the two former being by far the most important. All are natives of Eastern countries; but they grow to great perfection, as respects pungency of flavour, in the British islands:—

The Onion.—For a crop of onions, the soil should be rich, light, and deep, and well exposed to the sun. Before sowing, work and enrich the bed to the depth of eighteen inches, and then beat it flat and firm with a spade. Sow the seeds at any time in March, thus—scratch drills by the line just so deep as to be clearly discernible, and sprinkle the seeds along them about three or four in an inch. Sift fine sandy earth over the seeds, and pat the surface even. As the onions advance, thin them out according to the variety, allowing alternately an intervening space fully equal to the breadth of the onion between bulb and bulb. In September twist the necks, take up the crop when the leaves become yellow, and expose the onions to sun and air under a shed till they be externally quite dry. Many sow onions broadcast in beds, in which case they likewise require thinning.

A summer supply of onions, at a time when the previous stock is exhausted, and the growing autumn crop has not come into season, must be desirable, and it is easily obtained. Prepare the ground early in February; select a number of those small bulbs that are always found in every bed of the larger kinds, which are not above an inch broad. The bed being ready about the end of the first week, mark out squares on the surface by means of cross-strings, but do not move the ground. At each intersection of the lines, press in an onion, the root downward, to one-third of its depth, so that the bulb remain firm and erect. Thus, when completed, the bed will exhibit the onions in squares five or six inches asunder. The onion forms its bulb in the first year of its growth, and the flower and seed in the second year. These small onions will therefore naturally attempt to produce a flower head, which, as soon as it is fairly visible, is to be pinched off. Another attempt will be made, and that also must be frustrated. The natural course of the vital-fructifying sap being thus interrupted, will be diverted to the bulb, and gradually, almost imperceptibly, two, three, or four onions of medium size will be produced and grow freely. These are to be taken, as soon as they are ripe (which, if the summer be fine and sunny, with occasional showers, will be in July), and dried in the open air as before directed.

The leek is another of the garlic family, and if properly treated in a favourable soil and situation, grows to a very large size. It is a plant which is much improved by proper transplantation, but yet can be grown very well in its seed-bed: the London leek is the best. Sow the seeds in a shallow drill at the close of February or early in March, and cover them with half an inch of fine soil; as the plants grow, keep the surface clear of weeds by hand-picking and passing the Dutch hoe lightly on each side of the leeks. Presuming that they are thinned out at first to stand three inches asunder, half of the plants will remain, and the other half will be removed to another situation. Thus the plants in the seed-bed will stand six inches asunder, and will be greatly assisted if the ground be opened on each side of them at the distance of nine inches, and manured spit deep. A crop of fine middle-sized leeks will thus be obtained in the succeeding autumn.

To transplant leeks, prepare a bed at the end of June, to contain either two or four rows, nine inches asunder, and manure the soil richly to the depth of a foot or fifteen inches. Let the bed settle during a week or more, and in July make holes along the intended lines six inches deep and as far apart. Collect a number of the strongest leeks, trim off the straggling roots, and all the suckers or offsets. Drop a small handful of powdery manure or reduced year-old cow-dung into each hole, place in it a leek, and holding it by one hand, fill the hole with water. The object is to fix the leek as in a case, to which it can adapt itself, and will fully occupy, becoming, under propitious circumstances, a plant of large size and of most excellent quality.

Garlic, one of the most pungent species of *allium*, is increased by dividing the bulbs into cloves or small bulbs, and planting them in good sandy loam at any period between the middle of February and the end of April. Draw drills two inches deep and ten inches apart, then press the root-end of each clove firmly into the earth till it stand erect; let the distance between each be six inches, and fill up the drills with fine sand. Keep the ground free from weeds, and when the leaves turn yellow—which usually happens about the end of July or the beginning of August—take up the bulbs with a trowel or handfork, and keep them in a dry room. *Rocambole*, a mild species of garlic, may be cultivated in the same manner.

The shallot is a native of Palestine; its culture is precisely the same as that of garlic, therefore both may be grown to great advantage by adopting the plan suggested by the late Mr Knight, described in the 'Transactions of the London Horticultural Society,' vol. ii. Let a rich soil be placed beneath the roots, and raise the mould on each side to support them till they become firmly rooted. This is then removed by a hoe, and by pouring water from the rose of a watering-pot, till the bulb stand wholly out of the ground. Thus they become mere surface bulbs, supported entirely by the fibrous roots, which pass deeply beneath into the rich soil. The growth of these plants, Mr Knight adds, so closely resembled that of the onion, as not readily to be distinguished from it till the irregularity of form became conspicuous. 'The form of the bulbs, however, remained permanently different from all I had ever seen of the same species, being much more broad and less long; and the crop was so much better in quality, as well as more abundant, that I can confidently recommend the mode of culture to every gardener.' Shallots have a strong but not unpleasant odour, and are therefore generally preferred to the onion for various purposes of cookery, and for making high-flavoured soups and gravies.

Chives, one of the smallest of the garlic tribe, is a hardy and useful vegetable, far superior to young immature onions. The plant grows in tufts somewhat like small rushes in appearance, but of a colour resembling the yellow green of young onions or scallions; it never bulbs. A crop is readily increased by dividing the roots in April or early in May.

Salads.

Salads are those watery plants whose long fresh leaves are eaten at table raw, or only dressed with zests and condiments without the preparation of cooking. The principal vegetable of this kind is

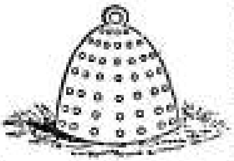
The lettuce, of which there are several varieties, but all may be classed under two heads—the upright or cos lettuce, and the open or cabbage lettuce. Of the upright, the green and white cos, and of the open, the inner cabbage and grand admirable, are the best. In spring culture, sow every month in very shallow drills of fresh-digged ground, in good heart, made extremely rich with rotten manure. Strike the drills a foot asunder, and as the plants rise, thin them to stand in regular order, first to two inches, then, for table use as small salad, to six inches, and for the larger sorts, finally to one foot. Never transplant during spring and summer, as the plants, by removal, sustain a check which urges them to fly up to seed. Spring and summer lettuces are sown from February to July. In September, two small sowings should be made of the hardy sorts, to come in use during late winter and spring; but it would be safer to make use of a large three-light frame. Some lettuces heart freely; those which do not should be assisted by passing a string of bast round them from the middle upwards. This bandage must not remain many days, otherwise the plant will run to seed, and become bitter.

In autumn culture, sow in August, in drills pretty close together, for the express purpose of transplantation in September or October; they will not then run up. When the plants are three inches high, thin out half of them, and transplant some into warm quarters, and others under a frame; protect by coverings of hoop and mats those in the open ground; and if they bear the winter, thin the plants early in the spring to six inches apart. The plants in the frame will rarely fail if the earth be free from slugs.

To save seed, transplant some of the finest lettuces when about half grown; they will produce a flower-stalk, and when the down of the seeds becomes visible, cut off the upper portion of the stalk, and dry it in a warm and airy room: thus save all the seed as it ripens in succession, for it is very valuable.

Endive is a salad of a pleasant bitter taste, and some authorities say it has been imported from China. There are three principal sorts in ordinary cultivation—the *green-curled*, *white-curled*, and *Batavian*, with undivided flat leaves. The seeds are sown at different periods between the beginning of June and the second week of August, as required for the autumnal, winter, and spring crops. When the plants are three or four inches high, they may be removed to beds of moderately-enriched loam, to stand a foot apart. But transplantation is not essential, for very fine plants are produced in the seed-beds. When they are nearly full grown, they must be prepared for the table by blanching, as otherwise they would be too bitter for use.

Blanching may be effected by several methods: the most simple is that of passing a string of soft bast matting round the centre of each plant, so as to exclude the light from the heart; but as hard frost is very injurious, some plants ought to be removed to a bed of dryish earth or sand under an airy shed; or a garden frame, partially covered, might be placed over a certain number of those already tied up. A good kind of pot for blanching is one of French invention, made of earthenware, and perforated with holes, as represented in the adjoining figure. Many persons blanch



by only throwing straw loosely over the plants, but this makes a litter not very pleasing in a garden. The curled endives would blanch in a short time without tying within a darkened frame or pot, and be thus less liable to decay; for it is known that the plants suffer from being tied. The Batavian endive, however, requires a bandage at all times, otherwise its harsh green leaves will be useless, and the central heart, which alone is edible, will never be rendered tender and white. Some persons blanch in a simple way by laying a tile over the open heart of the vegetable.

Corn-salad, or *lamb's lettuce*, a native of Britain—formerly used much more than it now is, and cultivated in gardens as an agreeable but rather insipid salad. A quarter of an ounce of seed was estimated by Abercrombie as sufficient to sow a bed four feet by five broadcast. The first sowing is effected in August, the second in September, for winter use. Thin out the plants when an inch high, to stand at three times that distance asunder. For summer salading sow once a month, beginning in March. Cut the plants for use as soon as they are large enough; this the taste will determine; but they should be taken very young, otherwise they become rank.

Garden cress.—In alluding to the culture of this common salad, we will include *mustard*, because they naturally are companions, and are always mentioned together, though they are of two very different families. In cultivating mustard and cress, it is essential only to remark, that the latter should be sown three or four days in advance of the former, because cress is more tardy than mustard. Both are very accommodating herbs, inasmuch as they will grow upon wetted flannel in a saucer placed in any apartment, as well as on the floor of a green-house. On shipboard, under cover, they can thus be obtained throughout the winter; and in the garden from March to November, by successional sowings made once every fortnight. Sow either broadcast over the surface of a fresh-digged bed, raking, and patting in the seeds by the flat of the spade, or in shallow drills half an inch deep, covering the seeds with a little fine soil. Sow thickly, and if the young plants rise, as they are apt to do, with a covering or cake of earth over them, remove it by means of a light heath-whisk. Salad should be taken before the true rough leaves be fully developed.

Water-cress, a valuable antiscorbutic, and wholesome as a fresh alterative to the inhabitants of cities, is grown to most advantage by the edge of running streams. If a small rivulet can be introduced into the garden, nothing can be more easy than to plant the roots in spring, and when they have once seeded, there will be speedily a mass of water-cress, which it requires only trouble to pull. The moisture is required principally in summer. The soils best calculated to bring the plants forward are loams inclining to gravel. The London markets are now supplied with immense quantities of 'fine spring water-cresses,' from the moist lands of Essex and neighbouring counties.

Celery is a native of Britain, found in ditches and marshes near the sea. The odour of the wild plant is very rank and disagreeable, and its juice is acrid and dangerous. By cultivation, this dangerous weed has been brought to the condition of that highly-esteemed vegetable which is called sweet celery. Of this there are three varieties:—1. The common upright hollow white celery; 2. The purple-stalked; 3. The giant white and red. Of the last (for which Manchester is particularly celebrated) there is a new sub-variety, extremely tender and delicate in flavour, the plants growing in favourable soils, and under skilful management, to an enormous size, but in ordinary cases not larger than the common white, yet always possessing a superiority in texture and flavour. Half an ounce of seed is deemed sufficient to sow a bed 4½ feet wide, and ten feet long, comprising, therefore, forty-five square feet of surface; and it may be sown in a frame, with gentle heat, at the end of February, for the first crop, and thence to the end of May, on a warm sheltered border for succession. All the seedling plants should be pricked out into intermediate beds of soft rich earth (the first sowings over a gentle hotbed), to bring strong transplants in June and July.

The roots of celery become bushy, and its leaf-stalk firm and stout; it likes moisture, and the soil to be rich with decomposed vegetable matter. Self-sown seed, that which falls from a seedling plant, if it light on rich earth, as that of a newly-dressed asparagus bed, in October, will bring noble plants in the spring, fit to go at once into trenches. Such plants may be thus shortly described: they are about six or eight inches long, with numerous stout leaves, and a massive collection of short fibrous roots. If these be produced by autumn-sown seed, nothing more is required; but the spring-sowings will always furnish weak and lax plants, that, when grown three inches high, must be removed to a nursery bed over manure to strengthen and become stocky. Few kitchen gardeners can obtain these plants till June, unless grown constantly under glass.

To trench for celery, prepare the trenches by previously manuring the whole plot in the method recommended for asparagus; and after the ground has settled, dig a trench or two for the first plants a moderate spade's depth, depositing the earth on a ridge to the right and left of the trench. Clear the bottom, lay on it three inches of leafy manure, and re-dig the ground, to incorporate it with the manure. Then select a number of the strongest and most regular plants, trim off loose straggling fibres, and all the side suckers, but do not touch a true leaf: set the plants four or five inches, and the large sorts six inches asunder, and fill the holes with water; shade during sunshine for three days, and give water every evening, unless there be copious showers. The size of the young plants will indicate the season for transplanting.

As to future attention, water the plants frequently in the evenings till they begin to grow; and when they become three inches higher, stretch a line along each edge of the trench, and cut down by the spade as much soil as will suffice to earth the stems to that height; break it fine, and grasping each plant firmly in the left hand, insinuate the soft soil around it; then place a little finely-reduced manure along the channel of the trench on each side, remote from the stems; this will nourish the fibres, without coming into contact with the leaves; water poured once or twice along the course of this manure will promote its action. Repeat the earthings as often as the plants advance three inches, and manure the extreme edges where the spade has made a groove, till at length the trenches become level with the surface of the ground. Then dig out soil, and add it, sloping ridgewise, till the plants are 'landed' up fifteen, eighteen, or more inches above the surface level. Celery may be preserved from frost by boards placed as a pent-house over the leaves.

Celeriac, or turnip-rooted celery, is raised and nursed the same as celery; but in planting out, the ground is dug and enriched, not trenched, and the plants are set by the dibble or garden trowel along the course of shallow drills drawn by the hoe, six inches apart, watering them freely. As the growth advances, bring earth to the plants, by which the knobby roots will be bleached, and made delicate and tender. When these are the size of small turnips, they are fit for the table. Celeriac is never eaten raw; it is boiled, and served up with melted butter. The seeds of both the species ripen freely in the summer of the second year, and many fine plants are obtained from self-sown seeds; which may serve as excellent substitutes should the spring-sowings fail.

Sweet Herbs.

These we shall class under two heads—namely, those that are fragrant, and esteemed for that quality alone, and those which are used for culinary purposes.

Rosemary and lavender are hardy undershrubs, natives of the south of Europe. They yield powerful essential oils when distilled with water, that of lavender being employed, as are also the dried flowers, in the preparation of the spirit usually, but erroneously, called *lavender water*. Bees are extremely partial to the flowers of rosemary. Both these plants are propagated with great facility by slips of the young side shoots, trimmed of the strip of ragged bark, and merely dibbled into the soil. They will grow almost anywhere, and in any aspect; but the flowers possess the highest degree of fragrance when the plants grow in a dry, sandy, or gravelly earth. Spring or September is most favourable to the propagation by slips.

Thyme and *lemon thyme* are used in seasonings; the latter is one of the most fragrant herbs of the garden; both are raised from seeds sown early in spring, or by opening the earth around the stems, spreading the reclining shoots like layers upon it, and strewing some fresh sandy mould over them. Roots are soon formed, and thus a supply of young plants is obtained. It appears essential to renew thyme, and to place it (lemon thyme particularly) in new soil, otherwise the plant dwindles and perishes. A dry and rather poor soil seems most favourable to the growth and fragrance of thyme, which may be economically grown as a border.

Sage, red and green, is propagated in the same way as lavender. 'All that is necessary,' says Mr Roger in his 'Vegetable Cultivator,' 'in the after-culture, is keeping the plants clear from weeds in summer, cutting down the decayed flower-stalks in autumn, and slightly digging between the rows.'

Of marjoram there are three sorts—*pot marjoram*, *sweet* or *knotted marjoram*, and *winter marjoram*, all hardy or sub-hardy perennial and biennial small shrubs, natives of the south of Europe, which grow readily in a dry light soil, but require change of situation. The first and third sorts may be propagated by division, in the manner of thyme, but the sweet marjoram should be raised from seeds sown in April every year, the plants to be thinned out to the distance of six inches. The flowers are gathered usually in July.

Savory.—Winter and summer savory; the former is propagated either by slips and cuttings, by separating the lower shoots, or rooted offsets, in spring; the latter is an annual, sown in April, and becoming fit for gathering in the summer and autumn.

Mint.—Spear or garden mint, and peppermint, are not properly sweet herbs; the latter, indeed, is only used medicinally, the essential oil possessing extremely pungent qualities, which render it one of the best diffusible stimulants we possess. Spear, or garden mint, is used in the kitchen for a variety of purposes familiarly known. All the species, including *pennyroyal*, another medicinal mint, are cultivated by division of the roots in spring. Mint delights in moisture; and when growing in a soil which it affects, extends with great rapidity. Care, however, is required to give it a new situation when the plant becomes weak, and its leaves appear of a pale and yellowish hue.

To dry and preserve these herbs, select the shoots just as the flowers form and show colour, but before they expand; suspend them in an airy situation, under cover, not exposed to the sun.

Miscellaneous Vegetables.

Artichoke, though esteemed by many, yet is found in few gardens; it is a native of the south of Europe, and was brought to England nearly three hundred years ago. Two varieties of it are cultivated in the best gardens—the conical oval-headed, and the round-headed, with dark purplish heads, the scales turned in at top. The plant has fibrous, rather fleshy roots, large deeply-cut leaves, whitish with down, and it produces an upright stem, bearing at the summit an oval or roundish flower-head, not unlike a thistle. Artichokes can be raised from seed, but much more speedily by offset-suckers, which are produced freely by the parent plant. Select a spot of open ground; any soil will do, but a free light loam is to be preferred. Dig out a trench two feet wide, and of the same depth, if the good soil extend so low; if not (and this remark will apply to every future allusion to trenching), remove all the good soil, whatever its depth, to a space beyond the boundary of the farthest intended trench, and dig and turn the inferior bottom soil, incorporating with it three or four inches of good half-decayed stable manure. Then mark out another two-feet trench, and throw into the first eight or nine inches of the surface-soil of the second trench; add another similar layer of dung, and work it and the earth thoroughly together. Again, throw in the remainder of the good soil of trench 2, and add a third layer of manure, which mix also with the soil. Thus trench 1 will be completed; and by repeating the work till the earth dug out of 1 be deposited in the last intended trench, all will be manured and laboured alike; and a piece of rich ground will be prepared that may be expected to keep in heart during many years. These directions apply to all enriched trenching, and need not therefore be repeated. The work ought to be performed before frost sets in; and if the land be heavy, it will be prudent to set it up in ridges.

Suckers are generally ready at some period of April; and gardeners are willing enough to part with them. Having procured the desired number, level the ground, dig a portion of it again, and reduce the surface to the finest condition possible; then, after trimming off decayed leaves and damaged roots, plant the suckers in a row, two feet asunder. It is usual to form a complete bed of three or more ranks, the rows to be five feet apart—and we have prepared ground, as above, for such a bed—but in truth artichokes and all other permanent vegetables ought to be set in single rows ten feet apart, because the ground between the rows can be cropped with other annual vegetables, which will benefit the artichoke, not only by the rich manure applied at the first, and other successional croppings, but by abstracting from the soil whatever it may exude from their roots of an excrementitious nature, and which, of necessity, must be injurious to the individual itself, though nutritious as manure to a vegetable of a different habit and character. The garden, in all its crops, permanent or temporary, ought to be made a laboratory of corrective rotations, wherein one crop shall attract and consume that which another deposits. A dozen good artichokes will be sufficient for a moderate family; but as some suckers may fail, it will be prudent to set the plants one foot asunder, securing the roots firmly in the soil, and giving a copious watering at the time of planting; the supernumeraries can be removed when all are safe.

The subsequent culture is as follows:—Hoe occasionally to destroy weeds, and keep the surface open. A crop cannot be anticipated during the first year; and if little heads be pushed up, it will be wise to remove them as soon as seen. When the plants become torpid and yellow in autumn, a few of the outside leaves are to be scaled off by the hand; the ground should then be marked by the line on each side at eighteen inches distance from the plants; and being cut straight by driving the spade to its full depth along the line, the earth is to be dug up, broken fine, and laid on the surface of the eighteen inches left on each side of the plants, bringing it carefully against them, so as not to fall into their hearts, but yet to protect them effectually near the tops of the leaves; the operation is called *landing up*. This done, fill the trenches with stable litter, straw, dung, or fern; and in the event of hard frost, bring more litter close to the plants, and lay it over the *landing* earth, for artichokes are rather tender, and may be destroyed during severe winters. This practice is to be observed every year, with the additional precaution to cut the flower-stems close down.

Spring-dressing consists in removing suckers after levelling the earth, and digging in a little of the short manure that is left on the ground after clearing away the straw, &c. and making the soil neat. One or two of the strongest suckers may be left on the stock.

Asparagus is justly esteemed one of the choicest vegetables of the garden; and indeed it possesses every quality to recommend it—flavour for the palate, hardihood of constitution, facility of culture, and it brings profit to the grower. It is a native of the British isles, but in its wild state bears little resemblance to the plant in a state of cultivation. Perfectly hardy, so much so as to resist a frost below zero, it nevertheless benefits by protection and generous tillage. In forming new plantations, it is customary to purchase two years' old plants, because they are safely removed at that age, and will come into bearing in two years more. April is the best season for planting; but having ourselves produced beds from *seeds*, we prefer that method of propagation. Let the ground be prepared before frost sets in by deep trenching and rich manuring; but by all means adopt the practice recommended by Grayson, who produced what he styled *giant asparagus* about the year 1830. We give his own concise directions in the following quotation:—'If your ground be stiff and unpleasant to work, get some milder earth to mix with it, and a very large cart-load of rotten dung to about every ten square feet; trench it two spit deep, and loosen the bottom; let the dung and earth be well mixed together. When your land is fit for planting, draw your drills six inches deep and sixteen inches from the first row to the second; that will form a bed; and ten inches between each plant in the row. Do not raise your beds till they have been planted one year; then put on about four inches of mould out of the alleys, and cut till the 10th of May. If you keep them well manured, they will last twenty years; but *never cut later than the 4th of June*. Let them be eight feet in the clear from bed to bed, so that you may crop between, and lose no land.'

Here we find the sum of all that constitutes asparagus planting; but after all, persons must be content with such plants as the constitution of their ground will produce; for this very sort, which in the rich water-deposited grounds (alluvial) about the Thames, produced shoots an inch in diameter, would and did dwindle in the loams of ordinary gardens to less than half that size. Nevertheless, if the beds be narrow, thoroughly manured at first, remote from each other; if, also, about February of the first year after planting, a trench eighteen inches deep, and a foot wide, be formed on each side of the narrow bed, and twelve inches distant from the plants, and be half filled with the best rotten dung, incorporated with an equal quantity of the earth dug out, a most excellent asparagus will be obtained speedily, and the quality will not deteriorate. This enrichment may be occasionally renewed, but these auxiliary trenches are to be made at an increased distance each time, so as to avoid cutting and mutilating the roots, which extend very rapidly. As this vegetable will no doubt be sold by the cottager, too much pains cannot be bestowed in order to obtain an early supply of the very finest quality.

The seed of asparagus may be purchased, but it is yielded abundantly by every good bed, and should be gathered before it falls off, and kept in the berry till spring. We will presume the object to be double—first, to raise bearing beds; and second, to raise a stock of young plants for forcing. In the former case, the ground is to be in readiness for narrow beds, eight feet asunder; in the latter, wide beds, like those directed for artichokes, should be made. Towards the latter end of March rub out the seed, and place the line along the course of the bed; strike two drills with the hoe at the distances directed by Grayson, two inches deep: or in the broad beds make similar drills nine inches asunder; and in both scatter the seeds pretty thickly, say half an inch apart; cover with fine earth, and pat it to a smooth surface with the spade. Watch the coming up of the plants, and be prepared to dust them with air-slaked lime, if slugs threaten them. When they shall have fairly formed rows of young seedlings six inches high, thin out the *narrow beds* first to four inches apart, and again to nine inches. The *seed rows* for forcing, thin first to three, and afterwards to five inches, and then leave both to grow, observing to use the Dutch or thrust hoe repeatedly to keep down weeds.

In future treatment, suffer the stems to become yellow, then cut them down at two inches above the soil; clear the surface with hoe and rake, and lay on the beds eight inches of decayed leaves. This surface-manuring, which will generally take place about the end of October, will tend greatly to protect the young plants, and impart a stimulating principle to the ground; so that in early spring the plants will be strongly excited, and rise through the remaining manure in perfect safety. The trench manuring also, before alluded to, will come in aid of the top-dressing. We have cut excellent 'grass' within three full years of the sowing, and still reap profitable crops from beds twelve years old. These annual enrichments, be it observed, might be persisted in with every bed that is used for cutting; but for the beds devoted to raising plants for forcing, it will suffice to make the ground thoroughly rich at the time of trenching; because the plants, when three or four years old, will be removed to the forcing department; yet a coating of half-decayed leaves or manure, after the stalks are cleared off, will not be lost, as the stronger the plants, the more remunerative will be the produce.

When once asparagus is in full bearing, if the cuttings be judiciously made—that is, by taking only the strong shoots, always leaving one or two of medium strength to each crown, and duly applying manure—a bed may keep in high condition for twenty years. But it must not be forgotten that if every shoot be taken off a crown, to the end of a long season that root will be destroyed. To prevent the crowns from being too deeply buried, in consequence of the autumnal dressings, it is customary to fork the beds late in March, digging them carefully, or rather loosening the surface with a fork of three prongs, and raking the rough earth into the alleys; this operation also gives freedom to the plant by opening the top soil.

With respect to forcing, it is very easy with narrow distant beds to bring the plants somewhat more forward in the spring, by digging trenches eighteen inches wide, or wider, and above a foot deep, and filling them with warm stable dung, blended with a third part of forest-tree leaves, raising the dung to six inches above the surface-level. The gentle warmth communicated will stimulate vegetation, and it would be assisted by covering the beds with hoops and mats, or with boards set up ridgeways, in the event of sharp frosty nights. Successional forcing-beds are prepared as soon as the cutting of the earlier begins to decline, or even when it is at its height.

The cucumber and *melon* are somewhat delicate in growth, and require a fine climate and extremely rich soil. The cucumber is usually grown over a heap of old horse-dung, on a spot of ground open to the south, and large enough to permit a two or three-light frame to rest upon it. Dig out the soil a foot in depth, and lay it on one side, or around the trench. If this soil be a light friable loam, incorporate it, a month before it is to be used, with one-third part of leaf or vegetable earth and old decayed dung, and again dig this mixed earth two or three times. But if the soil produced from four or five year-old couch-grass roots, harrowed from a field of sound loam, can be procured, it is the best aliment for the cucumber. The soil should be ready in

April, and the work of planting begun in the first week of May, by filling the excavation with stable manure to the height of six inches above the surface-level of the unmoved earth, and placing on it the frame and lights. In a week the manure will have settled, and is then to be covered with a six-inch layer of the couch mould or other soil, and a hill of dryish earth raised a few inches higher under each light, in which eight or ten seeds of any approved variety may be sown. If preferred, the seeds may be prepared by previous sowing in pots in a slight hotbed, and the plants so raised can be transferred to the hills. But as the plan now recommended is not one of forcing, it is safer to begin on the spot by sowing seed and covering the bed with the lights, and these with mats or boards every night.

As the plants rise, observe them carefully, and pick out the central buds when the true leaves have become strong. Persons differ much in opinion at this stage concerning the practice of stopping the shoots. M'Phail, gardener to Lord Liverpool at Addiscombe, Surrey, pointed out the true theory and results of stopping, as may be perceived by the following abbreviated extract from his work on the cucumber. He first directs to stop (nip back) the young seedlings at their second joint, then—'When the plants shoot forth after a second stopping above the second joint of the laterals, produced by the first, they seldom miss to show fruit at every joint and also a tendril, and between this tendril and the showing fruit there may be clearly seen the rudiment of another shoot. This shoot is then in embryo, but if developed, it becomes a fruitful lateral. And when the leading shoot has extended itself fairly past the showing fruit, then with the finger and thumb pinch it and the tendril off just before the showing fruit, being careful that, in pinching off the tendril and the shoot, the showing fruit be not injured. This stopping of the leading shoot stops the juices of the plant, and enables the next shoot—the rudiment above-mentioned—to push vigorously, and the fruit thereby also receives benefit.' The remarks will avail equally with the melon-plant as with the cucumber; and after the few remarks which follow on forcing, nothing farther need be said of the cultivation of melons.

Whether cucumber and melon plants have been raised separately in pots, or from seeds sown in the frame, they ought to be progressing early in June, and should be stopped occasionally, till fruit begin to show itself. The soil must never be wet, but always retained in a free and rather moist condition, water being kept in the frame for the express purpose. No water ought to be poured against the stems—it should be applied to the soil around the slope of the hills only. Air ought to be admitted in all warm days, by tilting the back of the lights till three o'clock; but after that hour the frame should be kept closed. When fruit is visible, stopping, according to M'Phail's direction, should be persevered in, and its fertilising effects will soon be apparent. Cover with mats, and boards over them, at sunset. Every decayed leaf and weak shoot should be removed as soon as perceived.

In order to raise and fruit cucumbers or melons before midsummer, *forcing* must be employed. The hotbeds of the best-regulated gardens are conducted without masses of manure under the roots; heat is excited by an atmosphere of warm air; thus injury from internal rank vapour is avoided, and manure is economised. By this method cucumbers and melons can be produced during the spring and summer months with certainty and precision. In the cultivation of both these plants equability of heat is important; and nothing would be more likely to secure this, and also to ward off sudden accession of cold, than to case the frame with an inner lining of thin boards, leaving a space of an inch or two between them, to be filled with some imperfectly-conducting substance, such as powdered charcoal or dry sawdust, taking care to secure it from the ingress of water. The expense would be trifling, and the security afforded very great.

Nasturtium, or Indian cress, is a native of South America, but is not tender; it is used occasionally (that is, the green seed-vessels are) as a pickle. These, when they ripen, separate and drop on the ground, where they remain torpid till the spring. Thus the plant sows itself, and so do most of the garden ornamental varieties. It therefore requires no minute directions; and any one who once possesses a plant, can multiply it by sowing seed in any way or place which may suit his taste. It may be sown with safety from the middle of March to the middle of May.

Parsley.—Several species and varieties of parsley are in cultivation; these are the plain and curled-leaved, and the common and the broad-leaved, or Hamburg parsley. Preference ought to be given to the curled-leaved parsley. This vegetable is one of the most easily cultivated, and it will long keep the ground with little trouble. It is sown in drills (generally in March) in any spare patches of border, lies long in the ground before springing, and arrives at maturity the next season. When it has attained this state, sprigs may be taken from it when required; even during a long winter storm, if the precaution has been taken to cover a drill or two with pease-stakes or other close wattling. When it becomes rank, it may be rooted out, and fresh parsley sown.

Rhubarb is a large vegetable, grown for the sake of its firm leaf-stalks. The leaves are very broad and spreading, to catch moisture, and shelter the ground around the main stem from the exhausting heat of the sun. When once planted, it requires no trouble, but keeps growing till the plant runs up to seed. To give additional size to the stems, cut off the seed-stalk. Suckers taken from known and approved plants succeed well, but the plant can easily be raised from seed. Each plant requires considerable space. In taking away the stalks for use, do not cut them, but wrench them from the main stock, so as to take them out by the socket. The earliest sorts in repute are *Buck's scarlet*, and the *new Tobolsk*, or yellow stalked. *Radford's scarlet Goliath* is later, but remains in season till August; it surpasses for delicacy, fullness of flavour, and extreme productiveness, all its competitors. Rhubarb may be forced by very simple means. A common method is to cover it in the early part of the year with a box, to which air is admitted, and covered with a little stable manure. This blanches, as well as brings forward the stalks; but that is an advantage, as it renders the vegetable more tender and delicate in flavour. Some bring forward rhubarb in pots in darkened forcing-houses, and for this purpose plants two years old are most suitable. Watering copiously is necessary in the early stages of growth, whether in the open air or under boxes. As rhubarb forms a valuable vegetable for tarts in spring, before gooseberries are ready, it would not be misspent time or trouble for a cottager to attempt forcing by the simple means above recommended. A well-planted plot of rhubarb, according to Mr Paterson, will continue productive for seven years; but a new one should be made a year or two before removing the old, and in the meantime some light crop may be raised on the new ground, which is but thinly occupied by the young plants.

Sea-kale is a perennial vegetable, deriving its name from being found growing in a wild state on the sandy downs which border the southern coasts of England. The method of garden culture is as follows:—Beds or spaces for single rows should be trenched and prepared as for asparagus; and at any dry period of March, when the surface earth will work freely, one or more drills should be drawn by the line, two inches deep, and the seeds scattered along the drill; or the line being strained tight, five or six seeds should be inserted in rings two inches deep, made at the distance of two feet apart. The seeds are then covered with earth, and when the plants become strong, they are to be thinned of supernumeraries, leaving one or two of the strongest remaining eighteen inches or two feet asunder every way. If the plants be weak, it will be prudent to retain double the number. During the first season, nothing more will be required than to keep the bed or row free of weeds. In the following spring, if the plants stand nearer to each other than eighteen inches, the surplus number should be carefully raised, and transferred to another prepared space, planting the crowns of the roots two inches below the surface. Eighteen inches to two feet, according to the strength of the plants, may be the regular distances at which they are to remain. The first bed, if pots be placed over the crowns, will yield a moderate supply of blanched kale during April or May of the second spring.

Sea-kale may be forced at various periods, commencing with November, by inverting large pots over the plants, and covering those with warm dung, or dung and leaves, to excite and maintain a heat in the pot and soil of about fifty-five degrees. Sea-kale, like other plants subjected to heat, can be, as it were, educated and made to conform to induced habits. Thus at first it seems to remain long torpid, even though the heat be considerable; but after a second season, provided the gardener be himself regular, the plants will yield to the stimulant almost to a day, though is be comparatively mild; hence sea-kale is at command from December to March by heat, and then the succession can be maintained during April and part of May by the cold beds or rows. 'You may have excellent sea-kale,' says the author of the 'Manse Garden,' 'in April from drills ridged up with earth; in which case every pair of drills must have greater distance for the convenience of mounding, and the plants may be so much closer in the bed. Straw in contact with the plants is unsuitable to blanching, as it communicates a bad flavour; but raked leaves do well, perhaps fern, sand certainly. Where the plant grows wild, as it does by the seashore in several parts of England, it is gathered in the finest condition when whitened by the sand, which the wind piles gently over its head in the manner of a snow-wreath.' As soon as the kale is cut from one or more roots, a sharp spade should be thrust through it, so as to cut the plant level with the surface.

Spinach is an annual of which there are many varieties. The following are the principal kinds:—1. The round-leaved, smooth-seeded, which is sown chiefly for spring and summer crops; 2. The triangular-leaved, prickly-seeded, or winter spinach—it is sown in August, stands the winter, and continues in full-bearing during spring and till midsummer; 3. The New Zealand spinach, a plant very different from the true spinach, and now neglected; 4. The white beet spinach, cultivated only for the leaves. The round-leaved should be sown about the end of January, and again in February and March, for successive spring and summer crops. The triangular-leaved is to be sown at the end of July or first week of August, and the leaves come into use at the beginning of winter; the plants require thinning and hoeing. The outer leaves only are to be taken during winter and spring, the inner leaves forming in their turn an ample succession. The seed or flower-stalks will become apparent in the early part of the summer, and some of the best plants, male and female (for spinach produces both separately), should be left to perfect the seeds. Plants designed for seed should be thinned to the distance of eight or ten inches. Spinach, according to the 'Vegetable Cultivator,' succeeds in any common garden soil; but the more that soil has been previously enriched with dung the better; and for winter spinach especially it is hardly possible to manure the ground too highly. Always select an open situation, not too near low-spreading trees, &c.; as in close and shady places it is mostly drawn up weak, and soon runs to seed, without attaining perfection.

Vegetable marrow is a species of gourd (*cucurbita*) cultivated extensively of late years—the pulp of which, from its richness and flavour, has been called *marrow*. It was brought originally from Persia, and was particularly noticed by Mr Sabine, in the 'Horticultural Transactions,' vol ii., where he described the best culinary variety as bearing a 'fruit of uniform pale-yellow or light-sulphur colour; when full grown, about nine inches in length, four inches in diameter, of an elliptic shape, the surface being rendered slightly uneven by irregular longitudinal ribs, the terminations of which uniting, form a projecting apex at the end of the fruit, which is very unusual in this tribe.' There are other varieties which produce fruit that weighs twenty or thirty pounds, oblong in figure, and quite green during growth; such fruit, however, is coarse in flavour, and in no respect equal to the small cream-coloured variety.

Sow in pots of any light soil early in April, treating the plants exactly as cucumbers under glass. About the middle of May, transfer them to a bed of rich earth over a trench filled with warm stable dung. Protect the plants by a hand-glass or frame, which, if the shoots are to run on the ground, should be raised by four or more bricks, giving air freely. When danger of frost ceases, remove the light or frame.

We have seen the best plants nailed and secured to a wall, as trees usually are. They bear profusely in summer and autumn, and are not subject to be injured by damp. The seeds are sown on the spot at the end of May, and one strong plant remains, being stopped once or twice at the tips of the advancing shoots, of which six are enough for each plant. It would be wise to place a large spare light or two sloping in front till midsummer, and again early in September. Glass diminishes the direct solar power to the extent of from eight to twelve degrees, but it wards off the primary attack of frost, which is at once fatal to these vegetables. If it be desirable to save seed, preserve the fruit first formed on a plant reserved for the purpose.

Mushrooms.—We have great hesitation in saying anything of the artificial growth of this species of vegetable, both on account of the difficulty which unprofessional gardeners labour under respecting the right sorts, and the complex methods which require to be employed for bringing forward crops. The greater number of mushrooms brought to market are of natural growth on old rich pastures; and it would appear that, without providing a similar kind of soil full of decaying matter, the plants cannot be raised. The method of procedure is very peculiar. The mushrooms are not sown in the form of seeds, for they have no observable seeds, but by spawn, or portions of their substance, mingled in the prepared soil. Mr Rogers, in his work 'The Vegetable Cultivator,' to which we would refer for much useful information on kitchen gardening, describes the process of mushroom culture, which, he says, is that approved of by the Horticultural Society. We extract a few passages for the sake of general information. 'In June or July take any quantity of fresh horse droppings (the more dry and high fed the better), mixed with short litter, one-third of cow's dung, and a good portion of mould of a loamy nature; cement them well together, and mash the whole into a thin compost, and spread it on the floor of an open shed, to remain till it becomes firm enough to be formed into flat square bricks; which done, set them on an edge, and frequently turn them till half dry; then with a dibble make two or three holes in each brick, and insert in each hole a piece of good old spawn, about the size of a common walnut. The bricks should then be left till they are dry. This being completed, level the surface of a piece of ground, under cover, three feet wide, and of sufficient length to receive the bricks, on which lay a bottom of dry horse-dung, six inches thick; then form a pile, by placing the bricks in rows, one upon another, with the spawn side uppermost, till the pile is three feet high; next cover it with a small portion of warm horse-dung, sufficient in quantity to diffuse a gentle glow of heat through the whole. When the spawn has spread itself through every part of the bricks, the process is ended, and the bricks may then be laid up in a dry place for use. Mushroom spawn, made according to this direction, will preserve its vegetable power many years if well dried before it is laid up; but if moist, it will grow and exhaust itself.

The next subject to be treated of is the preparation of the dung for the bed; and for this purpose none answers so well as that of the horse, when taken fresh from the stable: the more droppings in it the better.

About Michaelmas is the general season for making mushroom beds (though this may be done all the year round). A quantity of the dung mentioned should be collected, and thrown together in a heap to ferment and acquire heat; and as this heat generally proves too violent at first, it should, previously to making the bed, be reduced to a proper temperature by frequently turning it in the course of a fortnight or three weeks; which time it will most likely require for all the parts to get into an even state of fermentation. During the above time, should it be showery weather, the heat will require some sort of temporary protection, by covering it with litter or such-like, as too much wet would soon deaden its fermenting quality. The like caution should be attended to in making the bed, and after finishing it. As soon as it is observed that the fiery heat and rank steam of the dung are gone off, a dry and sheltered spot of ground should be chosen on which to make the bed. The place being determined on, a space should be marked out five feet broad, and the length (running north and south) should be according to the quantity of mushrooms likely to be required. If for a moderate family, a bed twelve or fourteen feet long will be found (if it takes well) to produce a good supply of mushrooms for some months, provided proper attention be paid to the covering.

On the space marked for making the bed a trench should be thrown out, about six inches deep; the mould may be laid regularly at the side, and if good, it will do for earthing the bed hereafter; otherwise, if brought from a distance, that of a more loamy than a sandy nature will be best. Either in the trench, or if upon the surface, there should be laid about four inches of good dung, not too short, for forming the bottom of the bed; then lay on the prepared dung a few inches thick regularly over the surface, beating it as regularly down with the fork; continue thus, gradually drawing in the sides to the height of five feet, until it narrows to the top like the ridge of a house. In that state it may remain for ten days or a fortnight, during which time the heat should be examined towards the middle of the bed, by thrusting some small sharp sticks down in three or four places; and when found of a gentle heat (not hot), the bed may be spawned; for which purpose the spawn bricks should be broken regularly into pieces about an inch and a half or two inches square, beginning within six inches of the bottom of the bed, and in lines about eight inches apart; the same distance will also do for the pieces of spawn, which, in a dung ridge, are best put in by one hand, raising the dung up a few inches, whilst with the other the spawn can be laid in and covered at the same time. After spawning the bed, if it is found to be in that regular state of heat before-mentioned, it may be earthed. After the surface is levelled with the back of the spade, there should be laid on two inches of mould—that out of the trench, if dry and good, will do; otherwise, if to be brought, and a choice made, that of a kindly loam is to be preferred. After having been laid on, it is to be beaten closely together, and when the whole is finished, the bed must be covered about a foot thick with good oat-straw, over which should be laid mats, for the double purpose of keeping the bed dry and of securing the covering from being blown off. In the course of two or three days the bed should be examined; and if it is considered that the heat is likely to increase, the covering must be diminished for a few days, which is better than taking it entirely off. In about a month or five weeks (but frequently within the former time, if the bed is in a high state of cultivation) mushrooms will most likely make their appearance, and in the course of eight-and-forty hours afterwards they will have grown to a sufficient size for use; in which case the author recommends that, instead of cutting them off close to the ground, they be drawn out with a gentle twist—the gatherer filling up the cavity with a little fine mould, gently pressed in level with the bed.'

As mushrooms may be said to cost no more than a little trouble, manure, and space for growth, at what an inconsiderable cost might not this excellent vegetable be abundantly procured! No product of the garden has hitherto been less attended to, and few afford so high a relish, either in their substantial form or as ketchup.

HORTICULTURAL MONTHLY CALENDAR.

Having in almost every instance mentioned the seasons for sowing, planting, transplanting, and otherwise attending to the culture of vegetables in the kitchen garden, it would only be waste of room to repeat directions, as is usually done, in connection with the different months. It is hoped, therefore, that the following general references to the months will be sufficient:—

January.—Trench and delve up all open grounds, if the weather permit; and in warm exposures, sow articles that are to be brought forward early.

February.—Continue turning up the ground designed for early crops; sowing may go on a little more briskly, especially in warm and well-sheltered borders.

March.—This is a particularly busy month, being, from its open and drying character, favourable for all works of preparation. Peas, beans, asparagus, onions, carrots, &c. are sown; and various articles are transplanted from frames.

April.—A continuance of preparing, sowing, and planting; hoeing, thinning, and clearing out of weeds require also to be attended to. In very dry weather seedling beds should be carefully watered.

May.—The main crops are now to be sown, early peas earthed up and staked, and young plants transplanted. The garden is now supposed to have assumed its perfect summer garb, with all things advancing in their early and mid-stages of growth.

June.—Sow kidney-beans, runners, &c.; water growing plants, if required; hoe potatoes, cabbages, and peas; and thin out beds. Gather medicinal and sweet herbs, when in bloom, and dry in the shade for winter use.

July.—Sow broccoli for the last time; also turnips, lettuces, &c.; and prepare all the unoccupied plots of ground for autumn and winter crops.

August.—Commence now to sow for the crops of next year, such as onions, early cabbages, and parsley; also winter spinach. Earth celery; hoe and thin turnips; cut down stems of gathered artichokes, and generally clear out all stumps and stalks of used plants, for their continuance exhausts the ground to no proper purpose. Cut herbs for distillation or for winter use; and gather all bulbous crops, such as onions, as soon as they are withered in the stem.

September.—The kitchen gardener has now got his principal labours in cropping over, and his chief work is continuing to sow for winter and spring successions; he also digs potatoes that seem ready, and takes care to cut down and clear off weeds.

October.—The garden having been prepared for spring vegetables, sow what was left over last month, including celery, asparagus, also early peas and beans. The cabbages and savoys require to be earthed up as high as the leaves. Remove carrots and other roots, which store away for winter use.

November.—If temperate and open, a little sowing may be continued in sheltered borders; but frost usually sets in early in the month, and puts a stop to cropping operations.

December.—During the latter end of November, and the open period of this month, the chief operations are digging, manuring, or trenching vacant ground, and attending to the preparation of composts. In frost, the labour exerted on the plants need only be protective; and the gardener usually occupies much of this period in pruning his trees, and attending to the more delicate plants in frames and sheltered borders. In mild weather a few early peas and radishes may be sown in dry warm borders, and small salads and cucumbers in hotbeds.

THE FLOWER GARDEN.

Flowers are the ornament of vegetable existence, and have in all ages been cultivated by persons of leisure and taste, for the beauty and variety of their forms, colours, and fragrance. While generally healthful and exhilarating, from being pursued in the open air, flower-culture is justly reckoned a pure and harmless recreation, which, by leading to the tranquil contemplation of natural beauty, and diverting the mind from gross worldly occupations, has a positively moral and therefore highly beneficial tendency. It has also the advantage of being alike open to the pursuit of high and low, the peasant and the peer, the over-toiled man of business and the industrious artisan. It may be followed with equal enjoyment by both sexes, and as is well known, on every imaginable scale, from that of a single flower-pot or tiny front-plot, to the princely green-house and exquisitely varied parterre.

The natural grace, simplicity, and attractive colouring of flowers have afforded endless themes to moralists and poets; and volumes have been penned to show how many associations of feeling, simple and sublime, these beauteous subjects are calculated to excite. As our desire is to improve the feelings as well as to instruct the understanding, we hope to escape censure for pausing an instant over this agreeable view of the importance of floriculture, and would refer, for one of the most glowing eulogies on the subject, to the elegant work of Miss Sarah Stickney—the 'Poetry of Life.' According to the well-expressed sentiments of this lady, few natural objects are more poetical, or more calculated to refine the taste than flowers. 'From the majestic sunflower, towering above her sisters of the garden, and faithfully turning to welcome the god of day, to the little humble and well-known weed that is said to close its crimson eye before impending showers, there is scarcely a flower which may not from its loveliness, its perfume, its natural situation, or its classical association, be considered highly poetical.

As the welcome messenger of spring, the snowdrop claims our first regard, and countless are the lays in which the praises of this little modest flower are sung. The contrast it presents of green and white (ever the most pleasing of contrasts to the human eye), may be one reason why mankind agree in their admiration of its simple beauties; but a far more powerful reason is the delightful association by which it is connected with the idea of returning spring. Perhaps we have thought long of the melting of the snow that impeded our noonday walk. But it vanishes at last; and there, beneath its white coverlet, lies the delicate snowdrop, so pure and pale, so true an emblem of hope, and trust, and confidence, that it might teach a lesson to the desponding, and show the useless and inactive how invaluable are the stirrings of that energy that can work out its purpose in secret, and under oppression, and be ready in the fullness of time to make that purpose manifest and complete. The snowdrop teaches also another lesson: it marks out the progress of time. We cannot behold it without being reminded that another spring has come, and immediately our thoughts recur to the events which have taken place since last its fairy bells were expanded.

It is of little consequence what flower comes next under consideration. A few specimens will serve the purpose of proving that these lovely productions of nature are, in their general associations, highly poetical. The primrose is one upon which we dwell with pleasure proportioned to our taste for rural scenery, and the estimate we have previously formed of the advantages of a peaceful and secluded life. In connection with this flower, imagination pictures a thatched cottage standing on the slope of the hill, and a little woody dell, whose green banks are spangled all over with yellow stars, while a troop of rosy children are gambolling on the same bank, gathering the flowers, as we used to gather them ourselves, before the toils and struggles of mortal conflict had worn us down to what we are now, and thus presenting to the mind the combined ideas of natural enjoyment, innocence, and rural peace—the more vivid, because we can remember the time when something like this was mingled with the cup of which we drank—the more touching, because we doubt whether, if such pure drops were still there, they would not to our taste have lost their sweetness.

The violet, while it pleases by its modest, retiring beauty, possesses the additional charm of the most exquisite of all perfumes, which, inhaled with the pure and invigorating breezes of spring, always brings back in remembrance a lively conception of that delightful season. Thus in the language of poetry, "the violet-scented gale" is synonymous with those accumulated and sweetly-blended gratifications which we derive from odours, flowers, and balmy breezes; and above all, from the contemplation of renovated nature, once more bursting forth into life, and beauty, and perfection. The jasmine, also, with its dark-green leaves and little silver stars, saluting us with its delicious scent through the open casement, and impregnating the whole atmosphere of the garden with its sweetness, has been sung and celebrated by so many poets, that our associations are with their numbers rather than with any intrinsic quality in the flower itself. Indeed, whatever may have first established the rank of flowers in the poetical world, they have become to us like notes of music, passed on from lyre to lyre; and whenever a chord is thrilled with the harmony of song, these images present themselves, neither impaired in their beauty nor exhausted of their sweetness for having been the medium of poetic feeling since the world began.

It is impossible to expend a moment's thought upon the lily, without recurring to that memorable passage —"Consider the lilies of the field, how they grow. They toil not, neither do they spin; and yet I say unto you, that Solomon in all his glory was not arrayed like one of these." From the little common flower called heart's-ease, we turn to those well-known lines of Shakspeare, where the fairy king so beautifully describes the "little western flower." And the forget-me-not has a thousand associations tender and touching, but, unfortunately, like many other sweet things, rude hands have almost robbed it of its charm. Who can behold the pale narcissus, standing by the silent brook, its stately form reflected in the glassy mirror, without losing himself in that most fanciful of all poetical conceptions, in which the graceful youth is described as gazing upon his own beauty, until he becomes lost in admiration, and finally enamoured of himself; while hopeless Echo sighs herself away into a sound, for the love which, having centered in such an object, was neither to be bought by her caresses nor won by her despair! Through gardens, fields, forests, and even over rugged mountains, we might wander on in this fanciful quest after remote ideas of pleasurable sensation connected with present beauty and enjoyment; nor would our search be fruitless, so long as the bosom of the earth afforded a receptacle for the germinating seed —so long as the gentle gales of summer continued to waft them from the parent stem—or so long as the welcome sun looked forth upon the ever-blooming garden of nature.

One instance more, and we have done. The "lady rose," as poets have designated this queen of beauty, claims the latest though not the least consideration in speaking of the poetry of flowers. In the poetic world, the first honours have been awarded to the rose, for what reason it is not easy to define, unless from its exquisite combination of perfume, form, and colour, which has entitled this sovereign of flowers in one country to be mated with the nightingale; in another, to be chosen, with the distinction of red and white, as the badge of two honourable and royal houses. It would be difficult to trace the supremacy of the rose to its origin; but mankind have so generally agreed in paying homage to her charms, that our associations in the present day are chiefly with the poetic strains in which they are celebrated. After all the pains that have been taken to procure, transplant, and propagate the rose, there is one kind perpetually blooming around us through the summer months, without the aid or interference of man, which seems to defy his art to introduce a rival to its own unparalleled beauty—the common wild rose. Blooming in the sterile waste, this lovely flower is seen unfolding its fair leaves where there is no beauty to reflect its own, and thus calling back the heart of the weary traveller to thoughts of peace and joy—reminding him that the wilderness of human life, though rugged and barren to the discontented beholder, has also its sweet flowers, not the less welcome for being unlooked for, nor the less lovely for being cherished by a hand unseen.' To these elegantly-expressed sentiments nothing need be added by the writer of these pages.

MODES OF LAYING OUT.

Flowers are cultivated in the borders and parterres of gardens of a mixed kind along with kitchen vegetables and fruits; and this may be said to be the general plan in those grounds of limited space belonging to persons of moderate means, and limited in the extent of their possessions. Many, however, cultivate flowers in gardens exclusively appropriated to them, and also in isolated clumps for the decoration of lawns. In whichever way, the method of culture is the same; and therefore it is unnecessary to enter into particulars with reference to the various sizes and kinds of gardens in which flowers may be grown.

The directions given in the previous sheet on the laying out, shelter, and exposure of kitchen gardens, apply also to flower gardens. The soil should be rich, dry, soft, and partially improved with decomposed peat and leaf mould; the exposure should be full and uninterrupted towards the sun; a free air should be allowed to play over the ground; and means should be at hand for procuring a plentiful supply of pure soft water for irrigation. Every flower garden, also, should possess a small store of fine washed sand as a restorative, and for scattering beneath the finer kinds of flowers when in bloom, as a protection from creeping vermin. Besides the utensils usually employed, the flower gardener should have a pair of small scissors to clip off decayed leaves, and some painted stakes and strips of bast for tying up drooping plants.

The greatest difference of taste prevails on the subject of disposing the various parts of a flower-plot or garden. Straight-lined borders, ovals, circles, and fancy figures, have each their admirers; and we should advise every one to adopt that form which will be most effective in striking the eye. If the garden is seen from a parlour window, as is often the case, the plan most agreeable is to lay out the foreground as a patch of well-shaven green, which is fresh both winter and summer; on its further side there may be a semicircular border; then a walk; and next parterres of such form and size as will suit the extent of the ground. If the garden contain kitchen vegetables, they should be out of sight of the windows of the dwelling-house, or at least not brought ostentatiously forward. 'It is more difficult,' says the author of the 'Florist's Manual,' 'than may at first appear, to plan, even upon a small scale, such a piece of ground; nor, perhaps, would any but an experienced scientific eye be aware of the difficulties to be encountered in the disposal of a few shaped borders interspersed with turf. The nicety consists in arranging the different parts so as to form a connected glow of colour; to effect which, it will be necessary to place the borders in such a manner that, when viewed from the windows of the house, or from the principal entrance into the garden, one border shall not intercept the beauties of another; nor, in avoiding that error, produce one still greater—that of vacancies betwixt the borders—forming small avenues, by which the whole is separated into broken parts, and the general effect lost. Another point to be attended to is, the just proportion of green turf, which, without nice observation, will be too much or too little for the colour with which it is blended; and lastly, the breadth of the flower-borders should not be greater than what will place the roots within the reach of the gardener's arm without the necessity of treading upon the soil, the mark of footsteps being a deformity wherever it appears among flowers.'

Whether all the flowers of a class—such, for instance, as violets, hyacinths, &c.—should be cultivated together, or interspersed and mingled with others, is another matter for taste to decide. The preferable plan seems to be to form a choice variety in borders and other spots, but also to cultivate a quantity of certain sorts in compartments by themselves. Neill judiciously observes, on the choice of flowers for borders—'The plants are arranged in mingled flower-borders, partly according to their size and partly according to their colour. The tallest are planted in the back part, those of middling size occupy the centre, and those of humble growth are placed in front. The beauty of a flower-border, when in bloom, depends very much on the tasteful disposition of the plants in regard to colour. By intermingling plants which grow in succession, the beauty of the border may be prolonged for some weeks. In a botanic garden, the same plant cannot be repeated in the same border; but in the common flower garden, a plant, if deemed ornamental, may be often repeated with the best effect; nothing can be finer, for example, than to see many plants of double scarlet lychnis, double sweet-william, or double purple jacobea.'

The Dutch, who are among the best flower gardeners in the world, have lately begun to copy the English in ornamenting turf lawns with plots of various kinds of flowers; but in all their large and regular gardens they still dispose each kind of flowers by themselves. 'We ridicule this plan,' says Hogg in his 'Treatise on Flowers,' 'because it exhibits too great a sameness and formality; like a nosegay that is composed of one sort of flowers only, however sweet and beautiful they may be, they lose the power to please, because they want variety. It must undoubtedly be acknowledged, that a parterre, no matter in what form—whether circular or square, elliptical or oblong—where all the shrubs, plants, and flowers in it, like the flowers in a tastefully-arranged bouquet, are variously disposed in neat and regulated order, is a delightful spectacle, and worthy of general imitation. Yet still, in some particular cases, I am disposed to copy the Dutchman; and I would have my bed of hyacinths distinct, my anemones, my ranunculuses, my pinks, my carnations distinct, and even my beds of hollyhocks, double blue violets, and dwarf larkspurs distinct, to say nothing of different sorts of roses. Independently of the less trouble you have in cultivating them when kept separate, you have beauty in masses, and you have likewise their fragrance and perfume so concentrated, that they are not lost in air, but powerfully inhaled when you approach them.' Leaving this question to be settled according to taste and other circumstances, we have only to recommend that no flower or herb of any kind should be sown or planted in figures resembling familiar objects. Some persons, for example, will be seen sowing annuals or planting crocuses in the figure of a letter of the alphabet, a ship, a house, a human profile, a crown, &c.—a practice so essentially vulgar that it cannot be too loudly condemned.

As to front-plots in towns and suburbs, if they be limited to a few square yards, it will be better not to attempt the growth of flowers at all, but to lay them down in green sward or clean gravel, with perhaps a variegated holly, box-tree, laurel, flowering currant, sweet-brier, rose, or some other hardy shrub, to enliven them. Nothing, however, can be more wretched than a few sickly plants struggling for a miserable existence amid the dust and smoke of a town; and a person of good taste will never attempt the growth of flowers unless he can command the requisite amount of air and sunshine. In laying out little front-plots of this description, circular, oval, oblong, and other simple forms should be preferred; for nothing looks more ridiculous than the imitation of labyrinths and intricate designs on so small a scale. A few plain forms, in keeping with the front of the building and size of the plot, may produce elegance; but intricate divisions, with lines of gravel between, scarcely broad enough for a human foot, are toyish and trifling in the extreme. Neat and simple edgings of box, daisy, Virginian stock, privet, and the like, should be preferred to showy borders, which are only adapted for large flower-gardens and ornamented lawns.

An error not uncommon in deciding which flowers shall be planted, is to select numbers merely for their rarity or novelty, without reference to what will be their appearance when in bloom, and which generally leads to disappointment. Unless for botanical illustration, make a choice of flowers on two principles—those which will be beautiful when in bloom, although common, and those which will bloom at the particular seasons required, to insure a succession of variegated beauty from spring to autumn. The true amateur gardener takes a pride in improving even the commonest flowers—urging them by careful culture to the highest state of perfection, as to size and brilliancy of colouring, of which they are susceptible in our climate.

CHARACTER AND TREATMENT OF FLOWERS.

All flowering plants belong to the division *Phanerogamia* in the vegetable kingdom; but it is only those in which the blossom is conspicuous, beautiful, or odorous, that are the objects of garden-culture. The part of the plant which constitutes the flower, bloom, or blossom, is the *corolla*; it consists of several divisions or leafy parts, called *petals*. The corolla encloses the *stamens* and *pistils*, or organs of reproduction (see VEGETABLE PHYSIOLOGY); and to bring these to perfection, so as to effect the development of the seeds, is the prime object of vegetable growth. When the seeds are perfected, or in the way of being so, the corolla languishes and dies. The design of the flower gardener is less to produce size and strength in his plants, than to cause them effectually to bloom: he wishes a fine corolla. It is proper, then, to mention, that whatever tends to give excessive vigour to the stems will prevent the formation of flower-buds; and the same result will follow from stunting or starving the plant. To induce flowering, the plant must be fully exposed to sun and air; at a lower temperature than 50 degrees the blooms cannot be expected to open; but from that to 65 degrees the sap will ascend, and the buds, if duly provided with moisture and fresh air, will be rapidly developed. When freely exposed to seasonal influences, flowering plants appear withered and nearly gone in winter; they begin to shoot up in spring, come to perfection in their bloom in summer, and languish and yield their seeds in autumn. But if treated properly in the artificial climate of a greenhouse, they will be found, after proper training, to disregard seasonal influences, and perhaps to bloom in winter or in spring.

It has been remarked that when plants have been slightly checked by frost or dry cold air, they sooner come into bloom. 'This,' says Mr Rennie in his 'Alphabet of Gardening,' 'arises evidently from the pulp being concentrated instead of being expended in the production of new leaves and branches, while perhaps part of the effect may be owing to increased excitability. On this principle the early potato, which does not flower freely, may be made to do so by removing the tubers; and, on the other hand, the tubers are increased in the late sorts by picking off the flower. The greater the quantity, then, of good healthy pulp which can be prepared by the leaves, the more really vigorous and healthy will the plant become; and as flowering and fruiting exhaust a great quantity of this pulp, and of course tend to weaken the general system of the plant, it follows that the artificial prevention of flowering must preserve in the plant the digested pulp which would have gone to nourish the flower and the fruit. Thus by pruning off the luxuriant shoots of melons, &c. the pulp induces the shoots to spring into flowers and fruit. Upon this principle is founded the practice of treating bulbs so as to cause them to bloom vigorously, by cutting off the flowering stem as soon as it appears, in some cases, and in others so as to have the blossoms evolved when placed in water, taking care to encourage the growth of the leaves by rich soil and free exposure to air and sunshine. In this way the greatest quantity of strong pulp is stored up in the bulbs, and luxuriant blossoms are produced the succeeding season. The practice, consequently, of some unskilful gardeners, of trimming off the leaves of snowdrops, crocuses, and tulips, after the blooming is over, for the purpose of rendering a border or a bed neat, is very bad; and it is not much better to tie up the leaves, as is also preposterously done, for in this way they cannot be duly exposed to the air and the light. The same principle will apply to all other flowering plants. When a flowering branch or stem has been produced, and has begun to show the flower-buds, it must be considered that it can only blow finely in proportion to the quantity of healthy pulp either previously in the branch, or from time to time prepared by the leaves of that branch. Consequently, if there are two or more flowers on the branch, each will require its due proportion of food; but if one or more of these be artificially removed, all the spare pulp will go to feed the one, two, or more blossoms which may remain. On this is founded the practice of thinning out the flower-buds from the bunches of auriculas, polyanthuses, chrysanthemums, and other plants, in order to increase the size and beauty of those which are left to expand. It is in consequence of the same principles that free exposure to air is indispensable for producing fine flowers, inasmuch as they depend for nourishment on the pulp, which without these cannot be formed. The vivid colours and pleasant odour of flowers depend on the same causes—for in the shade these are both feeble.'

Flowering plants are usually divided into the following kinds:—*Annuals*; plants which require to be sown annually, as they live and bloom only one season. *Biennials*, which do not blossom till the second season after sowing, remain a certain time in perfection, and then die; they are produced by seed, but some of the finest double varieties are continued by cuttings. *Perennials* are plants which continue for many seasons to grow and blossom annually. *Indigenous plants*; those which are natives of this country, and may have been perfected by culture from a wild state. *Exotics*; plants of foreign origin, which have been introduced into this country. The greater number of our fine flowers and fruits are exotics. Many of these have been acclimatised, or accustomed to our climate, and rendered hardy by a course of culture; but others require to exist in greenhouses and hothouses, or under glass frames, for at least a part of the year. It would appear that each region of the globe possesses plants as distinctive in their features as the different races of men. On this subject Mr Loudon remarks—'The native countries of plants may often be discovered by their features, in the same manner as the national distinctions which are observable in the looks and colour of mankind, and which are effected chiefly by climate. Asiatic plants are remarkable for their superior beauty; African plants for their thick and succulent leaves, as in the case of the *Cacti*; and the American plants for the length and smoothness of their leaves, and for a singularity in the shape of the flower and fruit. The flowers of European plants are but rarely beautiful. Plants indigenous to polar and mountainous regions are generally low, with small compressed leaves, but with flowers large in proportion. Plants indigenous to New Holland (or Australia) are distinguishable for small and dry leaves, that have often a shrivelled appearance. In Arabia they are low and dwarfish; in the Archipelago they are generally shrubby, and furnished with prickles; while in the Canary Islands, many plants, which in other countries are merely herbs, assume the post of shrubs and trees.'

The different kinds of plants generally cultivated for their blossoms are either *herbaceous*—that is, succulent, and full of juice; or *shrubby*—that is, having ligneous or woody stems. A *deciduous* tree or shrub is one which sheds its leaves every winter, and is recovered in spring. An *evergreen* is a shrub which retains its leaves during winter, but casts them in spring as the new buds come out. A *fibrous-rooted* plant is one whose roots send out small fibres; polyanthuses are examples of this section. A *tuberous-rooted* plant is one whose root forms small tubers or lumps; dahlias, peonies, ranunculuses, and anemones, are examples among flowers, and the potato among kitchen vegetables.

The prevailing colours of flowers are yellow, orange, white, pink, scarlet, red, blue, purple; and many are variegated, or composed of different tints. Proper culture, with pure air and sunshine, increase the brilliancy of the tints, and give massiveness to the corollas. Plants of a kindred species may likewise be improved by hybridising or crossing, the general principle of which is the artificial application of the pollen of one plant to another (see VEGETABLE PHYSIOLOGY, p. 80). By this means some of the most beautiful flowers have been originated. Change of soil and climate, however, are the great means of improvement. As long as it is confined to its native habitat, the corolla of the plant and all its other appurtenances are meagre and generally unattractive; but when nourished in a cultivated soil, and all its wants supplied, the whole plant strengthens and expands, and the corolla flashes on the eye with new brilliancy of colour. The changes effected on the daisy, the rose, and the violet, will here occur to remembrance, as striking instances of metamorphoses by culture and change of habitat. Speaking of the laws by which a change of colour is produced, Dr Lindley, in his 'Introduction to Botany,' observes—'A blue flower will change to white or red, but not to bright yellow; a bright yellow flower will become white or red, but never blue. Thus the hyacinth, of which the primitive colour is blue, produces abundance of white and red varieties, but nothing that can be compared to bright yellow; the yellow hyacinths, as they are called, being a sort of pale yellow-ochre colour, verging to green. Again, the ranunculus, which is originally of an intense yellow, sports into scarlet, red, purple, and almost any colour but blue. White flowers, which have a tendency to produce red, will never sport to blue, although they will to yellow; the rose, for example, and the chrysanthemums. It is also probable that white flowers, with a tendency to produce blue, will not vary to yellow; but of this I have no instance at hand.' (See No. 5, pp. 77–8).

Improvement in the brilliancy or change of colour is not effected without a certain loss in the odorous properties of the plant. It is remarked that cultivation generally renders the odour less intense, and sometimes altogether destroys it. Thus the fragrance of the wild violet is not to be found in the heart's-ease.

Propagation.

Flowering plants are propagated in various ways—by sowing seeds at the proper seasons, by dividing the root, by suckers, layers, pipings, cuttings, and bud-grafting:—

Dividing the Root.—This is one of the most simple methods of propagation. The root of the growing plant is partially uncovered, and one or more portions are removed; the root is then covered up, and the detached parts transplanted in soft earth prepared to receive them. Nine-tenths of herbaceous perennials may be treated in this way.

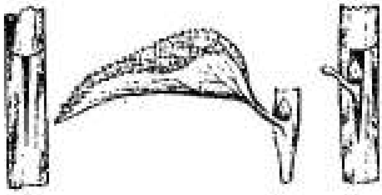
Suckers.—These are young shoots thrown up from the roots of the main plant, round which they cluster. They may be removed by taking up along with them a part of the root. They should be removed in spring, after the plant has begun growing, and immediately planted out. If any flower-buds be developed on them, take them off, so as to give strength to the leaf and root-developing principle of the plant.

Layers.—Some plants, as, for instance, strawberries, send out layers or runners along the ground; these have joints, if we may call them such, at certain points; and where any joint strikes the earth, it takes root, and becomes the centre of a new plant. Thus a running plant will speedily cover, as with a network, a large space of ground. Nothing is more easy than to propagate by causing the layers of some plants to take root. In the case of the carnation and similar plants, fix a stem at one of its joints to the ground, with a hooked stick or peg, covering it slightly with mould, and giving it a little moisture. Roots will in general strike out in a few weeks; and at the end of the season the plant is ready for being cut from its parent, and transplanted. Where layering is tedious, propagation by division of the root may be adopted.

Pipings.—Propagation by piping is an expeditious mode of raising young plants. The following is the method prescribed in a small and useful work entitled 'Every Lady her own Flower Gardener:'—'Take off the upper and young part of each shoot close below a joint, with a sharp knife, and cut each off at the third joint, or little knob; and then cut the top leaves down pretty short, and take off the lower and discoloured ones. When you have piped in this way as many as you require, let them stand a week in a tumbler of water, which greatly facilitates their doing well. Indeed I never failed in any pipings, slips, or cuttings, which I allowed to soak and swell in water previous to planting. When you plant the pipings let the ground be newly dug, and raked very fine; dibble no hole, but gently thrust each piping half-way down into the soft earth round each, to fix it in the bed. Water them often, if the weather is dry, but moderately, just to keep them moist; and shade them from the hot sun in the day. If pipings are covered with a hand-glass, they root earlier by three weeks than those which are exposed. Laying, piping, and slipping, are done in June and July. The plants will be well rooted and fit to plant out in October.' Slips are shoots wrenched off at a joint, instead of being cut, and are treated precisely in the same manner as pipings.

Cuttings are strong shoots of last year's growth, cut from the parent stem or branch, and set in the ground. The cutting should be about six inches long, and cut off slantingly and smoothly. The soil in which the cutting is inserted requires to be dry, or not too moist. Roses and honeysuckles are among the plants usually propagated by cuttings. The operation should be performed in January or February, so that the cuttings may root and vegetate in the opening of spring; but several months are required to bring the cutting to a state fit for transplanting. Some cuttings of flower-stalks may be set as late as May and June.

Budding is a method of propagation chiefly used in connection with fruit-trees; but as it is likewise applicable to rose-bushes, it may here be described. It is a species of grafting, and consists in inserting the fresh-cut extremity of a small twig or bud beneath the bark of another plant. A leaf-bud, easily known by its tapering point, should be alone selected, and not a bud on which a flower is developed. The leaf on the selected bud is to be taken off, for if it remained, it would exhaust the sap, and the bud would in all likelihood wither and die. Along with the bud, a small slip of bark is to be taken; and if this bark separate freely, it is a test of there being pulp enough to form a union. The slip of bark is to be inserted beneath the bark of the other plant, in a slit made for the purpose, and the whole tied with a strip of mat to keep out the air. The subjoined cut represents the various parts in budding: *a* is the bud cut out, with a



b a c

shield of bark attached to it; *b* the stem, with a slit in the bark to receive the shield attached to the bud; *c* the bud inserted, and the leaf cut away.

Shrubby plants are also propagated by *in-arching*; but a notice of this, and also of ordinary *grafting*, will be more appropriately given under FRUIT GARDENING.

SELECT FLOWERS FOR THE GARDEN.

Flowering plants are now so numerous, both as respects species and varieties, that a bare list of them would more than fill the present sheet. All, therefore, that can be reasonably expected from us is a few hints as to those which are most approved, and cultivated chiefly in the open air. A person with little experience should stock his garden only by degrees—a small number of different sorts every year, according to fancy, and what he finds to be the capabilities of the soil and exposure. In commencing to make a choice for a moderately-sized garden, or for still smaller plots of ground and borders, we should also recommend the plan of cultivating a mixed variety of different colours and different heights—those which are smallest being in front, and nearest the eye, and the other rows rising in height and massiveness as they recede. With as few as four colours, four sizes, and six different periods of coming into bloom, a mingled border may be established with ninety-six sorts, which will present a pleasing assemblage to the eye.

Annuals.

Some annuals are called *hardy*, and others *half-hardy*. The hardy kinds will grow and blossom in open borders, without artificial heat or protection; those which are more tender will also grow in the open air, but are improved by being brought forward under hand-glasses. Of the delicate class of annuals which must be constantly kept under glass frames, it is not our purpose to speak. The greater number of annuals may be sown at the end of March or beginning of April. The soil should be fine, and have a warm exposure; and on being sown, cover the seeds with only about half an inch of mould; peas and lupines should be an inch below the surface. If the weather be dry, irrigate with pure soft water occasionally. Take care that the seed you sow is fresh and good: the way to test its quality is to throw it into a glass of water; if it be worthless, it will swim; if good, it will sink to the bottom.

Among the vast number of annuals that offer themselves to the choice of the gardener, the following, each having varieties as to colour, may be mentioned as taking the lead in the *half-hardy kinds*:—African marigold, French marigold, China aster, marvel of Peru, chrysanthemum, sweet sultan, Indian pink, love apple, gourds, bottle gourd, convolvulus, yellow balsam or touch-me-not, amaranthus, ten-week gilliflower, white ten-week stock, cannacorus, and Chinese hollyhock. *Hardy kinds*:—Adonis-flower, candytuft, larkspur, lupines, sunflower, lavatera, poppy, convolvulus major, nasturtium, Tangier pea, sweet pea, winged pea, Lobel's catchfly, dwarf lychnis, Venus's looking-glass, Virginian stock, heart's-ease, snapdragon, mignionette, xeranthemum, purple jacobæa, Clarkias.

If annuals are required on a more extended scale, the best plan is to leave the selection to a respectable nurseryman. Such a person will at least present a copious list to make your choice from, and mention the size or height to which the plants will respectively grow. Mr Loudon, in his 'Encyclopædia of Gardening,' quotes a list by Mr Swinden, a Brentford nurseryman, consisting of nearly ninety hardy annuals, distinguished in ranges according to heights. From this we make the following extract—for the sake of simplicity, leaving out the Latin names:—

'*First Range—from 8 to 12 or 14 inches high.*

Cape marigold; purple and white. Large caterpillar; yellow, and singular pod. Venus's looking-glass; light purple. Ram's horns; yellow: the pod is its beauty. Round snails; yellow, and singular pod. Dwarf variegated lychnis; crimson and white. Heart's-ease; purple and yellow. Half-moons or moon-trefoil; white, and singular pod. Blue meadow lychnis; sky-blue. Dwarf virginian stock; purple. Small hedgehogs; yellow, and singular pod. Woodroof; light blue. Red hawkweed; pale red. Large hedgehogs; yellow, and singular pod.

Second Range—from 12 to 18 or 20 inches high.

Oak of Jerusalem; yellowish, with fragrant smell. Small white candytuft; clear white. Long-horned devil in a bush; yellow, and singular pod. Convolvulus minor; bright blue, with yellow eye. Large purple candytuft; light purple. White Lobel's catchfly; reddish white. Annual snapdragon; purple and yellow. Scarlet or wine peas; dark and light red. Large white candytuft; clear white. Striped convolvulus minor; blue and white. Red Lobel's catchfly; bright red. Dwarf nasturtium; deep orange. Broad Spanish nigella, with brown seed; deep blue. Red flos Adonis; dark red.

Third Range—from 20 to 24 or 22 inches high.

Spanish nigella, with black seed; light blue. Spanish hawkweed; pale yellow, and purple eye. Blue Moldavian balm; deep blue, and fine scent. Annual rest-harrow; pale red. Double Roman nigella; white mixed with blue. Small running nasturtium; dark orange. Nettle-marjoram; yellowish, no smell but to the over-curious. Rocket larkspur; pink and white. Sweet-scented lupines; bright yellow. White Moldavian balm; fair white, and fragrant smell. Dutch lupines; fine blue. Annual hare's ear; pale yellow. Purple jacobæa; purplish-red and yellow eye. Dutch ranunculus-marigold; sulphur-colour. Red-topped clary; pale red, and pink leaves.

Fourth Range—from 2 to 2½ or 3 feet high.

Belvidere; yellowish—a handsome plant. Small variegated corn-poppy; various, red and white, &c. Double upright larkspur; blue, blush, &c. Cyanus minor; blue, crimson, &c. Thorn-apple; white, and singular pod. Prince's feather; dark crimson. Crown larkspur; pale pink, spotted, &c. Honey scabious; pale blue, and globular pod. Portugal lychnis; pale red. Small blue lupines; bright blue. Love-lies-a-bleeding; light red. Ranunculus-marigold; deep orange. Honeywort; dark purple. Strawberry spinach; bright-red fruit.

Fifth Range—from 3 to 4 feet high.

Venetian small-flowered mallow; purplish-white. Double crimson jagged-leaf poppy; dark crimson. Tall narrow-leaf wallflower; bright yellow. Arach; deep crimson. Double striped carnation poppy; red and white. Blue sweet trefoil; lead-colour. Red lavatera; light changeable red. Branching larkspur; blue and white, &c. Tall white lupines; clear white. Double black carnation poppy; rose-colour. Small Peruvian nasturtium; dark orange. Lord Anson's peas; fine blue. White lavatera; snow-white. Dwarf double and quilled yellow sunflower; deep yellow. Bladder ketmia; pale sulphur and purple eye.

Sixth Range—from 5 to 7 or 10 feet high.

Tall double yellow sunflower, with black seed; deep yellow. Painted lady sweet-scented peas; pale red and white. Arach; sulphur-coloured. Purple sweet-scented peas; dark and light purple. Tall Indian persicaria; bright crimson. Painted lady crown peas; black and white. Convolvulus major; fine purple. White crown peas; clear white. Large Indian nasturtium; dark and light orange. Tall double brimstone sunflower; sulphur-coloured. White sweet-scented peas; clear white. Plain Tangier peas; fine crimson. Tall oriental mallow; purple. Painted lady Tangier peas; pale red and white. Scarlet beans. Curled leaf, upright mallow; white, tinged with purple.'

Whether tender or hardy, all annuals should be carefully trimmed, and kept from straggling. Some will require thinning. Preserve the strongest blossoms for seed; and remove withered and imperfect blooms, to add vigour to those which remain.

Biennials.

The difference between biennials and perennials is in many instances very ill defined. A biennial is said to be a plant which, when sown, does not bloom till the following spring, and dies out in the course of autumn. This is true as respects some biennials, but it is equally certain that many will survive and bloom year after year, the same as perennials. For instance, carnations are called biennials, although it is notorious that these plants will grow and multiply by roots in the same spot, year after year, with only ordinary culture. Another circumstance requires notice. No treatise on gardening that we have seen sufficiently recognises the power which biennials and other plants possess of continuing themselves by dropping their own seeds on the spot where they grow; by which means, in point of fact, many biennials, and annuals also, possess much of the virtue of perennials. In all treatises, far too much stress is laid on the necessity of artificial propagation. In most instances, biennial and perennial flowering plants simply die off from the top to the bottom of the stems at the beginning of winter, and the roots remain dormant in the ground till revived by the warmth of the ensuing spring. Except, therefore, as respects thinning, and propagating by a division of roots, and transplanting occasionally for the sake of change of soil, the unprofessional gardener has little or nothing to do in the way of multiplying the number of his plants, or artificially keeping up the species during winter. Of course we here refer to gardening operations in the British islands, where the winters are generally so temperate, that every kind of root is safe in the ground, excepting certain bulbs, and those of a tuberous nature, such as potatoes, dahlias, ranunculuses, &c. which the frost would reach and destroy.

Among biennial plants suitable for ordinary flower gardens are included the following, each having several varieties:—Canterbury bells, carnations, French honeysuckle, globe thistle, hollyhocks, scabius, sweet-william, rose campion, wallflowers, lavatera arborea, purple digitalis, and stock gilliflowers. Some of these are very beautiful, and none more so than carnations.

The *carnation* is an elegantly-formed flower, with a slender stem and blossom at top, each blossom consisting of a convolution of petals like the rose. As a number of stems grow up together, the show of brilliant heads is considerable. There are many varieties of the carnation, but all are arranged in three classes—flakes, bizarres, and piquettees. Flake carnations possess but two colours, with large stripes through the petals. Bizarres are variegated in colour, with irregular stripes and spots. Piquettees have a white ground, spotted with purple or some other colour, and are serrated on the edges: they are the most common. According to amateurs, the finest carnations should have a flower at least three inches in diameter, with the edges of the petals waving or smooth, not serrated. The petals must fill the calyx, but not to bursting; if a calyx burst, the flower has been imperfectly cultivated. 'The calyx,' says Hogg, 'should be at least one inch in length, terminating with broad points sufficiently strong to hold the narrow bases of the petals in a close and circular body. Whatever colours the flowers may be possessed of, they should be perfectly distinct, and disposed in long regular stripes, broadest at the edge of the lamina, and gradually becoming narrower as they approach the claw of the petal. Each petal should have a due proportion of white, one-half, or nearly so, which should be perfectly clear, and free from spots. Bizarres, or such as contain two colours upon a white ground, are esteemed rather preferable to flakes, which have but one, especially when their colours are remarkably rich and very regularly distributed. Scarlet, purple, and pink, are the three colours which predominate in the carnation. When the pink flake is very high in colour, it is customary to distinguish it by the appellation of rose flake.'

The following, which we copy from an agreeable horticultural treatise, 'The Manse Garden,' are the plainest directions we have seen respecting the culture of carnations:—'The best soil for carnations is good loam, enriched with well-rotted stable dung, and quickened with a little sand. The quantity of manure can only be determined by the previous strength of the ground: if made too rich, the flowers will lose their fine colours; if left too poor, they will want vigour. No recent manure should ever come near a fine plant. Let the ground be prepared before winter with dung, and a rough furrow laid up to the frost. In April give a fresh digging, and plant in rows three feet by two. This width is to make room for layers, without which a fine blow of carnations cannot be maintained above one year. As the plants shoot up, they must be tied to neat green rods; and in order to have a fine blow, superfluous flower-buds must be pinched off, leaving only three or four to each stem. The young shoots near the ground, which do not run to flower, are denominated grass; and from these the layers are selected. The operation is somewhat nice, but when rightly done, is always successful, and good flowers are thus preserved and multiplied from year to year. Towards the end of July, stir up the ground about the plants, and mix with the soil a little old well-wrought compost. Have at hand a sharp penknife, a trowel, and a number of small pegs with an angle at the head: pieces of fern will do, or wood of no more strength than to bear pushing into the ground. Scoop out the earth in the form of a basin around each plant; select the strongest grassy shoots for layers, and remove such as are in the way; crop the top leaves an inch from the heart, and pinch off all the rest, taking care not to peel the stem. Begin an incision on the under side of the shoot, a little below the second joint from the top, and cut upwards till the joint is slit in the middle. Set the pointed extremity made by the slit into the bottom of the excavation, and there fix it with the peg; place the head of the shoot erect, fill in the earth, make it firm, and finish the work with a good watering. The young plants will be ready for removal by the end of autumn, when they may be set in flower-pots if the soil is too damp, and apt to cause rotting in winter; but if sufficiently dry, the layers may remain till spring, and it will be of use before winter to earth them up, sloping and beating the mould about them so as to throw off the rain. Although the propagation of this plant by pipings (as the grass shoots taken off and stuck in the ground are called) is by no means so sure as the above method, yet of a number some will take root; and as pipings are more easily procured than plants, the experiment may be made. If carried to some distance, steep the slips in water till they swell to their proper size; trim them as above directed, and set them firm into old elastic compost; water plentifully, and set over them a hand-glass, first throwing water on the glass, and then earth to darken it, and let it not be stirred for some days, it being found that a deficiency both of light and air promotes the striking of slips—probably on this principle, that the sick, having no appetite, must avoid the exertion which requires food as well as that which food requires.' We may add that carnations require room to expand and blow; and when fully grown, the stalks should be tied with a strip of bast to a small stake thrust into the ground at their side.

The *hollyhock* is a splendid flowering plant, and exceeds all others in tallness. With good soil, shelter, and proper exposure, it will attain a height of twelve or fourteen feet, and generally reaches seven or eight. It is a substantial herbaceous plant, with a thick stem, along which, to the top, are the broad showy blossoms; and from this attractive appearance it is very suitable to ornament fronts of cottages, edgings to shrubberies, or the centre of clumps in lawns. The colours are very various, as pink, dark purple, yellow,

&c.—the double sorts being the richest and most esteemed. The seeds of hollyhocks are sown in May; and in September or October the young plants are transplanted into the ground where they are intended to blossom. Although classed as biennials, the plants will spring and bloom for a number of years.

Wallflower.—There are several sorts of this fragrant plant, those flowers which are dark and most massive being most highly esteemed. Every cottage-garden should have two or three wallflowers, as their perfume is very pleasing, and their culture no way troublesome. 'To insure,' says the author of the 'Manse-Garden,' 'a succession of the best breed (and the method applies to the double flowering, which yields no seed, and cannot otherwise be preserved), about the beginning of July pinch off a hundred slips or young shoots of five or six inches in length, taken only from the finest stocks; crop the leaves, and strip the rest of the stem bare; dibble the slips so prepared into a bed newly dug, and shaded by trees or a north wall. Sprinkle them with water, and shade any part to which the sun has access. Not one will go back; and in this way a profusion of one of the sweetest flowers, and the best of its kind, may be had from year to year.'

From what are usually called biennials, we turn to the copious list of *perennials*, which may very properly be sectioned into those with bulbs, those with tuberous roots, and those with fibrous roots—the latter by far the most numerous, and including plants of a herbaceous and shrubby nature; to these may be added climbing and aquatic plants.

Perennials—Bulbs.

In this class are included the hyacinth, narcissus, iris, lily, tulip, snowdrop, crocus, and others:—

The *hyacinth* has a tapering bulb, shoots up long green leaves, and in the centre is a stalk on which the bloom, in the form of bells, grows all round, causing it to droop or bend. There are several varieties, differing in colour—as blue, red, and white; but the blue is the most common. The hyacinth is a favourite of the Dutch, by whom it has, like the tulip, been brought to great perfection. The best kinds have double flowers with brilliant colours. A sandy soil and saline atmosphere, with a warm exposure, are favourable in developing these properties. In the British islands they will endure the winter in the ground, and are among the earliest blossoming plants of spring. In Holland, the bulbs are lifted and carefully stored during winter.

Of the *narcissus* there are many varieties, which include daffodils, white narcissus, jonquils, and polyanthus narcissi. The chief difference is in colour and size of petals. Most have a lightish-yellow flower, with a deeper yellow cup. A fine narcissus has tall and firm leaves, and from the centre springs the round tube-like stalk, on the top of which is the bright yellow bloom, with petals spreading out like rays from a star. Some send up two flower-stalks; and the criterion of excellence is massiveness and distinctness of colour in the corolla. Of the polyanthus species there are at least a hundred sorts, sulphur-coloured, single and double, white, &c. Like hyacinths, the bulbs may remain in the ground during winter.

Of the *iris* there are various sorts, some low, and others tall, but all of them beautiful from the delicacy of colour. The Persian iris is low, with delicate blue and violet blossoms: the Chalcedonian is taller, and distinguished by the great size and magnificence of its flower, which is a purple-blue striped with white: the English is of still greater height, and has flowers double the size of the former. None requires much sun.

The *lily* is a plant equally tall with the larger iris. There are many species, with different colours—white, orange, and carmine. The orange, speckled with dark dots, is the more common. This plant will grow and bloom with little sun, or under the shade of trees. The effect of the orange blossom is pleasing among green plants which require to be set off by a contrast.

The *tulip* is the pride of the garden, or at least stands pre-eminent in general estimation. Like most other bulbs, it is a native of the Levant, and was brought to its perfection in Holland, where tulip-fancying was at one period a mania, and the bulb is still a large article of trade. The finest tulip-gardens are at Haarlem, which has a warm and saline climate, with a soil light and rich. Round the roots and over the beds sand is freely scattered, so that the tulips seem as if growing from a sandy beach. In planting in this country, follow the same practice. Before planting, take off the brown outer rind. Plant in October, or early in November, so that the plant will blossom in April. In forming a bed of tulips, the bulbs should be set at a distance of seven inches apart, and in straight rows, taking care to mix the different colours. To raise from seed, or to improve the varieties by crossing, are works of time, and not to be thought of in ordinary circumstances. Bulbs can be obtained from nurserymen at a price ranging from five shillings a dozen to five guineas a bulb. Half-a-crown each is a common price for tolerable bulbs; but of course all depends on taste. The following is Hogg's criterion of a fine variegated late tulip:—'The stem should be strong, elastic, and erect, and about thirty inches above the surface of the bed. The flower should be large, and composed of six petals: these should proceed a little horizontally at first, and then turn upwards, forming almost a perfect cup, with a round bottom, rather widest at the top. The three exterior petals should be rather larger than the three interior ones, and broader at their base: all the petals should have perfectly entire edges, free from notch or serrature; the top of each should be broad and well rounded; the ground colour of the flower, at the bottom of the cup, should be clear white or yellow; and the various rich-coloured stripes, which are the principal ornament of a fine tulip, should be regular, bold, and distinct on the margin, and terminate in fine broken points, elegantly feathered or pencilled. The centre of each leaf or petal should contain one or more bold blotches or stripes, intermixed with small portions of the original or breeder colour, abruptly broken into many irregular obtuse points. Some florists are of the opinion that the central stripes or blotches do not contribute to the beauty and elegance of the tulip, unless confined to a narrow stripe exactly down the centre, and that they should be perfectly free from any remains of the original or breeder colour. It is certain that such appear very beautiful and delicate, especially when they have a regular narrow feathering at the edge; but the greatest connoisseurs in this flower unanimously agree that it denotes superior merit when the tulip abounds with rich colouring, distributed in a distinct and regular manner throughout the flower, except in the bottom of the cup, which should be a clear bright white or yellow, free from stain or tinge, in order to constitute a perfect flower.'

In order to have tulips in anything like perfection, they require a vast deal of care. As strong sunshine injures them, they must either be placed in some shady situation, or covered with a slight awning from the sun's rays. They must also on no account be allowed to go to seed, for in that case the bulb is exhausted and done. To prevent this catastrophe, they should be watched when they approach perfection, and the head and stalk cut off. A usual signal for cutting is when they cease closing at sunset, or when the edges of the petals exhibit the slightest appearance of withering. They should be cut rather too early than too late. After cutting, admit the sun to the stems; and when these wither, which may be in June or July, lift the bulbs and lay them aside in a dry airy situation; there let them remain till the period for planting, which is the end of October or beginning of November. If the bulbs require to be sent to a distance, twist each separately into a piece of paper; in this state, and kept dry, they will remain dormant, yet fresh and ready for planting, for several years.

The *crocus* and the *snowdrop* are two small bulbous plants, so well known for their hardy growth, that little need be said of them. Crocuses are very various in colour—blue, yellow, white, and so forth; and the principal thing in planting is to dispose these colours in a pleasing variety. When the bloom withers, remove it, but do not cut away the numerous small green leaves. Crocuses, like other bulbs, require occasional transplanting: this may be done in October.

Perennials—Tubers.

In this group the *Dahlia* (named from Dahl, a Swedish botanist), both from its beauty and size, deserves the first place. It is a native of the temperate plains of South America, and requires a dry and airy situation for its growth. The tubers at the root resemble long potatoes, and as they spread to some distance, the plant should have a free space of from two to three feet all round. The stems, at and near the top of which are the rose-like blossoms, rise to a height of four feet, and require to be supported by stakes. A new plant may be procured by separating a part of the root, to which a stem is attached. Frost at once blights the green stalks; and when these seem utterly withered and dried, carefully lift the tubers and place them in a dry situation for the winter. In May they must be sprung on old manure under a glass frame, and then planted out and occasionally watered. Dahlias are now found of almost every colour—the *Acmé*, a white variety edged with crimson; Amanda, rosy lilac; Ariel, white and lilac; Augusta, purple; Countess of Liverpool, scarlet; enchantress, creamy-edged cherry; Lord Althorp, dark puce; yellow perfection; peerless white; and so on—every year adding its novelty.

The *ranunculus* is a stock beauty in all gardens, and it has some hundreds of varieties. The tubers are small, and require to be treated like those of the dahlia. The blossom resembles a compact small rose of a flattish form. The soil in which the plants are placed requires to be fine and in good heart. In planting ranunculuses and dahlias, the colours should be arranged so as to produce an agreeable variety.

The *marvel of Peru* is a very fine tap-rooted plant, rising to a height of two or three feet, and bearing beautiful transient flowers, differing in colour, as pink, white, and yellow, according to varieties. There is a succession of blossoms daily, the old ones dropping off and a new set advancing. In its native climate, the blossoms do not open till after the heat of the day is over, about four o'clock; the plant is therefore viewed as a kind of time-measurer, and is sometimes called the *West India four o'clock*.

Fibrous-Rooted Perennials.

The genera, species, and varieties of flowering plants with fibrous roots include the greater part of vegetable productions. A few of those most prized are all we need notice. Take, first, the humble *daisy* (day's-eye), which has been cultivated up from the wild *gowan* or daisy, the 'wee modest crimson-tipped flower,' and is now found in two principal varieties—the mottled crimson and white, and the pure crimson. This plant is the hardiest of the herbaceous tribe, keeps longest in bloom of any, and may be propagated to any extent by simple separation of roots.

Pinks are another universal favourite; they may be viewed as an inferior kind of carnation, and are divided by florists into the three classes—damask, cobs, and pheasant's-eye. The criterion of a fine pink is clear white petals, laced with crimson-purple, and finely serrated on the edges. The branches of stalks require tying to stakes; and they should be cultivated, so as, if possible, to avoid bursting the calyx.

The *primrose* family includes several pretty flowering plants—all, as is believed, sprung and cultivated up from the wild primrose (*primula vulgaris*) and cowslip. There is no great beauty in the primrose as a garden plant, but it is useful as an early spring flower, and succeeds the crocus in giving colour to the borders. The highest cultivated of the race is the *polyanthus*, which sends up stems loaded at top with a bunch of peduncles brown, red, and yellow. The colour most admired is that shaded with a light and dark rich crimson, resembling velvet, relieved by a bright golden hue. The *auricula* (*primula auricula*) is a larger plant, but varying in colour, and more delicate in many respects. It flourishes best in rich soil from old turf and rotted cow-dung. The chief colours are red, pink, crimson, white, blue, apple green, and mulberry. On the petals there is a fine meal, which is injured and marked by drops of rain or artificial irrigation; and therefore flower fanciers take care to shelter the plants with frames, and allow no drops from the watering-pot to touch them. When treated with attention, a bed of auriculas may be rendered very beautiful.

The *anemone*, when double, is a pretty flower, with a number of flattish petals forming a cup, in the centre of which is a great number of long small petals clustering over each other. The *lobelia*, in its different varieties, is a fine tall showy flower; that which is most common is the cardinal flower, with splendid scarlet blossoms. The *lychnis* is another pretty scarlet flower, but small in size. The *sweet-william* is deserving a place in every garden; it may be had of various colours, shading from deep crimson to light pink. The *campanula*, or pyramidal bell-flower, in its different varieties, blue and white, is a graceful flower, with pendant bells, which should also be found in all tastefully laid out borders. It may be kept long in flower, by cutting off the blooms as soon as they begin to wither. The large herbaceous *peony*, with its brilliant and deep crimson disk, is another choice flower; it requires little care beyond supporting with stakes.

The *violet* family, which now embraces what are termed *heart's-ease* and *pansies*, is a cultivation from the original wild violet (*viola odorata* and *viola tricolor*). By the French, the cultivated violet or heart's-ease is called *pensée* (thought); hence our name *pansy*. No flower in the garden has lately engaged so much attention as the heart's-ease; and by means of culture and hybridising it has attained a most extraordinary degree of perfection as respects size and richness of colour. We cannot do better than offer the following intelligible directions on the subject from Harrison's 'Floricultural Cabinet':—'The most approved method of propagation is by taking off young slips in the autumn, which is the best time, as then the ground and weather are most suitable for the formation of rootlets, on account of its dampness and dulness. About the first week in October a bed is prepared of light but rich soil, raised a little above the path, in order to drain off all superfluous moisture. The cuttings are then made ready, by stripping them of their under leaves, and cutting close below the bottom joint, from which the roots must spring; for if this is not done, the cutting will decay to that joint, which frequently destroys the whole. After the bed is prepared, the cuttings are arranged according to their varieties, each sort being marked by a tally-stick, numbered or named according to the pleasure of the owner. The cuttings will be found to be well rooted in about six weeks, when they may be planted out for blooming in the spring, or potted to keep over winter in a frame.

The soil in which the pansy is found to flourish best is a compost of cow-dung one-half, fresh loam one-quarter part, leaf mould one-eighth part, and coarse sand one-eighth; but peat soil should on no account be intermixed, as it burns up the pansy completely. These ingredients should be well mingled together, and purified from worms and slugs by having lime-water frequently thrown over the heap, and in a short time it will be fit for use. The situation best adapted for the heart's-ease is one which is sheltered from the mid-day sun, but which receives a little in the morning, as it is then not so powerful as to injure the colours. Transplanting may be performed at any season, but in doing so an error is prevalent. We see the plants taken up with a ball of earth around them, and planted again with it. Now, as everything deteriorates the soil in which it grows, and as the pansy entirely pierces every particle of earth its roots can reach, therefore that which we take up with it must be entirely exhausted. When replanted, the pansy can receive very little food from its new situation, as its roots do not by nature struggle far from the stem. To prevent this starvation, it would be much better to wash away all the soil from the roots, and replant the flower with its roots unconfined; then it would be able to seek food for itself abundantly, and thereby produce much larger blossoms.

The following list contains some of the best varieties in cultivation:—Argo, Augusta, Anne Eliza, British Queen, Colonel Dundas, Captivation, Dandie Dinmont, Eclipse, Feronia, Haidee, Henrietta, Imogine, Jewess, Livia, Laura, Magnet, Miss June, Miss Towers, Paul Pry, Peter Dick, Platonia, Penelope, Queen of the Whites, Reliance superb, Triumph, Victoria superba, Wycomb Abbey, Westminster Abbey, Windsor Castle, White Perfection, Liberal, Acme of Perfection, Ringleader, Revenge, Victory, Miss May, Glory of North Durham, Beauty of the Wear.' To this we may add the Fair Maid of Perth, and Lord John Russell.

Shrubs—Evergreens.

Among these the *rose* unquestionably deserves the first place, having from time immemorial been a favourite in every garden. There are some hundreds of species and varieties of roses, among which are included China roses, hardy climbing roses, moss roses, select double Scotch roses, red and white roses. The China rose is delicate, with few petals in the flower, and yields a succession of blossoms monthly through a great part of the year; it is hardy, and is green and flourishing in winter. Among red roses, the moss rose is the most beautiful, and next it may rank the cabbage rose; but both are excelled in fragrance by the leaves of the *sweet-brier*, a rose shrub, which, for the sake of its delicious odour and hardy green leaves —a thing of moment in making up a bouquet—should have a place in every garden. All kinds of rose-bushes are exhaustive of the soil, and should be frequently manured, if not transplanted to fresh mould. In order to keep them in bloom, cut off all blossoms which seem about to wither. The branches require careful pruning. For adorning the walls of summer-houses, cottages, &c. the *honeysuckle* excels, and should, both for its beauty and fragrance, by all means have a place in every garden, however humble. The honeysuckle is a *twining* plant, and has a tendency to climb in a spiral direction from right to left, which requires to be accommodated. The *hop*, which is sometimes grown in gardens, and allowed to climb on tall poles, twines in an opposite direction, or left to right, or with the sun, and this peculiar tendency also must not be frustrated, but assisted by strips of bass. In point of massiveness of green surface, the honeysuckle is surpassed by the *jasmine*, a tall running shrub, growing up in numerous branches, which, being well covered with small narrow leaves, is very suitable for leading up to verandas or concealing pieces of wall. It does not adhere, and requires nailing; when carefully treated, its massive green and elegantly-drooping small branches have a pleasing effect. *Ivy*, the most pertinacious of climbing plants, will grow almost anywhere, and only requires pruning to keep it within bounds every winter or spring.

Among the various tall bushy shrubs most appropriate as an ornamental background in gardens, are the different species of laurustinas, azaleas, rhododendrons, and lilacs. The *laurustina* yields a plenteous crop of small variegated blossoms. The *arbutus* is likewise a beautiful shrub, but more suitable as an embellishment in lawns; it has small whitish bell-shaped flowers, and yields a strawberry-like fruit in warm exposures. Perhaps all out-of-door exotic shrubs should yield the palm of beauty to the *ribes sanguineum*, a plant profusely adorned with small red blossoms, which appear in spring. It resembles the common currant, and matures its berries in our climate.

Evergreens constitute a class of shrubby plants, more suitable for the ornamental front-plots of dwelling-houses, or for approaches and lawns, than for gardens; because although the green of the leaves is pleasing in winter when other vegetation is dead, these plants are very exhaustive of the soil; often prevent the sun from getting to the borders; and keep the ground in a litter with fallen leaves at a time when trimness is expected. Many species of evergreens are now cultivated in gentlemen's grounds; but those which are most generally esteemed for ornamental plots or other limited situations, are the various tribes of *laurels*, *alaternus*, *arborvitæ*, *holly*, *juniper*, and *box*. With proper care, any of these may be lifted and transplanted into situations more agreeable to the eye, either at the beginning of September or May, when young shoots are preparing to burst forth. The plan is to dig all round them, at a distance equal to the compass of the branches, sinking the trench to a point beneath the sole of the plant; then lift them bodily with the whole mass or ball of earth round the roots. A pit must be prepared for the reception of the ball, and when placed in its new situation, fill in the rest of the pit with fine earth, laying the rootlets straight, and packing in all neatly to the surface. A copious stream of water must now be poured from a watering-pot upon the newly-placed mould, round the stem; this carries the particles of earth to the rootlets, surrounding each with its proper nourishment, and giving solidity to the whole. If likely to be exposed to winds, the plant should be supported till thoroughly rooted in its new abode.

Concluding Remarks on the Garden.

The preceding are the principal flowering plants, annual and perennial, herbaceous and shrubby, usually grown in open gardens in Great Britain; and we now wish to impress on the minds of the unprofessional flower-culturist three main principles which should govern his labours:—1. Let him, by every reasonable attention to soil, culture, and other circumstances, endeavour to produce the finest corollas of which any given flower is susceptible: 2. Produce these flowers only in their proper season, and throw away as little time as possible in forcing blooms at unnatural periods: 3. To maintain a garden as far as possible in continual beauty, try to keep up *successional variety*, for in that is exhibited the experience and foresight of the gardener. The directions given in the foregoing pages, and in the floricultural calendar appended, it is hoped will assist in leading to this arrangement, on which so much beauty depends; and as a farther aid, we offer the following hints furnished by a correspondent to the 'Gardeners' Chronicle:'—' It is the desire of every one who possesses a garden, to have as much variety of colour and succession of gaiety throughout the season as the situation and means of the possessor can accomplish; yet in viewing most gardens, even where expense is not an object, borders devoted to the cultivation of particular plants may frequently be observed to be attractive only when such plants are in blossom, and looking bare, if not unsightly, after the bloom is over. Supposing equal skill in the cultivation of plants in general to exist among gardeners, the great superiority in effect of one garden beyond another consists in the distribution and arrangement of the plants themselves, so that a succession of blossom, and a due contrast of colour should, where practicable, keep every border furnished even to the end of autumn. In this respect most gardens are deficient. Succession is not attended to, except for the more limited space and favoured spots near the mansion, or in front of the conservatory. In most gardens it is considered sufficient to keep any border where plants have blossomed free from weeds and neatly raked. To the mind of the gardener this border tells its own history, of the beauty of which he had boasted but a few weeks since; but the visitor or casual observer who walks through the garden, only seeking to please his eye with varied gaiety, makes no allowance for the past which he has not seen; and remarks, that though some parts are beautiful, a great portion of the ground has nothing worth looking at.

By the subjoined method, the comparative gaiety of the scene may be kept up, and a relief to the eye, not without interest to the observer, preserved. Mix the seeds of the following well-known annuals:—

Mignonette,	Heart's-ease,
Carnation poppy,	Clarkia pulchella,
Papaver amœnum,	Do. white,
Dwarf Dutch poppy,	Godetia of all sorts,
French poppy,	Antirrhinum majus,
Branching larkspur,	Do. sparteum,
Eschscholtzia Californica,	Do. versicolor,
Do. crocea,	Collinsia bicolor,
Campanula speculum,	Coreopsis tinctoria,
Candytuft, varieties,	Convolvulus minor,
Nasturtium,	Gilia tricolor, and other species.
Centaurea Cyanus, various.	

Then let this mixture of seed be very thinly scattered upon the borders early in the spring; it need not interfere with any ordinary work on the borders that may be required afterwards; and in places where the ground may be disturbed, many of the seeds will only appear at a subsequent period, and consequently flower later in the autumn. Most of these annuals will continue flowering until the frost kills them, and if not removed too soon, will leave behind them sufficient seed for years to come. Every gardener has remarked the strength, the beauty, and the effect of single plants of self-sown annuals that spring up occasionally in a flower-border, and have escaped that destruction which the merciless hoe, in the hand of the undiscriminating labourer, inevitably entails upon them; yet if the intelligent labourer is properly instructed, he will soon learn to confine his extermination to weeds, and his skilful eye will spare the annuals at proper intervals.

One case yet remains of much consequence to present as well as to future effect, though generally but little attended to: this is the frequent examination of all annuals as they expand their first flowers, and the pulling them up, unless in habit, form, and colour, they are fit to remain for stock. Crowded as annuals generally are in the patches sown in gardens, their true character and beauty are seldom seen; and if among the mass sown some few blossoms appear more striking than the rest, and the seed of these is considered more worthy of preservation, it is generally too late to take away the worthless without destroying the plants most desired; and the seed so saved from the most select variety is but little better than that from any of the other plants.

The system now recommended gives the advantage of separation and a power of selection, with the certainty that a selected plant will, by its position as a single plant, not only blossom in beauty and vigour, but afford that abundant harvest of good seed which will amply repay in future years the trifling care thus proposed to be bestowed upon it.'

Garden-Walks.—In the previous sheet on the KITCHEN GARDEN we recommended walks to be three feet broad, laid with gravel, bedded on hard cinders, and edged with dwarf-box. As an improvement, some place a bed of stones beneath the cinders, or at least the upper gravel, and on this point all must, less or more, be governed by circumstances. Where it can be afforded, asphalte pavement may be employed instead of all other materials. In the neighbourhood of London, where fine yellow Kensington gravel can be obtained at little cost, it is largely employed, and forms a beautiful walk, the yellow contrasting finely with the green of the plants. On the subject of garden-walks and borderings, the author of 'The Manse Garden' offers the following recommendations, in which we unite:—' In making walks amongst shrubs and flowers, dryness and variety of edging are the chief things to be promoted—there not being here, as along a fruit wall, for the sake of the trees, any scruple as to the burying of stones, and there ought to be none as to the trouble of a two-feet excavation; for every cart-load of earth so saved is worth money, and the convenience of depositing stones in place of the earth will save a great expense of carriage. Box, though tiresome, if there be no other, is by far the best edging for general use; but the planting of it is often bungled, or done at a needless expense. Take up with a spade a portion of the edging that has grown too old, and part the roots: one yard of the old will serve for ten of the new—a supply that is not obtained from the nurseries without cost. In parting, tear all the old bush down into the smallest shreds; throw away every one that is thicker than a crow-quill, and cut off all the roots beneath the uppermost tier of fibres; a single fibre is enough; with none the plant may do, but it is not necessary to try it. The plants so trimmed should be about four inches in length. Having filled the excavation with stones, all to four inches left for gravel on either side of the walk, dig the surface, set the line to a nicety, using many pins at every turn, to make the windings easy; bring the level exactly to the line, and beat all smooth and firm, so that the earth may stand cutting. With a trowel, cut by the line to the depth of three inches, pulling the earth towards the walk, and lay the green tops of the plants to the line, setting their heads above it, not more than one inch, and all touching one another. The roots will vary a little in depth, but let a few plants be held exact at the top with one hand, whilst the earth is applied to the unequal roots with the other. The reverse rule of evenness, providing for the roots and not the tops, is frequently adopted; hence the straggling appearance that ensues—some leaning out, and others in; some set like a tree, having a stem from which branches proceed, and others having branches sunk up to the middle. Box may be planted in September, October, or November; in February, March, or April. To wet clay, brought up by new trenching, coal-ashes may be added; and to avoid rotting by moisture without growth, the plants may be set in May.

For other edging, sea-pink is very good, but it soon gets deformed with blanks, unless taken up and replanted: whereas box, annually clipped in autumn, will serve for the half of a lifetime. London-pride admits of paring, and will last for five years; coarse polyanthus or primrose does well beneath trees. Should the root of an old tree come in the way, it is easy to keep up the green line by planting periwinkle, which needs little soil, or ivy at some distance, and leading the runners past the tree, where they will take root all the way, and being clipped, make a handsome appearance. The propensity of ivy to run up the tree is easily counteracted; but should it be indulged, few things are more beautiful, and the tree is there rather for ornament than for the value of its timber. Double-daisy and cowslips may be used, and may be kept any length of time by occasional lifting and parting of the roots. Hepatica, blue and red mingled, make a beautiful edging, and will last an age: but the most brilliant of all is dwarf gentian; it lasts long, but must have half a foot in breadth, to secure plenty of its bright sky-blue flowers. The pansy or tricoloured violet is also fine, but must be replanted every year. For any place where the walk gets amongst high shrubs or trees, or where a sloping bank is of difficult keeping, there is nothing so fit for a low hedge as butcher's-broom; it suffers no injury by drip or shade, and grows immovably strong; and not agreeing with the shears, it is in such a place more suitable in the natural sluggishness of its growth.'

PLANTS FOR THE GREENHOUSE, &c.

These are of various kinds, both herbaceous and shrubby, and require to be distinguished from the preceding only because they are exotics, too delicate for open-air exposure in all weathers, and require to be kept in a temperature above the freezing-point. This is done by placing them in a conservatory or greenhouse, which is a light fabric, covered with glazed frames, and, if necessary, heated a slight degree in winter by means of flues or pipes of hot water. The most approved situation of a greenhouse is against a wall with a southern exposure; and, if possible, placed in connection with a range of artificial vineries or hot-houses. In many instances a conservatory is connected in a very agreeable way with the parlour of a dwelling-house, by which its beauties are enjoyed without the trouble of going out in bad weather or during the inclemency of winter. All the plants are in pots; and whenever it can be done without risk of injury, the frames are opened, and free exposure permitted. At the country seats of various English noblemen conservatories are formed on a magnificent scale, so as to allow the free growth of even tall trees, such as the palm and other large tropical plants.

The most beautiful greenhouse flowers usually cultivated are camellias, geraniums, fuchsias, orchids, and those of the cactus tribes, to which has lately been added the *Azalea Indica*. The camellia, or *Camellia Japonica*, is a woody shrub, yielding splendid rose-like flowers, of colours varying from white to red. The geranium is a well-known herbaceous exotic, with clustering bunches of flowers of different colours. The fuchsia, introduced from Chili, is a handsome shrub, of different varieties, yielding exceedingly beautiful flowers, of a bright crimson hue; and the manner in which these flowers depend from the branches, like drops of ladies' earrings, has a singularly graceful effect. The cacti are an interesting kind of exotics, distinguishable by their thick and substantial leaves or fronds, on which usually grow small and sharp prickles; the flowers are splendid. Besides these, we may enumerate, either for their great beauty of blossom or fragrant odours, the nerium, jasminum, gardenia, daphné, heliotropium, acacia, mimosa, eucalyptus, diosma, gnidia, xeranthemum, bignonia, passiflora, amaryllis, gladiolus, and calceolarias; the latter very beautiful, and suitable for open air in summer.

An airy parlour or drawing-room, with windows facing the sun, may be considered a domestic greenhouse; and these apartments, as is well known, may be furnished with flowering plants, which will bloom and thrive if certain precautions be adopted. Flowers of nearly every kind may be thus treated, and made to form an elegant ornament, and means of delightful recreation in a dwelling-house. According to their nature and size, they are planted in earthenware pots, or small wooden tubs or boxes, filled up with the appropriate mould, which requires occasional renewal, at least in part, with the removal at the same time of the outer rootlets. Bulbous plants will grow and blossom in glasses filled with water; but the plants are necessarily weakened by the process. The glasses should be dark-coloured, for roots are injured by light.

On the subject of the cultivation of flowers in windows we find the following useful observations in the 'Gardeners' Chronicle:'—'The three principal things requiring consideration are *air*, *light*, and *moisture*. Plants kept in windows naturally extend their branches and leaves to the light, and they thereby become one-sided; and it is wrong to endeavour to make them otherwise by frequently turning them, as the plants will as constantly turn their growth to follow the light, which not only weakens them, but spoils their appearance. As for plants receiving no perpendicular light, it is more natural to spread them out, forming one good face or tier of healthy foliage to the window; for well-balanced heads under such circumstances are almost out of the question. Place them as near the glass as possible; of course windows having a south aspect possess the greatest advantage.

Judicious watering of plants in rooms is perhaps the most important feature in their management; and it is unfortunately in most cases ill understood, being too often given mechanically, as it were at stated times, whether required by the plants or not; and by a too eager desire for their welfare, they are frequently surfeited to death with water, which is justly termed "killing by kindness," and is practised with success, especially by ladies, from a false apprehension of their wants. In summer, this cannot be easily accomplished, unless the plants are allowed to stand in saucers constantly filled with water, which, by overloading them with juices, will soon engender sickly soft growths, unsuited for the production of flowers or healthy foliage. An exception to this rule is the growth of annuals in pots during summer: they, if well drained, may stand in feeders; but these, whenever used, should be half-filled with fine gravel or sand, which may be kept in any state of moisture. The best and only general rules that can be adopted are—in *winter*, keep plants not then growing fast rather dry; in *spring*, increase the quantity with their activity and the sun's power, keeping them in a medium state of moisture; in *summer*, water daily; and in *autumn*, decrease with the length of day and the returning torpidity of the plants, until the dry state of winter is again reached. All this resolves in the following:—Plants, when growing fast, may have free supplies of water, which must be lessened as their growth approaches maturity, and cease, or nearly so, when that is attained, until the return of their growing season. As regards *air*, similar rules to those given for watering may be followed; and indeed they are analogous. In *winter*, when the plants are not growing, large supplies of air are not so important, enough being usually given by the room door. As *spring* advances, increase the quantity, carefully guarding against the cold of mornings and evenings, or cutting winds; and if the plants are placed out in the middle of fine days, take care to bring them in before the chill of evening comes on. After the first or second week in May, they may be set outside for the summer; and towards the end of September, or as soon as heavy cold rains occur, they should be placed again in their quarters for the winter, setting them out of doors when fine, or supplying them with plenty of air by the window, until the cold weather and decrease of moisture at the roots bring them to a state of comparative rest. It should be remembered in spring and autumn that the plants must not go out to-day because they were placed out yesterday, but the weather alone must determine: sudden changes must at all times be avoided. The leaves of plants act as lungs, by which they breathe; if they become dirty, their respiration is impeded; therefore an occasional careful sponging will be useful to them. In spring and summer allow them the full benefit of genial showers, which will do them more good than any artificial watering. Never use spring water if soft or rain water can be had; and always let it be about the same temperature as the air in which the plants are growing. It should hardly be necessary to mention the removal of decaying leaves and flowers; the last are exhausting as well as unsightly.

One principal potting is usually required, and afterwards as often as the plants may fill their pots with roots, or seem to require it. The most important thing is good soil, which, if composed of three parts loam of a fibrous open texture, with a fourth dung, most plants will thrive in, using plenty of drainage to allow water to pass off readily. Never suffer the surface-soil in the pots to become hard or moss-grown, but let it be loosened occasionally with a piece of stick.

Succulents are well suited for growing in rooms, as they are not so impatient of either air or water as most other plants; and the abundance of their beautiful flowers renders them objects of interest. Cactus speciosus, Jenkinsonii, flagelliformis and speciosissimus, mesembryanthemums, and flowering aloes, deserve especial notice.'

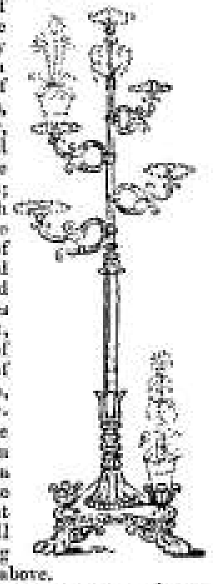
To the foregoing is added the following list of flowers for pots, with the period of their blossoming:—'*Spring*.—Snowdrops, Russian violets, early tulips, crocus, narcissus, hyacinths, heart's-ease, mignionette, mimulus, moschatus, ranunculus, anemone, myrtle. *Summer*.—Pelargoniums, mignionette, ten-week stocks, China roses, double wallflowers, pinks, carnations, cactus, aloes; annuals, as nemophila, schizanthus, collinsia, &c.; myrtle, heliotrope. *Autumn*.—Pelargoniums, lobelias, campanulas, salvias, hydrangeas, verbena, fuchsias, petunias, calceolarias, myrtles, heliotrope. *Winter*.—Chrysanthemums, pelargoniums, heliotrope, myrtles, fuchsias, aloes, cactus.' We mention the preceding as suited for open pots; but there are many others of long and well-established repute to be had from ordinary greenhouses, or even in slips from private cultivators.

All that is necessary for successful in-door culture is attention to the general directions previously given. If plants have sufficient air, light, warmth, and moisture, and be potted in proper soil, nothing else is needed, save a little care in keeping them clean, occasionally stirring the upper portion of the soil, turning them regularly to the light, loping off old wood, pruning unseemly shoots, and removing decayed leaves. It may sometimes happen, notwithstanding all ordinary care, that a few, such as the pelargoniums, may be infested with small green insects, or may otherwise take disease and languish. The former are generally destroyed by a sprinkling of powdered lime, the fumes of tobacco or sulphur, or even, where the nature of the plant will admit, by a thorough drenching with pure water. Disease is almost always the result of inattention, of too much or too little water, of confined pots, or of forcing into unnatural growth, and can only be remedied by recurring to proper treatment; such as removal into larger pots, a supply of new soil, cutting asunder and replanting matted roots, or by giving small doses of active manures, as nitrate of soda, ammoniacal water, liquid guano, and the like. When slugs or other vermin infest the soil in which plants are grown, the above manures will in general kill them; if not, a drenching with lime-water—allowing it to pass off through the holes in the bottom of the pot or box—is sure to prove effectual, the same time that it is likely to add to the vigour of the plants.

Another direction to be borne in mind is, never transfer a plant from one situation to another of a widely different character without some previous preparation. Vegetables no doubt possess wonderful powers of accommodation, but there is a limit to this principle; and a plant reared in the hothouse will no more endure the exposure of an open pot, than the animals of India could live and propagate in Iceland. Thus many of our rarest exotics are permanently injured by sudden removal from the stove to the open stand, or from the open air and conservatory to the drawing-room. Plants intended for transferences of this kind should either be taken at the period of their repose, or immediately before their breaking into blossom, if their flowers be the object in view. For example, is it wished to bring some showy orchid from the stove to the drawing-room, it ought to be kept as dry as its actual wants will permit some time previous to its flowering, and to be removed to its destination as soon as the first flowers make their appearance. On the other hand, it should not be returned to its original destination till the flowers have withered, and even then not till the soil has become pretty dry.

Pots and Stands.

Since the main object of domestic floriculture is to improve the taste for what is lovely and ornamental, it should be the aim of all growers who can afford the outlay to procure pots of as handsome shapes as possible. The common earthenware pot is often very clumsily made, though not of itself an inelegant object; but others may be constructed with ornamental mouldings in relief, or in the form of vases, urns, and the like, which would add greatly to the grace of a flower-stand. Pots may also be constructed of stone, of polished slate, as recently manufactured by Mr Beck of London, of cast-iron, wood, and the like, and in highly elegant fashions, either to be set on plain shelving or on ornamental stands. Elegance, however, does not consist in exuberance of ornament; the plainer often the better; and correct taste will avoid all grotesque and fantastic shapes—such as representations of plants and animals in postures and situations in which they are never to be found in nature. There is an endless variety of pots; some intended to afford better drainage than the common sort; others by being double—that is, a pot within a pot, and the space between filled with water—to afford a more equable supply of moisture; and many whose main object is display and ornament. Whatever be their form, the amateur should remember that gardeners do not speak of flower-pots as large, middling, small, or very small, but distinguish them by numbers, thus:—The smallest ones are called *thimbles*; the next *sixties*, which are 3½ inches deep, and 3½ inches wide at top; *forty-eights* are 4½ inches deep, and 4½ inches wide at top; *thirty-twos* are 5½ inches deep, and 5½ inches wide at top; *twenty-fours*, 6½ inches deep, and 6¼ inches wide at top; *sixteens* are 8 inches deep, and 7½ inches wide at top; *twelves* are 8½ inches deep, and 8½ inches wide at top; *eights* are 9 inches deep, and 9 inches wide at top; *sixes* are 10 inches deep, and 10 inches wide at top; *fours*, 11 inches deep, and 11 inches wide at top; *twos*, 12 inches deep, and 12 inches wide at top—all inside measure. It must be remembered, however, that these dimensions vary more or less in the formation of what are called *flats* and *uprights*; the former are of greater diameter than depth; the latter of greater depth than diameter; but all are made to contain nearly the same quantity of soil.

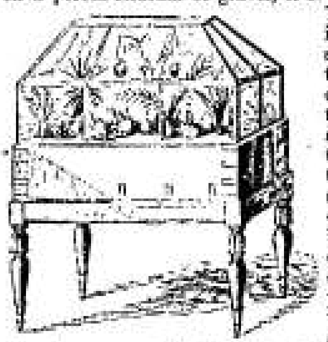


Stands are commonly made of wood or cast-iron; but we have also seen very cheap and pretty ones constructed of a wooden upright, with suspension arms of stout iron wire. Wooden ones, with plain shelving, of circular, or semicircular, or quadrantal forms, make very handsome stands for recesses and corners; those on single uprights, with branches for the support of the pots, are usually constructed of iron wire, or of cast-iron bronzed or painted, and are best adapted for central situations in lobbies and drawing-rooms. It may not, however, be in the power of some to procure flower-stands of either description; and for such, one board placed in the window-recess, so as to bring merely the top of the first row of pots within influence of the light, and a second level with the top of the first pane, will make no inelegant display; the effect of which will be heightened by suspending some light pots from the lintel above.

Of plants for suspension, a great variety can always be easily obtained, and as easily nurtured. Some require to be grown in pots, and watered; but many will send down their graceful pendants and blossoms for years with no other supply of moisture than what they absorb from the atmosphere. Indeed, a number can be grown without the aid of soil; a wet rag, a ball of moss, or of fresh turf, being the only protection their roots seem to demand. Pendant plants form very handsome appendages to a dwelling apartment, and no amateur should be without a variety to grace his collection. Of these may be mentioned, as worthy of adoption, saxifraga sarmentosa, linaria cymbalaria, fuchsias radicans and decumbens, Russelia juncea, lantana sellowiana, the epiphyllous sorts of cacti, ferns, lycopodiums, &c.; and with a little management, the prostrate verbenas, lobelias, and mimuluses, the trailing mesembryanthemums, with campanula rupestris, fragilis, hirsuta, and a multitude of plants which resemble them in their habits. Even some annuals, flowered in early spring, as nemophila atomaria and insignis, nolana atriplicifolia, &c. create a good display when suspended in pots; and many of the tender creepers hereafter mentioned (p. 541) may be trained pendant as well as erect,

Ward's Cases.

It may happen, from the vitiation of the air in towns, and in dwelling apartments, or from other circumstances, that it is impossible to grow the plants we most wish in open pots. To remedy this, a plan was some years ago devised by Mr Ward, a surgeon in London, of keeping the plants under close glazed frames, in which situation they grow and flourish in perfection. These frames are generally known by the name of Ward's Cases, and may be seen in almost every large town, constructed of every shape and size, according to the taste or means of the grower. By aid of these, any one, whether inhabiting the most humble or the most splendid dwelling, provided it be freely exposed to the sun's light, has it in his power to cultivate a miscellaneous collection of plants, at an expense so trifling, as to be within the reach of the most moderate circumstances. One of these cases, of a very complete structure, is represented, with its collection of plants, in the following figure. On the stand or table is a strong box, lined with zinc or lead, and filled with well-moistened loamy soil, underlaid by a thin subsoil of turfy loam, and this resting on a porous stratum of gravel, or broken earthenware.



This composition is meant to represent a natural fertile soil, which it does to perfection, the water lodging among the gravel till the wants of the plant in the superior mould require it. Over this box is placed a close-fitting glass cover, which completes the apparatus. The lighter and thinner the glass frame, and the finer the glass, the better are the plants exposed to view, and the more readily to receive the sun's light. This plot of soil, with its glazed framework of air above it, forms a little world of itself, in which the plants grow and flourish. When the moisture of the soil within is vaporised by the heat of the sun, it collects on the inside of the glass, and trickles down again, so that the plants are never subjected to irregular or capricious watering, while their own respiration and decomposition of water afford them nearly all the atmosphere they require. The case, however, is not absolutely air-tight; if it preserves a certain regular amount of moisture, warmth, and air, the while it excludes dust, soot, smoke, and other noxious fumes, it does all that is required. It must be evident that a Ward's case may be of any size or shape. It may be made like a lantern or bell-glass, to cover a single plant, or large enough to become a domestic conservatory.

Cases of the kind described may be used either for in-door or open culture; and answer as well for a little front plot, or back-court, as for a drawing-room. They can be also conveniently put up in balconies, or even over the entire window, so that the panes may serve for one side of the conservatory. Many such are now to be seen in our large towns, even in the smokiest and least inviting quarters. This sort of double window, if we may so speak, is admirably adapted for tall plants and flowery shrubs, or for suspending pots, and is altogether a very pretty annexation to a dwelling. Lofty and partially close cases of this sort are fitted for almost every species of greenhouse plant; but the moistened and shaded atmosphere of a small and closely-fitted case is destructive to flowering exogens. Plants of a succulent nature, and especially those having fleshy leaves, like the cactus and aloe, and all natives of damp and shady situations, grow and bloom in them to perfection. Among these are many lovely and rare plants, which will amply repay the attention of the case-grower, such as the melocactus, mammillaria, echinocactus, opuntia, epiphyllum, rhipsalis, and other varieties of cactaceous and epiphyllous genera; the aloe, cycas, agavé, cereus, side-saddle flower, Venus's fly-trap, sun-dew, nepenthes, lycopodium, &c.—all remarkable either for the beauty or peculiarity of their habits and structures.

Rare exotics need not, however, be sought after. 'The plants to furnish it,' says Mr Ward, 'can be procured abundantly in the woods in the neighbourhood of London. Of these I will mention a few. The common ivy grows most beautifully, and can be trained over any part of the case, agreeably to the pleasure of the owner. The primroses, in early spring, will abundantly repay the labour of fetching them, continuing for seven or eight weeks in succession to flower as sweetly as in their native woods. So likewise does the wood-sorrel, the anemone, the honeysuckle, and a host of other plants, independently of numerous species of mosses and of ferns. Some of these latter are more valuable than others, in consequence of the longer duration of their fronds, such as *Lastrea dilatata*, and its numerous varieties. There are likewise many cultivated plants procurable at little or no cost, which grow without the slightest trouble, such as the *Lycopodium denticulatum*, the common musk-plant, myrtles, jasmines, &c. All the vacant spaces in the case may be employed in raising small salads, radishes, &c.; and I think that a man would be a bad manager who could not, in the course of a twelvemonth, pay for his case out of its proceeds. These remarks apply chiefly to situations where there is but little solar light. Where there is more sun, a greater number and variety of flowering plants will be found to thrive, such as several kinds of roses, passion-flowers, geraniums, &c. with numerous beautiful annuals—namely, *Ipomœa coccinea*, the species of *Nemophila*, *Convolvulus*, and a host of others: the vegetation, in fact, can be diversified in an endless degree, not only in proportion to the different degrees of light and heat, but likewise by varying the quantity of moisture; thus, with precisely the same aspect, ferns and bog plants might be grown in one case, and aloes, cactuses, mesembryanthemums, and other succulent plants in another.'

Case-grown plants, after the first preparation, require little or no care; the case need only be opened for the removal of dead leaves, or for a little trimming when required. Plants in open flower-pots are exposed to the vicissitudes of change of climate, and require constant watering; but the plants in these cases seem to be independent of any change of temperature in the air, and water themselves. The moisture rises by the sun's influence from the moistened earth, cherishes the leaves of the plants in its aërial condition, and during the cool of night falls to the earth again like rain or dew. In this manner there is a constant succession of rising and falling of moisture, in imitation of the great processes of nature daily going on in the fields around us. The plant-case is a little world in itself, in which vegetation is supported solely by the resources originally communicated to it.

Walls and Trellises.

Where it is objectionable to fasten climbing-plants to walls, a light trellis-work of wood or iron wire may be employed; permanently fixed where the climbers are perennial, but movable where they are grown merely for summer purposes. By being removed in autumn, and kept dry, a wooden trellis, originally of small cost, will last for a long number of years; the while that its removal, along with the withered branches of the plant, is a positive improvement to the appearance of the dwelling. Nettings of string or wire make very convenient leaders when other material cannot be had; and these may be woven along the outside of doors and windows, where other frameworks might not be permitted. In trellising, the lines should be easy and graceful, in order to give scope to the free and rambling habits of the climbers.

Among the *hardy* species adapted for this purpose, there are the honeysuckle, the ivy, many varieties of the rose, the jasmine, the small white clematis, the pyrus Japonica, lathyrus, chimonanthus, cydonia, lonicera, or even the humble hop, where an easily-nurtured and quick-growing climber is wanted. For summer purposes merely, a selection from the following genera may be made, descriptive particulars being easily obtained in any catalogue:—Campanula pyramidalis; cobæa, several species; convolvulus speciosus; lathyrus, several; loasia lateritia; lophospermum, several; manettia cordifolia; maurandya Barclayana; pentstemon argutus; rhodochiton volubile; Thunbergia, several; tropæolum, several; passiflora cœrulea; Tweedia cœrulea. Two plants appear in the above list, which, though they cannot be called climbers, make a handsome display when fastened to a trellis or a wall; these are campanula pyramidalis, and pentstemon argutus.

It has been often remarked that, of all flowering plants, climbers present the most graceful forms which can be contemplated under the open sky; but true as this may be, the tender varieties are not the less graceful when cultivated in the greenhouse or drawing-room. Grown in pots, and sustained by appropriate frameworks, they can be trained to almost any shape, be it urn, vase, obelisk, or pillar—a screen of living network, or a fairy arbour. Trellises affixed to the outside of pots can be had of a thousand designs; and where purchase is objectionable, they may be constructed of wicker, slender painted rods, cord, or varnished copper wire, which is one of the most pliable and durable of materials. By the adoption of this plan, with frequent prunings in particular cases, climbers may be made to clothe a trellis not more than four feet high, and so requiring no larger space than a small shrub; flowering more profusely when of three or four years' standing than if they had been three times that age, and had covered a sixfold greater surface over an arbour or veranda. Indeed, climbers are not of difficult culture; for we have seen a cottager's window shaded within by a screenwork of leaves and blossoms, more effectually than it could have been by the costliest Venetians.

Rock-Work and Aquariums.

If space and means permit, a flower garden may be much improved by introducing a piece of artificial rock-work, and a small pond; because, in connection with these, certain highly interesting plants may be reared or kept, which would not answer in a plain earthy soil or surface. In order to increase the effect, the pond should be at the base of the rock-work, and receive from it the trickling of water which has been conveyed to the summit in pipes. Let the rock-work possess a natural appearance, with rugged sides, and perhaps be ten or twelve feet high. Rocks of the same kind and colour should be placed together; if intermixed, they seldom wear a natural appearance. A dark cave, penetrating into the thickest part of the erection, is not very difficult to construct; and when encircled with ivy, and inhabited by a pair of horned owls, which may be easily procured, it will form a most interesting object. Rock plants of every description should be profusely stuck around, and in one short twelvemonth the whole scene will exhibit an impress of antiquity far beyond anticipation. The undertaking, when completed, will present a field of varied and interesting study, and more than compensate for all the attention and outlay bestowed upon it. The aquatic and rock plants, which formerly were 'far to seek and ill to find,' will thus be brought within the range of every-day observation; the wagtail, oxeye, and stonechatter, will be attracted to the spot, not perhaps because they are lovers of the picturesque, but because they find everything here suited to their nature; and colonies of the wild-bee will soon be seen and heard around the interstices of the rocks, and heavily laden with their winter store. A weeping-willow adjoining, and one or two mountain-ashes, will add materially to the beauty of the scene; and if the spot be airy, there might, with advantage, be planted, on or about the top of the eminence, a variety of what is usually called the *Scottish thistle*. This elegant plant will not thrive in low or damp situations, and prefers a bracing to a warm atmosphere; hence, though a beautiful object in borders, it is difficult to bring to perfection in some situations.

Among the plants suitable for growing from the crevices of the rocks may be mentioned various heaths and mosses, the Valeriana diœcia montana, trifolium alpestre, thymus vulgaris, epilobium alpinum, campanula cervicaria, alyssum calycinum, and viola banatica. Many plants might be mentioned as suitable for the marshy borders of the pond, as the acorus, littorella, lychnis flos-cuculi, saxifraga irrigata, epilobium angustifolium, primula farinosa, and so forth. We should recommend the unprofessional gardener, in replenishing either a rock-work or pond with appropriate plants, to consult a nurseryman skilled in the subject; as soil, air, climate, moisture, and other circumstances, require careful consideration.

GARDEN PLOTS IN TOWNS.

The attempt to have a neat and flourishing garden or garden plot in populous towns is very often defeated by the abundance of smoke and other impurities in the atmosphere; for, as repeatedly mentioned, pure air is essential to the proper growth of plants. It is found, however, from experience, that certain kinds of shrubs and flowering herbs are less delicate in this respect than others; and that, with a reasonable degree of care, open plots in towns may be made to yield a surface of vegetable bloom and beauty. On this branch of flower-culture, so important to many town residents, there appeared some time ago a well-written paper in 'The Magazine of Domestic Economy,' describing the experience of an amateur florist. We take the liberty of extracting from it the following passages:—

'When I first took possession of my garden [in town], I found it encumbered with old lilacs and laburnums, the common aster, and other ordinary plants. These I immediately removed: by my west wall I planted a buddlea globosa and a Virginian creeper; and by my south wall, which was partly covered by a vine, I planted the jasminum revolutum, the small white clematis, and the pyrus japonica. The latter grew luxuriantly, and bore an abundance of flowers, which, glowing upon the light wall, enlivened my prospect in winter. I had a great deal of the south sun in my garden, but none of his morning beams reached it, and there was a corner which never had a gleam at all. In this spot I planted a quantity of roots of the lily of the valley, and they flowered well, although late. The laurustinus also grew well with me; and I should strongly recommend this pretty shrub, together with the laurel, instead of those deciduous shrubs which we see in town gardens. The latter become very shabby as they grow old; neither the lilac nor syringa flower well in confined situations; besides this, the untidy appearance of their falling leaves is a great annoyance. My jasmine grew quickly, and, with the clematis, soon covered as much wall as I could afford to them; the great inconvenience of the latter plant is, that it requires frequent attention as to nailing up, and this, where there is not a gardener always at hand, is troublesome; as, although the stem should be cut down within three feet of the ground every autumn, yet the young shoots soon grow beyond a woman's reach. However, it is worth while putting ourselves to a little trouble for the sake of the delicious scent of the flowers of this pretty trailing plant. As regards perennials, I daresay all who are fond of flowers have endeavoured to nurse the China rose, and induce it to flower in the town. I have grieved over many a healthy plant which refused to show a single bud, and watched the gradual wasting away of others, notwithstanding my unceasing care. The common Provence roses, both white and red, flower well in the town; but it is vain to attempt the China—it requires a very pure air; and I do not know any flower whose colour varies so much with the quality of the atmosphere. I am but slightly acquainted with the names given by botanists to the numerous varieties of roses; but I have tried many of them, and found the Tuscan, the rose de Meaux, the Tudor, the little early crimson, and one surpassing them all in beauty, the Bengal celestial (I believe), flower extremely well.

With regard to spring flowers, the snowdrop I could not tolerate in the city—the smoke robbed it of all its beauty; the crocus, either the mice or the sparrows would not leave undisturbed; and after replenishing the edge of my border several times, I gave up the matter. The hepatica and gentianella flowered well with me; anemones also I had of very good colours. Heart's-eases pined away after the first year, but they were easily replaced, and they were too ornamental to be relinquished. Then followed the white lily, and a variety of irises, all of which increased fast, and flowered abundantly. The peony I could never persuade to flower; in the first place, it does not blossom well until it has been for years settled in a garden, and I believe its beauty even then is greatly dependent upon the purity of the air. My buddlea was every spring covered with its golden balls, and grew so quickly that I scarcely knew what to do with it. I am surprised this beautiful shrub is not more common: it is perfectly hardy, even as a standard; it will remove well, even when it has attained a considerable size; it is very easily raised by layers; and there is an air of grandeur about it, both as to leaves and flowers, that raises it above the common flowering shrubs of our gardens. But we go on in the old-fashioned manner of planting our gardens. The same varieties of deciduous shrubs are taken, without considering with how much advantage their places might be supplied by those more lately introduced. The magnolia, for instance, grows quickly and flowers abundantly in the city upon a south wall; and the arbutus is not at all particular with respect to situation. The bignonia grandiflora also does not withhold its scarlet trumpet-like blossoms in the immediate vicinity of a steam-engine. To return to my garden, the glory of which in the autumn was the lobelia fulgens, I managed it thus: I sank in the ground, up to the rim, a large and deep seed-pan; this I filled to about three quarters of its depth with rich soil, properly mixed, and planted my roots. As soon as the shoots appeared, I supplied them plentifully with water, and from time to time added more soil. The plants grew luxuriantly, furnishing tall and thick stems, with large and highly-coloured blossoms; indeed, the gardener who had assisted me said that he had never seen finer flowers. The sweet-scented marvel of Peru thrived well with me, and the tiger-flower also. Carnations and picotees I tried one year, but was so much disappointed in the result that I gave them up, although very reluctantly, as I believe carnations do not require a very pure air; and I have fancied since that my failure with them arose from some other cause than the smoky atmosphere. Dahlias also, although they flowered very well, I gave up. The amaryllis lutea flowered well with me when once established, and the hemerocallias cerulea and flava did the same.'

After condemning annuals in general, the same writer goes on to say—'I own I am willing to make some exceptions myself in favour of the coreopsis, and such brilliant flowers particularly; the French marigold, too, and the scarlet zinnia, I could scarcely give up. The lupinus mutabilis blossoms well in the town, but it is very liable to be destroyed by a caterpillar; the easiest method of preventing which is to strew a little soot around the plant. The grub, I suppose, will not rise through this: I found it more effectual than tobacco, which I also tried. The scarlet colutia is much eaten by an insect: I found the same method succeed in this case. I had forgotten to mention that all bulbs of the narcissus and jonquil tribe flowered well with me: the primrose and polyanthus gave miserable-looking blossoms. I planted the double pomegranate against my south wall, and it grew well: I left the house before the plant was old enough to flower. I should notice one great recommendation which American shrubs possess to those who are likely to change their residence—they may be removed without danger at almost any size. Mine were planted in a border of common earth, in a hole filled up with peat and loam fit for them; and when a rhododendron, four feet in height, was removed, it was found that the roots formed a complete ball, none of the fibres having penetrated beyond the soil which was proper for them. The common and Portugal laurel may be removed when very large: I have myself seen one of the latter, which three men and a boy could with difficulty lift, transplanted with success. Of course it was carefully tended as to water. The scarlet lychnis does not mind the corrupt air of the town; but it will not grow to so great a height in such a situation as it does in the country. There are many other plants which might be treasures in a town garden; experience, however, is the best teacher in this as well as in more important matters, and if a garden be stocked with the plants I have mentioned, experiments may be made as to others; should they all fail, the garden will still be *gay*.' To the foregoing we need only add that much may be done to keep garden plots neat by frequent trimming and raking, and particularly by keeping the plots in grass close shaven.

FLORICULTURAL MONTHLY CALENDAR.

January.—Little can be done in the flower garden except the weather be open and dry; but advantage ought to be taken of favourable intervals to render the plots and borders neat; to protect by coarse screenings of leaf-mould, fuchsias, China roses, and other choice shrubs; for though they may not perish by frost, the mulch tends to enrich the soil, when forked in. Propagate by division of roots daisies and thrift; protect the beds of hyacinths, anemones, ranunculuses, and tulips, by a covering of coarse litter. Top-dress auriculas, using a compost of light loam and two year-old cow-dung, mixed with a twelfth each of sea or river sand, and rotten wood. Plant all the bulbous roots that are still out of the ground. In heat, sow mignionette, annual stock, pentstemon, diffusus, gentianoides, and other half-hardy annual and perennial plants, using the propagation-pot, by which means the entire number of seedlings (allowing for previous thinning out) can be transferred, with roots undisturbed, to the plots or borders. Commence sowing in the last week, for hothouse culture, seeds of gloxinia and gesneria; these, if obtained from impregnated plants, may yield new and striking varieties. Sow also (broken up and mixed with sand) the berries of psidium cattleyianum; this plant is one of the choicest evergreens of the stove, or even greenhouse, for it is not tender.

February.—Attend to the foregoing general directions, and now cut turf for lawns; fork and clean the flower-borders. Plant anemones, gladiolus, perennial herbaceous roots; and transfer others, dividing the crowns, to multiply the species. For examples of this division of roots, select the primrose, single, double, and the polyanthus. Transplant the rooted layers of carnations, also the divided roots of campanula, lobelia, lychnis, mullpink, and dianthus sinensis. Sow in mild heat any annual flower seeds, and of auricula and mimula, in boxes or pans. We include the beautiful primula sinensis. Excite choice dahlia roots, placing them in hotbed frames, or in troughs or pots of old tan, or any light moist substance, on the floor of a stove or vinery at work.

March.—Sow annuals, including balsam seed, collected from the best double flowers. Plant box-edgings, using much pit-sand; also evergreen shrubs of every description. Transplant autumn-sown annuals into pots, and protect them, till fresh-rooted, under glass; as clarkia of every kind, calliopsis, œnothera lindleyana, mignionette, schizanthus pinnatus, and porrigens. Sow in the last week, in the open ground, and at the same time, a pot of each in heat, or at least under glass, stocks, foxglove, china-aster, clarkia, dahlia, campanula, larkspur, pentstemon, amaranthus, tobacco, and all the hardy annuals. Take cuttings of hydrangea from the tops of the shoots. These, if the buds be full, sometimes will produce a fine flower-head, and the effect is striking. Soil, pure heath-mould, or leaf-mould and sand.

April.—Plant dahlia roots in richly-manured loam, hollyhocks, carnations, biennials and perennials: at this season every herbaceous plant is almost certain to succeed. Campanulas (the tall pyramidal), raised by cuttings of the roots in autumn, may now be transferred to pots of loam and leaf-mould; and as the plants grow, they are to be constantly shifted, till they come into pots, wherein they will bloom profusely. If placed in the borders, they will require no peculiar treatment. Sow in a pot the seeds of this variety of campanula (seedlings frequently produce the finest plants; they require profuse watering); also the seeds of the pansy or heart's-ease, to procure varieties. Propagate by cuttings, as directed for geraniums, or by single eyes, the Erythrina crysta Galli, and laurifolia. In propagation pots, using the same soil, all the salvias, verbenas, rockets, double wallflowers, and every species of fuchsia that has produced young wood. Try every plant by cuttings placed in ounce phials, three parts filled with rain-water. Bud China, noisette, and moss-roses, on dog-rose stocks. Divide the roots of dahlias, either retaining one single tuber with a sprouting eye, or twist out very cautiously a single shoot, so as to detach its base and the latent bud it contains, planting it in the smallest pot of sand and leaf-mould; a gentle hotbed will facilitate the protrusion of roots.

May.—This is the season to stock the flower-garden with those plants which have been prepared during autumn, winter, and spring; and therefore transfer, from the propagation pots, annuals raised in them, by lifting the whole mass, and depositing it in a spot prepared in the border: thus trouble and loss of time are obviated. Sow a few annual seeds in the open ground for succession. Plant the parterres with groups of fuchsias, calceolaria, petunia, Neapolitan violet, verbena; and at the latter end form masses of the scarlet and variegated geranium, and many less-prized but beautiful fancy varieties; such are Diomede, conspicuum, succulentum speciosum, Moore's victory, Dennis's rival, &c. &c. Propagate by cuttings the China roses of every kind; plant them two joints deep, in a shady situation; also calceolarias of the shrubby kind, Peruvian heliotrope, &c.: by division of the roots, Neapolitan violet, placing them in beds of manured loam, twelve inches apart; the heart's-ease of the best varieties, in shady situations; the soil, rich loam and leaf-mould. These favourite prize-flowers require a frequent renewal of soil; they dwindle if retained in one site, and degenerate to the condition of the poor weak flowers of former years. Propagate by slips lychnis, double rocket, and wallflower; thin out the superabundant shoots of asters, antirrhinums, pentstemons, phlox, and all luxuriant herbaceous plants.

June.—Propagate, as during the last month, and plant young side-shoots of the best lobelias, in shady borders, under a hand-glass. The pipings of pinks, placed in sandy earth, are to be closely covered in the same way, till completely rooted. Salpiglossis succeeds best in the open air; the plants should be now turned out of pots, and set in a dry border. Greenhouse plants may now be arranged in a north aspect; the pots to stand on a deep stratum of coal-ashes. Azaleas, acacia armata, and some such plants, are greatly improved by being turned out of pots, and planted with the entire balls in an open peat-border.

July.—Bud roses on wild stocks. A pretty effect is produced by inserting one or two buds of the deep-red China in the common China rose. The former is strengthened in its habit, and the different tints of the two roses are very pleasing. Propagate by cuttings the Chinese azaleas, half-shrubby calceolarias, linums, pelargoniums, fuchsias, myrtles, and other exotic shrubs. Layer carnations in sandy earth, with a little chalk; peg them near the incision with hooks of fern-leaves. Sow mignionette in small pots for winter; also annual flower-seeds for bloom in September.

August.—Bud, as before, but not the China rose. Plant seedling herbaceous plants, cyclamens of every kind, offset bulbs to gain strength; repot auriculas, removing the suckers, and detach the black ends of old roots with the finger and thumb. Sow the seeds of all the annuals mentioned under that head in a previous page. Use gentle heat; add any other favourites, as madia elegans, mimulus, the white night-flowering petunia, tall and dwarf larkspurs. Sow the seed of the best pansies. Take cuttings of all the fine pelargoniums that are out of flower early in the month; also of calceolarias, shrubby and half shrubby; of antirrhinum caryophylloides, pentstemon gentianoides, &c.; these require no heat, but should be placed in a cold frame.

September.—Plant the crocus and some other bulbs. Transplant herbaceous perennials and pinks to permanent beds, if perfectly rooted. Propagate by cuttings China roses in the open borders; and by slips petunias, heliotrope, salvias, gerania, calceolaria, &c.; they require only a hand-glass and light soil. Sow auricula seeds in pans in the greenhouse; also clarkia, collinsia, chelone, and other annuals, to be preserved in pots all winter. If the pyramidal campanula be out of flower, take up one of the finest roots, blue and white; break it to pieces, and half filling a large pot with loam, place the pieces on the earth; fill the pot with loam, and keep it merely protected from frost all winter. Raise every geranium or other greenhouse plant now in open ground, and repot them in soil suitable to each. Cut back to low buds, well situated, the horse-shoe geranium, and place all the plants under glass, to recover from the removal; make cuttings of the best amputated shoots of geranium. Gradually diminish the watering of all greenhouse plants.

October.—Plant towards the end bulbs of hyacinth, narcissus, and tulips, the common jonquil, and daffodil, and anemone roots, &c.; also shrubs of every description, though evergreens generally succeed in spring: cuttings, as before, if not completed. Hyacinths in pots, filled with a compost of light loam, sand, and vegetable earth, should be plunged to the rims in ashes, or light earth, under the glass of a cold frame; and when the plants begin to grow, the pots should be raised, cleaned, and placed in the greenhouse. Greenhouse plants must now be taken in, and be gradually inured to winter treatment by the free admission of air and abatement of water. Take up the Persian cyclamen, and pot it in loam, sand, and leaf-mould. There is a geranium which merits much attention; it is called the scarlet globe, and appears to be a seedling variety of Pelargonium zonale: cuttings of it strike freely in the open border early in summer; the handsomest of these taken up in September, and carefully potted in poor loamy soil, will flower throughout October and November, placed in the window of a south room: the flower-head assumes the figure of a Guelder rose.

November.—Bulbs; plant all, employing much sand about and above the bulbs. Protect fuchsias, if frost threaten. Screened leaves form the best substance to be placed as mulch. Dahlias should be taken up in airy and dry weather, when quite dry and clean: preserve the tubers in well-dried sand.

December.—Protect beds of tulips, hyacinths, and other choice bulbs or roots, with a layer of sawdust mixed with sand, or with ashes. Sawdust alone has been found the most effectual protector to the roots of potted plants in frames, the pots being plunged in it to the brims. If dry weather permit, lightly fork the surface of plots and borders; but at anyrate, if it be frosty, scatter some light manures around the stems of shrubs and the more tender plants; it will tend to enrich the ground at the first spring regulation. Secure begonias and other plants which die down by placing the pots in a temperate dry cellar.

THE FRUIT GARDEN.

The fruits produced in ordinary gardens under the climate of Britain are of three leading kinds—*kernel fruits*, of which the apple and pear are the principal; *stone fruits*, including the peach, apricot, plum, and cherry; and *berries*, of which there are many species, as the gooseberry, currant, raspberry, and strawberry. The kernel and stone kinds are produced from trees, the others from shrubs or from herbaceous plants. All the garden fruits, of whatever sort, have been greatly improved by a long course of cultivation from a wild state—this being a branch of vegetable economy which has engaged the unremitting attention alike of men of science and practical gardeners from a remote antiquity till the present time. Of the best means which experience has suggested for culturing fruit-bearing trees, and bringing their produce to perfection, we now propose to treat.

GENERAL MANAGEMENT.

Fruit-trees are grown as independent plants in an orchard, in which case the tree is suffered very much to assume any height or bulk that nature permits; also trained upon walls, or constrained to grow in a particular manner upon artificial palings called *espaliers*. In whatever manner the tree is planted, or designed to grow, the tendency of the main stem and branches of the plant is upwards into the atmosphere, and of the chief roots downwards into the soil. In general, the depth and spreading of the roots are proportional to the height and spreading of the branches, because the roots are the anchorage and food-seekers of the plant, and require a depth and compass of soil corresponding to the bulk of the tree and its demands for nourishment. On these accounts, it is of the first importance not to stint fruit-trees of a depth and breadth of good sound mould adapted to their expected dimensions.

Trees planted close to walls should have a depth of soil in proportion to the height of the wall. If the wall be six feet high, the border beneath will require to be trenched two feet deep; and so on to a ten-feet wall, which should have at least three feet of free penetrable soil. The principle is, the deeper the soil, the less will the roots straggle. As already said, their tendency is chiefly downwards; and it is only because they cannot get far enough down that they range abroad. Their object is to absorb nourishment wherever it can be obtained; and, abstractly considered, it is of little consequence whether this nourishment be procured beneath the main stem or at ten yards' distance. But, practically, the gardener is concerned in keeping the roots from straggling, and interlacing, as with a network, the under strata of his borders, thus impeding his operations, and perhaps robbing his culinary vegetables or flowering shrubs of a portion of their food.

It will therefore be observed that depth of available soil is as essential in fruit-tree culture as in any other department of gardening. If possible, a depth of three feet should always be obtained. Should the garden, when first taken possession of, not have more than eighteen inches or two feet of soil, our recommendation is, not to plant fruit-trees upon it at all till the ground be trenched, as directed in No. 32, to a depth of three feet, and till, by annual digging, the substratum be incorporated with that immediately above it. In the course of these preparations let the soil be well cleared of stones, meliorated by winter frosts, and enriched with old manure. Bear in remembrance that fruit-trees must never be excited by new and undecomposed manure. The material applied both before planting and also while the tree is growing, should be loam, mixed with a thoroughly-rotted compost of dung, leaves, and the like. Some persons, following an old prejudice, place a paving-stone at a certain depth beneath, to prevent the root of the tree from penetrating into the subsoil; but this is only waste of labour; for if the descent be counteracted, the roots will proceed laterally, and penetrate downwards as soon as they can conveniently do so. By giving a proper depth of soil, and keeping that soil in heart, no fear need be entertained for the tree receiving that injury from the subsoil which it was the object of the paving stones and lined pits of our forefathers to prevent.

When we say that depth of soil is advantageous, it is necessary to guard against an impression being formed that deep planting is also required. In general, the roots of trees should be placed near the surface. Mr M'Intosh, in his very beautiful work, 'The Orchard,' offers the following caution on this subject:—'Deep planting is an evil much to be guarded against; and many of the disappointments which have attended the fruit-grower may be traced to this cause. As some criterion for the guidance of the amateur, we would say, let every young fruit-tree, of whatever kind, be planted at least three inches above the ground-level; that is to say, let the part of the stem which was level with the surface while in the nursery, be kept three inches above the general surface of the ground when it is planted, and let the earth be heaped up to that height around it, for a couple of feet or so, in the form of a little hillock. Trees of larger size may be rather more elevated. This applies to soils of the ordinary description; but in damp soils the elevation should be still greater. When trees are set in a pit—which should always be a third larger in diameter than that of the extent of the roots, so that they may be all spread out to their full extent, without being doubled or turned round—they should be spread as regularly as possible, and the bottom should be made perfectly level; by this means the roots will have a horizontal direction given to them, which they will afterwards maintain. The intention of this arrangement is to induce them to extend themselves near the surface, and to prevent their extending downwards into a bad or cold subsoil.'

Propagation—Impregnation.

Fruit-trees may be propagated by seeds, layers, cuttings, budding, suckers, or grafting. By any of these methods, a main object of the culturist is to improve, or at least not to deteriorate, the quality of the plant. In a state of nature, every fruit is inferior to what it will become by cultivation. This disposition to improve is taken advantage of by gardeners; and by attending to various circumstances in the economy of any individual plant, they are able to produce and propagate the best varieties. The principal means employed is to select such varieties as have attained a certain degree of perfection, and then crossing two of the most nearly allied, in order to produce an intermediate variety. The discovery of the sexuality of plants, as established by Linnæus, has rendered this a comparatively simple operation to skilled gardeners. The following is a short exposition of the method given by Mr M'Intosh, who quotes from other authorities:—'The means used in the process of artificially fecundating the stigma or female parts of the blossom of one flower with the pollen or male dust of another, have been beautifully described and explained by Knight and others. That eminent pomologist has obtained thousands of apple-trees from seeds, many of which are of first-rate quality, by cutting out the stamens of the blossoms, to be impregnated before their own pollen was ripe enough for the purpose, and afterwards, when the stigma was mature, by introducing the pollen of the other parent, either by shaking the pollen of it over the flower containing the stigma only, by introducing the flower when deprived of its petals or coloured leaves, or by transferring the pollen upon the point of a camel-hair pencil from the one flower to the other. By these means he prevented the possibility of the natural fecundation of the blossom within itself, and thus greatly increased the chances of obtaining intermediate varieties by making use of two distinct parents.

'This process is called cross-impregnation, and is in its nature highly curious. Dr Lindley describes the action as follows:—"Pollen (the male dust) consists of extremely minute hollow balls or bodies; their cavity is filled with fluid, in which swim particles of a figure varying from spherical to oblong, and having apparently spontaneous motion. The stigma (the female organ) is composed of very lax tissue, the intercellular passages of which have a greater diameter than the moving particles of the pollen. When a grain of pollen comes in contact with the stigma, it bursts, and discharges its contents among the lax tissue upon which it has fallen. The moving particles descend through the tissue of the style, until one or two find their way, by routes specially destined by nature for their service, into a little opening in the integument of the ovulum or young seed. Once deposited there, the particle swells, increases gradually in size, separates the radicle and cotyledons, and finally becomes the embryo—that which is to give birth, when the seed is sown, to a new individual. Such being the mode in which the pollen influences the stigma, and subsequently the seed, a practical consequence of great importance necessarily follows—namely, that in all cases of cross fertilisation, the new variety will take chiefly after its polliniferous or male parent; and that, at the same time, it will acquire some of the constitutional peculiarities of its mother."' According to modern phytologists, the character of the female parent predominates in the flowers and organs of fructification of the hybrid; while the foliage and general constitution are those of the male parent.

Illustrating these principles by reference to the propagation of varieties of apple-trees from seeds, Mr M'Intosh observes, that 'the kinds of apples that it would be advantageous to cross by artificial impregnation, appear to be those which have a great many qualities in common, and some different qualities. Thus it would be proper to cross the golden pippin with other pippins, and even with some rennets, but it would be improper to cross it with codlins or the larger growing kinds. The numerous varieties of pippins raised by Knight and others have been obtained by the above rule. It is no doubt true that a small apple—say, for example, the golden pippin—crossed with a much larger sort, will produce a variety sufficiently distinct from the other; but it is almost equally certain that this new variety will be of inferior quality to either; "the qualities of both parents," as Mr Loudon has very justly observed, "of so very opposite natures being, as it were, rudely jumbled together in the offspring."'

Grafting—its Theory.

Grafting, which is a practice of great antiquity, is the union of two plants in a growing state, through the medium of the circulating juices. It is now a well-known fact in surgery, that if a piece of a finger which has been accidentally chopped off be immediately applied to the stump whence it was severed, and the wound properly bandaged, it will adhere, and become part of the living member, as formerly. This, then, is grafting in the animal economy, and it is analogous to the grafting of one vegetable on another. The only dissimilarity is, that the piece of finger is restored to its own stump, whereas the vegetable union is between parts of two distinct trees. But this is a point of no consequence; for it is probable that if two persons, in equally good health, were to have a finger chopped off at the same time, the pieces might respectively be changed, and each individual might have on his hand part of the finger of his neighbour.

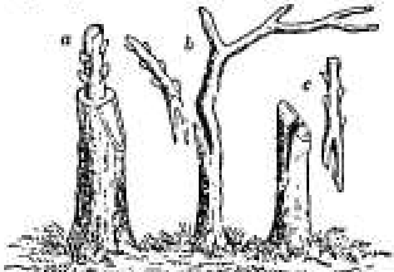
Gardeners assign five reasons for grafting:—1. The perpetuation of varieties of fruit, which could not be insured by sowing seed; 2. Increasing, with considerable rapidity, the number of trees of any desired sort; 3. Accelerating the fructification of trees which are tardy in producing their fruit; 4. Improving the qualities of fruits; and 5. Changing the sorts of fruit of one tree, and renewing its productiveness.

When a tree becomes old, but has still healthy and vigorous roots, and it is thought advisable to renew or improve its fruitful qualities, it is cut off across the lower part of the stem, and forms the *stock* on which *scions* are ingrafted, which scions taking root, become in time the fruit-bearing branches of the tree. As a general principle, the sorts to be united require to be considerably alike as respects disposition of woody fibre and sap and pulp vessels, so that no decided interruption may take place in the ascent or descent of the juices. Yet to effect any improvement in fructification, there must be a certain difference between the varieties. For example, the wild apple-tree, which bears only crabs, too sour to be eaten, forms one of the best stocks on which a graft can be made; and for that reason alone it is grown by nurserymen from seeds. The notice of this remarkable fact leads to a consideration of what are the radical principles on which improvement is effected by grafting. On this intricate subject we subjoin the scientific explanations of Dr Lindley:—'In proportion as the scion and stock approach each other closely in constitution, the less effect is produced by the latter; and, on the contrary, in proportion to the constitutional difference between the stock and the scion, is the effect of the former important. Thus when pears are grafted or budded on the wild species, apples upon crabs, plums upon plums, and peaches upon peaches or almonds, the scion is, in regard to fertility, exactly in the same state as if it had not been grafted at all; while, on the other hand, a great increase of fertility is the result of grafting pears upon quinces, peaches upon plums, apples upon white thorn, and the like. In these latter cases, the food absorbed from the earth by the root of the stock is communicated slowly and unwillingly to the scion; under no circumstance is the communication between the one and the other as free and perfect as if their natures had been more nearly the same; the sap is impeded in its ascent, and the proper juices are impeded in their descent, whence arises that accumulation of secretion which is sure to be attended with increased fertility. No other influence than this can be exercised by the scion upon the stock. Those who fancy that the contrary takes place—that the quince, for instance, communicates some portion of its austerity to the pear—can scarcely have considered the question physiologically, or they would have seen that the whole of the food communicated from the alburnum of the quince to that of the pear is in nearly the same state as it was when it entered the roots of the former. Whatever elaboration it undergoes must necessarily take place in the foliage of the pear—where, far from the influence of the quince, secretions natural to the variety go on with no more interruption than if the quince formed no part of the system of the individual.' Referring the reader to VEGETABLE PHYSIOLOGY for an account of the functions of the ascending and descending sap, we need only remark, that although increased fertility is produced by a decided difference between stock and scion, it is at the expense of durability; and that the practice is eligible only where it is wished to diminish the vigour and growth of the tree, and where its durability is not thought important.

All things considered, therefore, it is preferable to ingraft the scion of any approved variety on a sound stock, properly prepared for the purpose. As already observed, crab stocks are often grown to form the foundation of good apple-trees, and so are several other stocks propagated by professional gardeners from seeds and layers. We may now describe the different modes in which grafting is performed.

Scion-Grafting—Budding.

Grafting is performed in two principal ways—scion or slip-grafting, and grafting by approach, or in-arching. Of the first kind we have examples in the accompanying figure. Three modes are shown—*a*, *b*, and *c*, in each of which the process consists in placing a scion in an opening or cleft of a growing stock: *a* is called



whip-grafting, *b* side-grafting, and *c* tongue-grafting. By either method, the scion may be a shoot of a single year's growth, cut from a tree in a healthy condition. The season for the operation is about the middle of March, when the sap is rising and the buds beginning to be developed. The grafting should not take place immediately on cutting the scion: after removal from its parent stem, place it in the ground for a few days, so that it may be partially exhausted of its juices, and be more ready to receive the ascending sap from the stock. Keep it in dry ground, and not exposed to the sun. A scion may be brought safely from a distance by being stuck in a raw potato. Before applying to the stock, cut the extremity of the scion afresh.

Tongue-grafting, by which a tongue or slice raised in the sloping cut of the scion is inserted in a corresponding notch of the stock, is the more common method of procedure. It is performed when the stock is young, so that the scion which is added forms the stem of the future tree. The cut in both pieces requires to be smooth, and the joining so neat, that the bark on one side of the scion must be even with the bark of the stock. Having joined the two pieces, bandage them together with a flat strip of mat, but not so tightly as to prevent the circulation or expansion of the fibre. Over the bandage, plaster all round a handful of soft adhesive material, formed of clay, cow-dung, and chopped straw, taking care not to disturb the united edges. This mass will form a hardened lump, and may remain till the end of summer, when, the union being complete, it may be removed.

The principle upon which the external plaster is applied to the junction, is that of excluding the atmosphere from the wound, and is thus scientifically explained by Rennie:—'It is to prevent the oxygen of the atmosphere from getting to the fluid pulp at the joining, where it would unite with the carbon, and form carbonic acid gas, and thereby rob the pulp of its solidity. The exclusion of light is necessary on the same account; for, as in the case of a finger cut, the oxygen would unite with the carbon, and prevent the thickening of the matter of the blood. On the same account moisture, by supplying oxygen, would be injurious; and dryness might act both by exhausting the pulp, and by causing the edges of the bark to shrivel and gape, which would facilitate the entrance of the air with its oxygen. It must be obvious, from the simple principle (never, as far as I am aware of, before stated with reference to grafting) that no composition, whatever may be said of its peculiar power of healing, can act in any other way than this, any more than the farrago of plasters and salves for healing flesh wounds and cuts, which are only advantageous in so far as they keep the lips of such wounds together, and exclude oxygen and light.'

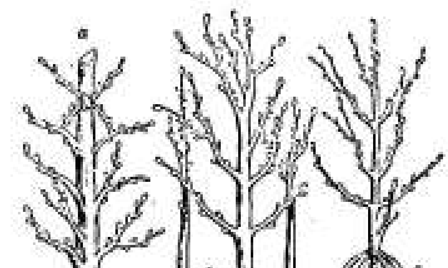
If the grafting has been properly performed, and other circumstances be favourable, the scion in two years will be in blossom, and yield a crop of fruit. What its quality will be, must depend on the nature of both stock and scion. If the scion be of a fine variety, that it will remain; and if the stock be equally fine, the quality will be improved. The excellence of the scion, however, is the prime consideration, for it is the part which is immediately concerned in the elaboration of the descending sap or proper juice, upon which depends the flavour and quality of the fruit.

Speaking of the descending sap, it may be here observed that the thickening of this juice, which is necessary for its accumulation, does not take place without the aid of heat and solar light; and thus, in cold wet situations, plants seldom produce so much fruit as in warm and dry ones. Abundance of carbon and nitrogen is further necessary; and scientific cultivators, having observed these facts, take advantage of them when they wish to throw trees into fruit, by keeping the roots so near the surface as to be within the reach of atmospheric air, from which they obtain carbonic acid and nitrogen. They also bend the branches in training them against a wall, so as to prevent the too rapid descent of the sap, and to force it to accumulate in those places where they wish flower-buds to be produced. If a ring of bark be taken off a tree in spring, the sap will rise just the same as usual; but when the sap begins to descend, a protuberance will be formed just above the ring, which will be occasioned by the accumulation of the sap; its further descent being stopped by the removal of the liber, which contains the vessels of the latex. This theory also explains why gardeners sometimes ring the branches of trees in order to throw them into fruit.

For an account of the process of *budding*, which is analogous to grafting, we refer to the previous sheet.

In-Arching.

This is an ingenious mode of grafting, by which one growing plant, without removal, is made to strike upon another plant, and thus form a union. It may be performed in various ways, as represented below. For



example, two branches of a tree (*a*) may be bent so as to meet and strike upon a wound in the main stem, by which a gap will be filled up; one growing tree (*b*) either from the ground or a pot, may be led to unite with another; or several suckers (*c*) may be led from the ground archwise to strike upon a point in the stem, thus bringing fresh aid to the productive part of the tree. By means such as these, quickset hedges might be thickened like a network, so as greatly to improve their appearance and protective qualities.

KERNEL FRUITS.

Kernel fruits, or *pomes*, as they are scientifically named (see VEGETABLE PHYSIOLOGY), include the apple, pear, quince, and others: those which require any notice here are the varieties of apples and pears.

The Apple.

The apple-tree is of universal European growth, and is believed to have been introduced into Britain by the Romans. It was greatly cultivated in the gardens of monasteries during the middle ages, and from that source the greater number of our cultivated varieties have drawn their origin. The *crab*, or wild apple is the type of the fruit when left to degenerate, and to which it would speedily return, but for constant culture and crossing. Culture, without crossing or grafting, is found to prevent an immediate return to the crab; and therefore, when an improved variety is obtained, it will yield seeds productive of a similar variety. The extent, however, to which varieties may be preserved without crossing, has never been accurately determined, as the practice among professional gardeners is not to risk degeneracy in the fruit; and they uniformly resort to one or other of the methods of grafting above mentioned. The apple-tree, if favoured by a good soil and climate, will live to a great age, two hundred years being not an unusual duration in a fruit-bearing condition. Some orchard apple-trees now existing in Herefordshire are said to be a thousand years old; and many were undoubtedly brought over by the Normans in the time of William the Conqueror.

The varieties of cultivated apples are now innumerable. In 1834, the catalogue of the garden of the Horticultural Society of London described 1400 varieties, and there are now in all probability several hundreds more. The numerous varieties are of three sorts—apples for the *table*, or to be eaten raw; apples suitable for *baking* and other culinary purposes; and apples for *cider*. Table apples are again subdivided into those which will keep, and those which will not. The choice kinds at present include Ribston pippin, which will keep till March, but is in its prime about Christmas; the Dowton nonpareil, scarlet pearmain, and Blenheim orange. The Keswick and Kentish codling and Hawthornden are early ripe, but the fruit will not keep beyond October. The nonsuch is a fine apple, and remains good in October. The old nonpareil is in every respect deserving of its title; its flavour is high and musky, and it keeps long; few apples bring such a high price in the market in February. Other choice long keepers to be named are, the scarlet nonpareil, the golden harvey or brandy apple, the winter pearmain, and the Easter apple, commonly called French crab. The best baking apples are the Colvilles for early use; the rennets and pearmains for autumn; the russets and Padley's pippins for winter and spring. To this short list hundreds might be added; but those who can grow what we have enumerated, and bring them to their full complement of bearing, can require no others as stock-trees. It must always be borne in mind, however, that what will succeed well in one garden may not do so in another, and that experience as to soil and climate, independently of advice from skilled neighbours, will in every case be necessary in the proper and profitable conducting of the fruit garden.

Mr London, in his 'Encyclopædia of Gardening,' mentions, that for *cottage gardens*, where the soil and situation are favourable for the production of the apple, the following sorts are recommended by Mr Thompson:—'Where the space will admit of only one tree, the best is the Ribston pippin; where two, the Ribston pippin and Dutch mignonne; where three, the Wormsley pippin, Ribston pippin, and Dutch mignonne; where four, the Wormsley pippin, king of the pippins, Ribston pippin, and Dutch mignonne; where five, the Wormsley pippin, king of the pippins, Ribston pippin, old nonpareil, and Dowton nonpareil; where six, the Wormsley pippin, king of the pippins, Ribston pippin, Alfreston, old nonpareil, and Dowton nonpareil; where seven, the Wormsley pippin, king of the pippins, Ribston pippin, Alfreston, Dutch mignonne, old nonpareil, and Dowton nonpareil.' Beyond this, Pennington's seedling and any other good sorts may be added. The same writer continues:—'It often happens that one or more trees can be trained against a cottage wall or roof, or against some wall appertaining to a cottage; in these cases, the proper sorts are, Ribston pippins, old nonpareils, and if a large kitchen apple be required, the Bedfordshire foundling. In situations liable to spring frosts, which so often kill the blossoms of the generality of apples, the Court pendu plat is recommendable, as its blossoms expand very late in the season. Under less favourable circumstances, where the Ribston may not succeed, the Bedfordshire foundling will be a hardier substitute, or the king of the pippins, which is still hardier; the northern greening may be planted for late kitchen use. For an autumn apple, perhaps none in this case is more to be recommended than the Keswick codling.' To these observations we need only add, that the cottager will do well in all cases to prefer one or two copious-bearing trees to a number of fanciful and fickle varieties.

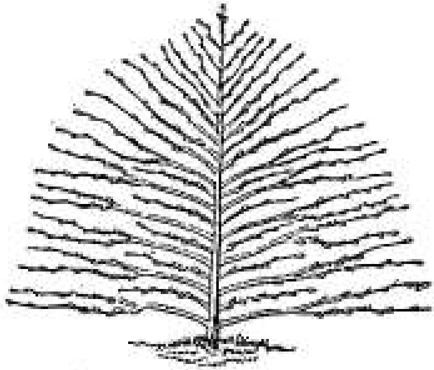
Standards.—Pruning and Training.—Standards are those trees which grow independently in open ground, and are classed as Large and Dwarf Standards. The proper object of cultivation is to give figure to the tree, of whichever kind, and bring it to a fertile or mature condition. Apple and pear-trees, as they approach to maturity, develop short *spurs* along the entire extent of the branches, and those spurs are the best in every respect which are produced naturally without the aid of the pruning-knife. But in addition to fruitful spurs, the trees produce a great number of superfluous wood-shoots, which, if not entirely removed, or at least so curtailed as to convert them to bearing spurs, would render the tree almost useless; in short, to effect prolific fruit-bearing, the shoots must be kept in subjection, or in the state of spurs. A recent writer on this subject observes:—'If a tree be a free grower, on a free stock, as the crab, or a strong pippin, from seed, all the leaders will be checked by shortening them back every year to a distance from the point of origin, which varies according to their strength; where they are very strong, the leading shoots should not be reduced more than within twelve or fifteen inches of their base; but when they are weaker, they may be cut to within nine inches. By this means the onward growth of the branch is momentarily arrested, the ascending sap is impelled into the lateral buds, some of which will be sure to grow so slow as to become productive.'

The foregoing directions comprise a view of the theoretical principles of pruning, and it affords an excellent groundwork for practice; but those who are strangers to the cultivation of fruit-trees, and, as such, undertake the management of an orchard, will be surprised and perplexed at the anomalies which continually present themselves; it will then be self-evident that gardening cannot, in its routine, be learned from books; that one tree assumes a certain mode of growth; another produces developments in an order which has not been foreseen or contemplated; another forms its fruitful spurs spontaneously, without solicitation or the adoption of means; while a fourth, in despite of the most rigid foreshortening, continues for years to yield nothing but growing shoots. We have seen numbers of spur-trees purchased at the same period, and treated upon the same principles, every one of which evinced a habit or constitution to a greater or less extent peculiar to itself; thus it is with trees as with the human genus—to be in any degree known, they must be individually and diligently observed and studied. This experimental fact being admitted, we may safely adduce the practice of pruning recommended by Mr George Lindley for dwarf standards, in his 'Guide to the Orchard,' &c. He observes that 'dwarfs on *crab-stocks* are much more adapted for large and ponderous fruit than standards, as they not only produce larger fruit, but are less likely to be blown down by high winds. Trees for this purpose should have their branches of an equal strength: those which have been grafted one year, or what are termed by nurserymen maiden plants, are the best; they should not be cut down when planted, but should stand a year, and then be headed down to the length of four or six inches, according to their strength; these will produce three or four shoots from each cut-down branch, which will be sufficient to form a head. At the end of the second year, two or three of the best placed of these from each branch should be selected, and shortened back to nine, twelve, or fifteen inches each, according to their strength, taking care to keep the head perfectly balanced (if the expression may be allowed), so that one side shall not be higher or more numerous in its branches than the other; and all must be kept as near as may be at an equal distance from each other. If this regularity in forming the head be attended to, and effected at first, there will be no difficulty in keeping it so afterwards, by observing either to prune that bud immediately on the inside next to the centre of the tree, or that immediately on the outside. By this means, viewing it from the centre, the branches will be produced in a perpendicular line from the eye; whereas, if pruned to a bud on the right or left side of the branch, the young shoot will be produced in the same direction; so that if the branches formed round a circle be not thus pruned to the eyes on the right successively, or the left successively, a very material difference will be found, and the regularity of the tree will be destroyed in one single year's pruning.'

What is here said refers only to the leading shoots which form the figure of the tree; others—side shoots (*laterals*)—are developed, and these require constant regulation. 'In pruning these laterals or supernumeraries, they should be cut down to within an inch of the bottom, which will generally cause the surrounding eyes to form natural blossom spurs; but where the tree is in a vigorous state of growth, branches will probably be produced instead of spurs; if so, they must all be cut out close, except one, which must be shortened as before. In all winter prunings, care must be taken to keep the spurs short and close, none of which should at any time exceed three inches; cutting out clean all the blank spurs, which have produced fruit the previous summer, to the next perfect bud below.'

It would perhaps be impossible for any writer to improve upon these directions generally; they comprise all the essentials for producing a balanced dwarf standard—that is, a tree low in stature, furnished with ten or twelve regular main branches, proceeding at a short distance from one central stem, each branch garnished from base to summit with fruitful spurs. But experience has instructed us to caution a pruner not to expect too much, but to watch the figure which his tree affects, and the course of its supernumerary shoots. If it evince a decided tendency to form short spurs naturally at a very early period, he may prune short, as above directed; but if its habits be so luxuriant as to produce wood-shoots after each pruning, it will be wise to defer the summer cutting of the spring shoots till the middle of July, instead of performing it at or before midsummer; and then either to snap the shoots or to cut them to a bud situated at least five inches from their base. This pruning, late as is the season, will generally cause each shoot to break its leading eye; in August, therefore, this new shoot is to be checked by nipping off its point; and finally, in September the spring shoot is again to be cut at the eye, below the one at which it was first pruned in July. In this way the vigour of the tree will be moderated, and several of the lower buds will probably enlarge, while the leading bud only expands into a growing shoot. If these hints be understood and acted upon, a young pruner will experimentally be taught to apply them, and thereby acquire the tact to discover the constitution of his trees individually, and to coax them into a condition of maturity. At the winter regulation, when the buds begin to swell, it will be easy to discern the fruitful eyes; and where any of these are discerned, the shoot projecting beyond them must be entirely amputated; and this may be done with safety, for spurs, when once fully formed, rarely break into barren shoots, though one of the eyes may do so.

Wall-training.—The circumstance of apple-trees producing fruit only on the outer parts, which are freely exposed to the sun and air, has led to numerous contrivances for exposing the inner as well as the outer stems. One method, as is well known, is the training of the tree in a flat shape against a wall—a plan also advantageous for enjoying the heat, which the wall radiates as a reflector against the branches. A difference of opinion exists as to the comparative merits of training the main stem in a serpentine or in a straight upright direction, and also whether the branches should be led perfectly horizontal or with an upward slope. If the height of wall permit, the upright stem and fan shape, as represented beneath, seems the most advan-



tageous, and certainly the least troublesome plan; and we would recommend unprofessional gardeners to attempt no other. Where the wall is low, the branches should proceed more horizontally; and the tip being restrained by pruning, those lateral stems will gain greater vigour. In either case, the branches, great and small, will require to be held in their appointed situations on the wall by stripes of list and nails. The nailing should not be so tight as to prevent expansion in growth, or be otherwise injurious. Iron nails rust and disfigure the wall, therefore nails made of zinc, where they can be driven home, are preferable. When a branch at any time becomes loose, it ought immediately to be refastened.

Espaliers.—These are rails generally formed of upright and crossbars of wood, but sometimes made of cast-iron. The best are of wood, and of from four to five feet in height. To these the trees are trained as on a wall, with this difference, that instead of being nailed, the branches are usually tied; the fastenings are soft hemp cord or strips of bast; but twigs of willow answer much better. The situation of espaliers is generally along the sides of walks; and if the trees be carefully trained, they have a neat effect. Care must be taken that they do not prevent the sun and air from reaching the kitchen vegetables. 'When properly managed and well exposed, espalier trees, observes Neill, 'generally produce excellent fruit, the sun and air having access to both sides of the tree: they commonly afford abundant crops, and the fruit is not apt to be shaken by high winds. Farther, they tend to hide the crops of culinary vegetables from the eye, and to render the kitchen garden as pleasant as an avenue in the shrubbery.'

The following hints on espalier training, by the author of the 'Manse Garden,' appear so eminently useful, that we take the liberty of giving them a place here. First, as to cultivation: 'Have the ground well trenched and manured [taking a crop of vegetables the first season], and plant the trees three or four feet from the walk, and twice as near to one another as they should afterwards be when full-grown. The reasons for this close planting are, that the value of a few crops is more than the expense of the trees; your rails are sooner covered; and when the trees begin to meet and incommode one another, you can then, having ascertained their various qualities, give scope to the best, by diminishing or rooting out the less worthy. For one or two years after the meeting has taken place, you may delay the pain of execution by allowing the young shoots to pass one another on the opposite sides of the rails. To incur no more expense than is necessary, the stakes may be placed two feet apart, in which case the annual shoots will require to be conducted from one resting-place to another by pieces of lath or wild brier, or willow of two years' growth. These conductors require a firm and separate tying, distinct from that which fastens more loosely the living wood; they thus give strength to the rails, and provide for straighter training than is commonly done by having the stakes twice as thickly set, and consequently at double the expense of timber.

Supplementary to both wall and espaliers is the following device, which has proved eminently successful:—Supposing that you have more garden ground than is necessary for the supply of vegetables, and that some part of it may be spared for a green shady walk amidst shrubs mingled with standard fruit-trees, on the south side of a row of evergreens, impervious to the eye, let a dry stone-wall be raised to the height of four or five feet, and coped with large stones, merely for strength and durability. Plant this on the north side with ivy, to assist the screen of shrubs, and in a short time not one stone will appear. From the south side take away all the good soil to a depth of two feet, a breadth of five feet, and a length equal to that of the wall, which may be sixty or a hundred feet, as you find convenient. This excavation, it is to be understood, runs close by the building, the foundation of which must of course have been secured by perhaps a foot of depth, and which will yet be uninjured, as the stones that cast up in removing the earth will immediately be thrown to the base in room of the materials taken away. Thus an effectual provision is made against the springing up of docks, nettles, or other troublesome weeds; the earth removed will be an invaluable treasure, whether for making compost or helping a thin soil; and the excavation itself will afford a most convenient receptacle for the immense quantities of stones which occur in trenching or raking the garden. Suppose the filling up in this manner to be nearly completed, let a row of large thin stones, set on edge, run along the southern boundary, and rise two or three inches above the surface of the ground. This will serve to keep the mass of stones distinct from the earth, that there may be no mingling in the process of digging. You have then on the one side of this excavation the low edging, and on the other a wall of four or five feet; and the design is, in the course of time, to fill up, with the riddlings of the garden or with clean stones, in whatever way, the whole space from the summit of the low edging to the top of the wall, to present an inclined plane facing the south, and nearly at right angles to the rays of the sun. On this [which is, in reality, a mound leaning against a wall] fruit trees are to be trained. Before the bank is completed to its proper slope, the trees may be planted along the southern boundary, and trained for two or three years upon poles laid from the edging to the top of the wall, according to their future destination. When the surface of the sloping bank is raised within an inch or two of its proper height, let a layer of coarse sifted gravel be laid on the top. This will much improve the appearance, and increase the reflected heat; and being free from small sand and earthy particles, will give no birth to annual weeds.

For the purpose of training, should peaches or apricots be planted, a close trellis will be requisite; but apples or pears will require nothing more than common espalier rails laid on the gravel, and held in their places by two slight spars running across, one at the top, and the other at the bottom. In the meantime, the ivy produces a beautiful and beneficial effect, surmounting the wall, and adding to the closeness of shelter caused by the evergreen shrubs. It should be clipped along the top after the manner of box-edging. Nothing can exceed the real snugness of the trees so placed, or the beauty of their glowing blossoms spread out under the eye; and the quality of the fruit comes fully up to the theoretic advantages with which it is favoured. The heat is undoubtedly much greater than that of the best wall; and the open flowers find, in their humble height, a shelter, like the daisy of the field, from the sweeping blast, which often scatters the petals of a higher tree like a shower of snow. Experience has fully proved the suitableness of this contrivance to all elevated situations. In some places very low and warm, the heat, so powerfully reflected, might possibly be too great; but in that case figs and nectarines might be so exposed, and would certainly take all that they can get.'

The Pear.

The pear-tree, like that of the apple, is found in a wild state in all parts of Europe, and has been similarly domesticated and improved into many fine varieties. The tendency of the tree is to a handsome pyramidal form. It is much longer in attaining maturity than the apple-tree; and on a dry soil, it will survive and continue fruitful for centuries. The tree may be propagated by seeds, layers, cuttings, budding, and grafting: it is more frequently raised from seeds than the apple; but grafting on its own species is also common, and is generally successful.

The observations already offered respecting soil for apple-trees apply equally to those of the pear kind, and nothing more need here be said, either on that subject or on general culture. The pruning, however, is different, because the pear is a very independent growing tree, and, as a standard, will assume its own natural figure in opposition to all restraint. All branches which lash one another must be removed; but unless the pruner cut and deform his trees in his attempts to create fruitful spurs, there will seldom be a redundancy of wood. A little foreshortening or disbudding in the spring and summer may be useful; but in general, as the pear can seldom become fruitful under seven or eight years from the grafting or budding, it will be prudent to watch the gradual development of the natural spurs, and to cut back the laterals to them when formed, and not before. Mr Knight pruned very little, shortening the main shoots occasionally, not sooner than July. He thus expressed his opinion in a letter to a professional gardener on the subject, in April 1833:—'I would recommend the knife to be little used upon the young pear-trees, particularly upon the horizontal branches. As a general rule for pruning trees that are to be kept low in gardens, I recommend the upright shoots to be shortened about the beginning of July.'

About 200 varieties of pear are enumerated in recent catalogues, all differing from each other in their qualities, time of ripening, &c. Among the finest sorts may be mentioned the Jargonelle, Marie Louise, Beurré de Capiaumont, Muscadelle, Bonchrétein, St Germain, Rousselet, Wilding, Beurré Diel, Glout morceau, Easter beurré, and Beurré rance. The word *beurré*, which here occurs several times, is from the French word for butter; and that, as well as the other names, show how much we are indebted to our continental neighbours for perfecting this delicious fruit. In selecting pear-trees, the nature of the locality must be consulted, subject to which the Jargonelle and others mentioned, also the Windsor, are general favourites. The summer, autumn, and winter Bergamots are not excelled for rich muskiness of flavour. The pear requires a warmer climate than the apple: hence some of the finer sorts, which grow well as standards in the south and central parts of England, will require a wall and shelter in northern or more keen situations. Any sorts worth the cultivating should have a rich aromatic flavour, and be either of the melting kind (*beurré*), or be firm and crisp, like the winter Bergamots.

Orchards.

An orchard is a piece of ground specially devoted to the rearing of fruit-trees, principally apple and pear, and is frequently an appendage of the English farm and manor-house. It should be a well-fenced enclosure, and if there be room for a choice, its situation ought to be on the side of a dry knoll sloping to the south-eastward; the best soil is a fresh sandy loam, of eighteen inches in depth or upwards, reposing on a subsoil of dry gravel or rock. If the ground be wet, it must be thoroughly drained in the first place, as no fruit-tree can answer its purpose if the soil be otherwise than dry. A damp clayey subsoil must be avoided; and the deep rich soil in the lowest dip of a valley is the worst situation to be chosen; for though it may be sheltered against wind, it is most liable to keep the trees in a growing state too late in the autumn, and to be severely assailed by late frosts in the spring, when the trees are probably in flower.

Shelter is necessary to orchards against the autumnal south-west winds; but this is best obtained by high hedges or forest-trees planted on that side. Winds from any other quarter need not be so much dreaded. Sheltering hills at some distance are an advantage, so as the orchard is not in the lowest dell at their base. Many orchards are almost barren, the trees covered with moss and lichen (a fine harbour for insects), only from their being too much sheltered, and deprived of a free current of drying air.

As an orchard is usually a pasture for sheep, cows, or other cattle, the trees to be planted in it must be standards; that is, trees trained in the nursery, with a clear stem six or seven feet high, from the top of which the branches diverge, and out of the reach of cattle. Sometimes the stocks are first planted, and when fairly established, are *worked*—that is, grafted or budded at the desired height.

If an orchard is to be formed out of an arable field, the ground may be prepared by the plough, laid into bands or ridges of eight yards wide, the trees to occupy the middle or crown of each ridge, these lying south and north. The trees should be planted in right lines, five, six, or eight yards asunder; and the whole area surrounded by a deep ditch and hawthorn hedge. When the trees are planted (which should be about the end of October), the ground may be laid down with a crop of barley or oats, with grass and clover seeds in the spring, and so remain.

If an orchard is to be formed in a grass field, it is drained, if necessary, and enclosed with a hedge and ditch as above; the trees are either planted in trenched pits or in trenched borders; that is, borders six feet wide are traced south and north, and regularly trenched fifteen inches deep, the turf being turned to the bottom. Along the middle of these borders the trees are put in at the distances already mentioned. This done, the broken ground is sown down with grass seeds, and the trees staked and protected against cattle, if they are in any danger. The pits, six feet square, are trenched and planted in like manner. In planting the trees, the ordinary care must be bestowed as well in taking them up as replanting; each should be set on a little mound of the finest of the soil, on which the roots should be regularly spread, and kept near the surface—for deep planting must be carefully avoided; the uppermost fringe of roots should just be within the turf, but no deeper; and they should be encouraged to take a horizontal rather than a downright direction. Orchards planted in either of these methods answer very well, if care is taken of the trees till they are fairly established, and can protect themselves.

The fruits chosen for such orchards are apples, pears, plums, and cherries, and of these such as are known to thrive, and are most fruitful in the neighbourhood of the intended orchard; for all fruits are not equally thrifty in the same locality, and this is a point deserving the consideration of the planter. Orchards of this kind are planted chiefly with a view to the service of a family, any redundance being sent to market, or sold on the trees to the fruit-monger; but when fruit-trees are planted as a special source of profit, a very different plan requires to be followed.

An acre or two of suitable land, with a proper exposure, is fixed on; the whole is trenched fifteen inches deep, and thoroughly drained, if necessary. The surface is levelled and laid into beds ranging south and north, and about twelve feet wide; along the middle of these the trees are planted; and the intervals are occupied by two rows of small fruits, either gooseberries, currants, or raspberries. Some of the intervals may have a rank of filberts introduced, which, when kept as low bushes, and properly spurred on, are as profitable as any other kind of orchard fruit. Such an orchard is intended to be a perfect thicket of fruit-trees: all, whether yielding large or small fruit, must be kept as dwarfs, and trained in the *bush form*. Of course the sorts which are naturally of a dwarfish habit are preferred, and if not dwarfish by nature, they must be made so by art. The bush form is obtained by encouraging the lateral growth of the branches, and depressing by some means or other those which have a tendency to grow upright. A sufficient number of branches is gained by pruning while the trees are young, and so disposed that they may aggregately form a rotund, compact, but not overcrowded head, shading a circle twelve or fourteen feet in diameter, more or less, according to the fruitfulness or individual strength of the trees. This close planting and low stature of the trees render them a shelter to each other, both against the frosty winds at the time of flowering, and against the equinoctial gales of autumn. The surface of this orchard is never dug. In dry summers, a mulching of half-decayed littery-dung is spread under the trees, and hoed in during the winter. Strawberries are introduced when the trees are young, but the ground must not be exhausted by surface cropping.

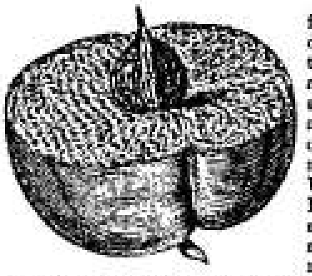
The success of such a fruit garden depends very much on a proper selection of the kinds, and on the skill of the manager in keeping the trees fruitful and dwarfish, without the application of the knife; for this is quite practicable, and is an art which must be had recourse to in the treatment of dwarfed trees.

In Herefordshire, Devonshire, and adjoining districts in England, orchards are maintained principally for manufacturing a beverage from their produce. *Cider* is the liquor made from apples; the trees in most estimation for the purpose being the new foxwhelp, the wilding, the cherry pearmain, and the yellow and red Norman. When the ripened apples have been shaken from the trees, they are allowed to remain in heaps for a month or so on the ground, to become mellow; after which the process of manufacture into cider commences. (See No. 46.) *Perry*, or the liquor from pears, is also a pleasant and wholesome beverage, and in some instances almost approaches the quality of sparkling champagne. The most austere varieties of the pear, unfit for the table, answer best for this purpose; and it is thought that a mixture of the wild pear with the cultivated sorts make a peculiarly fine liquor.

Quince and Medlar.

The *quince* is classed by botanists with the apple and pear, and these are often grafted on quince stocks, which confirms their consanguinity. It is said to be a native of eastern Europe, and to grow wild on the banks of the Danube. It was introduced into Britain from the isle of Candia, and grows readily in our hedges; but is not much used—the fruit in its raw state having a peculiar disagreeable smell, and an austere taste. It is sometimes employed to give flavour to apples in pies and tarts, and is occasionally made into a marmalade, which is much used in the south of France, where the quince is extensively cultivated. The *medlar* is also a native of south-eastern Europe, though long naturalised in Britain. It somewhat resembles a small apple, and possesses considerable flavour, but which is seldom developed, even in its ripe state, on the tree. It is gathered and laid aside until it begins to change or decay, and then only is it fit to be eaten.

STONE FRUITS.



The finest wall fruits of the garden are included in this division; these are, the peach (see section), nectarine, apricot, plum, and cherry, and all their numerous varieties. Under these well-known names we shall take a cursory view of each, referring the reader for minute particulars to the catalogue in Lindley's 'Guide to the Orchard and Kitchen Garden,' and to that of the 'Fruit Cultivator,' a small work of great merit, by the late Mr Rogers of the Southampton Nursery. Besides the familiar term *stone fruits*, botanists refer all the trees which bear fruit with a kernel contained within a hard bony shell, surrounded by a rich and saccharine pulp; this, consequently, would embrace that division (*Amygdaleæ*) which has the almond-tree for its type. The peach and nectarine were, till lately, considered species of the almond (*Amygdalus*), but they have been separated from that family, and constituted into a distinct genus (*Persica*). The nectarine, by some considered as a mere variety of the peach, and by others as a separate species, differs only in the epicarp or outer covering of the pulpy part being smooth instead of downy.

Peach and Nectarine.

Both are natives of Persia, introduced from that country in the year 1562, and extensively cultivated since that period. Each admits of two leading subvarieties—the melting peaches and nectarines, or *free stones*, and those with more solid flesh adhering to the nut, and therefore termed *cling stones*. The French consider them as one fruit, but arrange them under four divisions; but we prefer to simplify our description as above, and shall even dismiss the cling stones altogether from our catalogue, deeming them comparatively worthless, being later in their season, and of a flavour altogether inferior to the true melters.

The peach and nectarine (*P. vulgaris* and *lævis*) can be raised by sowing the stones, and excellent varieties have been so obtained; therefore it is not a fact that the trees raised from seed are wildings; but as there is no certainty of what a seedling may ultimately become, it is not prudent to trust to this mode of propagation; and though we would urge every gardener to make himself intimate with the process of budding—that approved and certain method of perpetuating approved varieties—yet as much time must thus elapse before a wall can be stocked with fruitful trees, we think it advisable that he purchase of a good and trusty nurseryman such varieties as are found to be adapted to the locality. The peach and nectarine are seldom grafted; it is usual to select buds of trees that are approved bearers and of fertile habits, and to insert them into young vigorous stocks of the muscle plum or seedling peach. Nurserymen raise their trees in this way, preferring the plum stock; the operation is performed late in July or early in August. The buds swell, but remain torpid till the spring of the following year, at which time the head of each budded tree is cut back to an inch above the inserted bud, which then expands, and forms one or more shoots. Trees in this condition are called 'maidens,' and many prefer such; but in general the nurseryman prunes and trains them into form during the two succeeding years, when they are sold as trained trees, at a price varying from 4s. 6d. to 7s. each. The mode of training thus commenced is usually that which is called the *fan* or *peacock's tail*. It is formed upon the principle of rejecting a central stem, and of leading all the main branches and their secondaries to assume the figure of an expanded fan. It is to obtain such trees that we recommend the planter to purchase the *trained* plants of the nursery garden. But there is another very excellent method of forming a tree, called the *Seymour training*, from the name of the gardener who introduced it. This plan requires a central stem, from which all the main shoots are trained at angles, varying according to the height of the wall and the vigour of the trees. The branches are led to the right and left alternately, at as nearly equal distances (about nine inches) as possible; and when a tree grows kindly, and the pruner is a man of dexterity and foresight, a handsome well-balanced tree is the result. To obtain these Seymour-trained trees, the planter must purchase 'maidens,' and either train them himself or employ an adroit pruner who is willing to attend to the required directions. We shall now attempt to explain the principles upon which all judicious pruning is founded.

The peach produces its fruit upon the spring wood of the previous year; occasionally, also, if the habit of the tree be very vigorous, upon secondary shoots from that wood; but this is by no means desirable under ordinary circumstances, because it proves that the tree is too luxuriant in young wood, which, being developed after midsummer, can scarcely become duly mature. A tree cannot be expected to produce or support a crop of fruit in a period short of four or five years from the budding; but during that period, the art of the gardener should be employed to lay in six or more regular branches to the right and left, which will form the skeleton or figure of the tree, and remain the permanent supporters of the young-bearing wood. In the fan method of training, secondary fruitful shoots are permitted to form at the under as well as the upper sides of these main branches; but in the Seymour training, the fertile secondaries are led off from the upper sides only; all those which break from the front (called *fore-rights* and *breast-wood*), or from the back next the wall, or from the under side, are obliterated as they appear, either by pinching them off with the finger and thumb, or by amputation with a sharp knife; this process is termed *disbudding*. The quantity of wood to be retained, year after year, so as to obtain a regularly-increasing proportion of fruit, without redundant wood, is chiefly produced by the judicious use of the knife in disbuddings.

We will suppose the example of a tree trained in the nursery during two years, then planted in October against a wall fronting the south or south-east, and cut back in February following, so as to leave all its branches about six inches long. The shoots of the first spring form the bases of the permanent branches, and are to be nailed, as they advance, in the most regular order, leaving them at their full length till February of the second year, when the strength and condition of the tree are to be consulted. As a first rule, we are taught, and experience sanctions the rule, 'that every shoot is to be shortened in proportion to its strength, by pruning to the point where the wood is firm and well ripened, by which all the pithy wood is removed, causing a supply of that which is better ripened for the ensuing year.' But in order to facilitate the ripening of the wood, it must be trained thin, retaining those shoots only that may be required for the ensuing year. After two years' growth in a good soil, we may reasonably expect that six or eight permanent shoots, a yard or four feet in length, will be formed and trained in, on each hand, and that all these branches are furnished with three or more secondaries, laid in at nearly equal distances from one another, and which, by the end of June, may be a foot or more in length. The tree will continue to grow till the end of August; but disbudding must be effected repeatedly, so as to leave it in the form and condition just described.

It has then become a bearing tree, which condition implies a series of strong woody branches of two, three, or more years old, that have produced other shoots in the spring, which, when ripe, are of a deep reddish-brown tint on the sunny side. These latter are the fruitful shoots, and they never bear twice; but if neglected, run on to an uncertain length, sending forth other weak laterals, which might indeed bear a little fruit, but such as could never compensate for the ruin, or at least disfiguration of the tree. It is a maxim among good pruners that a peach-tree should be *green* throughout or all over; that is, every space, even close to the main stem, has one or more leafy and fertile shoots. This maxim would be violated in two seasons were all the shoots permitted to extend themselves, and the tree would be found bare—every part of the centre becoming verdant and productive only at the remote extremities. Hundreds of fine peaches and nectarines can be found in this condition; and in fact the greater proportion of those in private gardens afford irrefragable evidence of neglect or want of knowledge.

The bearing-shoots, therefore, must be shortened to twelve or fourteen inches, if strong, and the weaker to eight or ten inches, or even to half that length, if very slender. The pruner should cut sloping from behind, and a little above a *treble* eye—that is, an eye with a shoot-bud between two blossoms, if there be such; for a branch or shoot not in a mature or bearing state has no treble eyes; but in furnishing a tree, it is not needful to cut away the wood-shoots as useless; because by pruning back to an eye seated rather low on the shoot, two good fertile shoots may be provided in lieu of a barren one. A single sharp-pointed eye is the origin of a wood-shoot; the blossom-bud is more bulky and rounded; but by deferring the winter regulation till late in February, the condition of the two will be no longer doubtful.

When it has once been so pruned, the leading branch will break its extreme bud, which will thus elongate that branch; and the fruitful laterals will also develop several minor shoots. It is from the last that a selection must be made to effect two objects of the greatest importance. The first is, to attract the sap along the entire shoot, in order to nourish the young fruit upon it; and this will require that the shoot at the extreme point, or at least one beyond the uppermost fruit, be permitted to extend itself, and be nailed securely to the wall, when it shall have acquired some strength and toughness. The second object is, to provide a shoot to succeed the one now bearing fruit; and in doing this, the lowest should be selected, because it will, by its situation, replace the present shoot in a manner most conformable with the gardener's maxim before adduced, and tend to keep the tree compact and fertile—*close home*. A third shoot ought also to be retained to guard against emergency or accident; all the others should be removed by disbudding early in May. In July also a general regulation must take place; when, by removing useless shoots, and nailing those retained, the fruit will be duly exposed to the sun's rays. Thus the growth of shoots and fruit proceeds; and if regularity and order be maintained, the tree will, year after year, elongate, and add branch to branch, retaining complete verdure throughout. A few lines from 'The Guide,' by G. Lindley, will suffice to complete our concise directions:—'Should young shoots, indicating extraordinary vigour, anywhere make their appearance, they should be immediately cut out, unless where a vacant part of the wall can be filled up; because an excess of vigour in one part of the tree cannot be supported without detriment to the other. Peach-trees, when in a state of health and vigour, generally throw out laterals from their stronger shoots' [he means *secondary* laterals, before alluded to]; 'when this is the case, they should not be cut off close, but shortened to the last eye nearest the branch' [this is, in fact, to spur them, in the hope to convert the lowest bud into a fruitful one]; 'and if there is room, one or two of those first produced may be nailed to the wall, or the middle shoot may be cut out, leaving the two lowest laterals, and allowing them to take its place—thus frequently obtaining two fruit-bearing branches, when the main shoot would in all probability have been wholly unproductive.

In the thinning of peaches and nectarines, and indeed any other drupaceous fruit, it is necessary to proceed with caution, as they are apt to fall off after having attained a considerable size. In order, therefore, to secure a crop, it will be the best way to thin them at three separate times: the first, as soon as the fruit is of the size of a hazel nut; the second, when of the size of a small walnut; and the third, as soon as the stone has become hardened; after this, it rarely happens that either peach or nectarine falls off before it is matured.' These directions apply in every part to the order of training by the Seymour method; for all the bearing wood of one year must be replaced, if possible, by young shoots proceeding from the base of that wood; this fact, if appreciated, will of itself render any adroit man an able trainer and pruner of the peach-tree.

Peach-trees are but too liable to be molested by insects and mildew; the former are usually some species of the aphis, commonly called *green fly*, though, as in 1840, it was *black*. Some trees doubtless escaped; but those which were attacked suffered to an extraordinary degree, insomuch that the crop dwindled, and the growth of the trees was checked—three distinct broods having succeeded each other between the middle of April and July. They obstinately resisted every kind of wash, though in general tobacco water is effectual. Scotch snuff and fumigation failed; and at last premature close-shortening was resorted to, and thus the new wood was seriously injured. We allude to this fact, as being in strict accordance with the concomitant visitation of the black aphis which locally destroyed the bean crop, and deformed kidney-beans, peas, and even the nettles and other weeds of the fields and lanes. A disease produced by frost, which is called 'the bladder blight,' frequently swells and distorts the leaves of peach-trees: we are acquainted with no other remedy but that of timely hand-picking. By these attacks the regular training and figure of the trees are much disturbed; and occasionally an entire season may be irretrievably lost.

With respect to soil and preparation of a border, what we have said under the head *apple* applies strictly to the peach. As wall-peaches must have a border, we can devise no plan more effectual or simple than that of clearing out a space of the required length, of eight to twelve feet in breadth, the depth of soil at the wall to be twenty inches, sloping to fifteen inches—making a fall of five inches from back to front. To effect ample drainage, the bottom should be paved, as before recommended, with chalk or fragments of stone, &c. rammed hard, and inclining to a rubble or stone drain running parallel with the wall, to carry away the superfluous water from the bed. A natural substratum of chalk or rock would suffice, but in that case depth of soil must be provided. The bed itself should consist of the rich, but not clayey loam and turf, of a common or pasture, having in it no manure whatever. The trees may indeed be top-dressed every winter with littery manure a yard or more round the boles, and so deep as to protect them from frost, just above the collar, at the critical periods of blossoming. It will also be a great preventive of drought in summer; and of this any one may satisfy himself by raising the mulch in the very driest weather, when the soil under it will be seen black and moist, though in other parts it be parched to aridity. The fruit can be one month accelerated, and its value proportionably enhanced, by growing a tree in a pit of 24 feet long, 60 inches deep at the back wall, and 30 inches at the front. The lights will thus obtain a sufficient slope, if their length be seven feet. Hundreds of fine fruit can be produced in July or August by one tree; but great watchfulness will be required about the period of blooming, to check the ravages of the aphides in their earliest approaches; by three days' neglect, we have seen the destruction of a crop, and the ruin of all the bearing wood of the year, in despite of every usual application. A strong lining, twice renewed between February and June, will greatly accelerate the advance of the fruit.

Selection of a few of the finest melting peaches adapted chiefly to the midland counties.

1. *Bellegarde, or Galande.	4. *Noblesse.
2. *Chancellor.	5. Royal George.
3. Late Admirable.	6. Susanna, or Yellow Alberge.

Nectarines.

1. *Elruge, or Claremont.	3. *Violet Hâtive (the best).
2. Fairchild's Early White.	

The trees marked thus (*) are stated by Lindley to be also suitable to the Highlands of Scotland.

The Apricot.

It is believed, upon the authority of Pliny and others, that the apricot is a native of Armenia; whence its present Latin name, *Armeniaca vulgaris.* It partakes of the habits of a plum and peach, and, till lately, was considered a plum—*Prunus Armeniaca.* It is multiplied by budding, either upon the common plum or the muscle plum. Lindley says that it is usual to bud the *Moor-park* upon the former; but he is persuaded that the tree would be better, and endure longer, were it budded upon the muscle; and if he be correct in this, we may safely assert that all the best apricots will succeed upon that stock without having resource to any other. The operation of budding, like that of grafting, may be most readily acquired by observing the practice of a good budder. The season of budding is comprised between the third week of July and the 16th of August, and showery weather is propitious. The buds should be selected from shoots of the spring wood; and in taking them off, a piece of bark one inch and a half long should be retained, from which the strip of wood it contains ought to detach itself freely, without bringing with it the eye of the bud. This eye or point is a vital organ, without which a bud cannot grow. This remark applies to every kind of bud, whether it be that of the apple, pear, peach, or any of their kindred; or of any ornamental tree or shrub which admits of being thus propagated.

The best varieties of apricot are—1. The Peach apricot, fruit high-coloured, and very large; 2. Moor-park, of high flavour, and also pretty large; 3. Brussels—oval, and capable of ripening on an open standard; 4. The Roman, hardy, and an abundant bearer.

As to pruning and training, when the figure of the tree is formed by having three or four branches proceeding from a main stem, each is shortened in the winter regulation, soon after the leaves fall, to six inches, in order to obtain new branches. These are secured to the wall in May or June, at five or six inches' distance from one another, removing all supernumeraries. At the second winter pruning, the leading shoots may be cut back to ten inches, the others growing upon them to six inches, more or less, as position and strength indicate. In May or June following, more wood is laid in from each branch; and thus, by disbudding and winter-shortening, a regularly-formed head is obtained, upon the shoots of which short fruitful spurs are duly and progressively developed. In all winter prunings and curtailments, the longest shoot that is retained ought not to exceed eighteen inches in length; thence diminishing, according to the strength of each, to nine, or even six inches.

These rules comprehend the essence of all the best practical directions; but one remark, which we seldom meet with, appears important: the apricot-tree comes early into bloom, when very few leaves, if any, are expanded; and it frequently fails to set or retain its fruit. This failure we have remarked particularly with low trees horizontally trained. On the contrary, when a tree having a six-feet main stem without a branch is then trained with a central leader to the height of from twenty to forty feet, and suffered to branch obliquely to right and left, the crop of fruit is frequently very great. We also saw, at the end of March, after the severe frost of 1838, one solitary branch of a tree which had been trained upon the breast of a vinery chimney, with fruit larger than nutmegs, and foliage fully expanded, while every other branch remained torpid as any of the exposed trees of the garden. These facts prove that the high wall of a dwelling, and the proximity of a warm chimney, are most favourable to the productiveness of this very fickle tree.

The Plum.

The common sloe of Britain is the type of this genus, *Prunus;* but those rich and luscious fruits which have been so long cultivated throughout Europe are of Eastern origin. Plums are propagated by budding upon the common plum stock; and for standards, Lindley recommends the insertion to be made nine inches from the ground, when, under favourable circumstances, the buds will produce vigorous shoots, standard high the first year. Open standards require little attention; they should be divested of all the superfluous shoots by pruning them out close to their origin, just before the season of spring growth. But wall-trees and espaliers are to be treated as espalier pear-trees; that is, by training them with a central stem, and a series of horizontal branches proceeding from it on each side, nine inches apart. These branches are not to be shortened; and the spurs which form naturally upon them are to be kept short and compact as they advance in length. Artificial spurs may be obtained by July foreshortening; but as fertility is promoted by whatever checks the luxuriance of the wood, it will, we think, be preferable to train in the supernumerary laterals, depressing them below the horizontal level till some natural spurs are formed near their origin, and then to cut the shoots back to the lowest spur.

The plum ripens in September and October. Of the earlier dessert-plums, the green gage and the two Orleans are the best. Coe's golden drop, and the Goliath, come into season in October; and for preserving, we name the winesour, the violette hative, the two varieties of magnum bonum, and the damson or damascene. The Imperatrice is the best late plum, being delicious in November. The soil already mentioned is favourable to the plum, though the tree will prosper in one of more binding quality. Plums are used at desserts, in tarts, and preserves; and, when dried, form the well-known *prunes* of the fruiterer. The fruit of the sloe, when ripe, makes a good preserve.

The Cherry.

The cherry-tree, or *Cerasus*, as it was called by the Romans, has been known as a cultivated tree for at least three centuries; orchards, the produce of which was sold at a high price in the year 1540, existing to a large extent in Kent. This circumstance conferred the name of Kentish cherry on that peculiar species. Lindley enumerates and describes twenty-eight, and Rogers twenty-five, different kinds of cherries; among which the best for general cultivation are the Kentish, the May-duke, the graffion or bigarreau, Harrison's heart, the black heart, and morella. All may be grown as standards, but the May-duke and morella produce larger fruit when trained against a wall.

Standard-trees form their own spurs, and require only a little thinning out of superfluous branches; but wall-trees must be treated as the apricot and plum, avoiding, however, to shorten the leading branches. The morella requires a somewhat different treatment, because it not only bears on spurs, but, like the peach, on young wood of the last spring. Mr Rogers offers some remarks in the form of anecdote, which are deserving of attention:—In the Surrendon Gardens, of which he had the charge, 'a north wall ten feet high had a border twelve feet wide, and very shallow, reposing on loose or rubble rock. The soil was a dark hazelly loam, of rather inferior quality: the roots were very near the surface, those nearest the stem actually above it. Five trees were originally planted, but subsequently the second and fourth were removed, leaving the centre tree at thirty-two feet from the end ones. Even at this distance the branches met; and in their progress, being kept very thin of bearing wood, the crops were magnificent.' The trees were simply planted on the natural surface of unprepared ground, without any manure or deep trenching. 'Neither was this border ever dug with spades, but slightly stirred with blunt forks, and having a little well-rotted horse-dung bestowed every second or third year. There cannot be a more mistaken notion and injurious practice than overloading and poisoning the fruit-borders with rich dung. In the early training of the morella, the knife should be used freely, to gain a sufficient number of leading branches—thinning out the laterals, but never shortening them.'

The cherry-tree grows to a large size, and its wood is highly valued by turners and musical instrument-makers, from its suitableness for being bored and formed into smooth tubes; in the luxurious East it is much used for the tubes of tobacco-pipes. The fruit of the cherry seems less impaired by growing in a wild state than other garden fruits; in Scotland, the wild cherries, called *geans*, are small, but fine-flavoured; and in Germany, the favourite liquor, *kerschwasser*, is distilled from the juice of this species of fruit. The liquor called *cherry-brandy* is made by putting the best black varieties in brandy. *Noyeau* is a liquor flavoured by the kernels of the *C. occidentalis*; and a large black cherry is employed in the manufacture of the *ratafia* of Grenoble. The *maraschino* of Zara is made from a peculiar species cultivated in Dalmatia.

BERRIES.

In this division will be comprised the currant and gooseberry, both members, with all their now innumerable varieties, of the same family or genus, *ribes*—the raspberry, strawberry, cranberry, and grape-vine.

The Currant.

The currant is a native of Britain; nevertheless, we are indebted to the Dutch for the great perfection to which it has now arrived. The Dutch red and white currant are unquestionably the best produce of the garden; the Naples black is preferred. Currant-shrubs prosper only in cool climates, and they are somewhat arbitrary in their choice of a situation even in our own moist country; they grow to an astonishing perfection in the rich moist vales of the middle counties, but the berries dwindle in hot and arid situations. A loam such as has been so frequently mentioned will also suit the currant, but it likes manure; and this can be advantageously and freely applied as a top-dressing in November, to remain on the surface till after the pruning in February, when it should be lightly forked into the soil without disturbing the roots.

Mr Knight raised three or four hundred bushes from seeds in the course of his scientific experiments upon crossings, but of these very few excelled their parents. One of them, the red crystal, is superior in all respects. We have also raised currants from seeds, and have acquired one fine white variety, but have thus been instructed that seven or more years elapse ere the plants become fruitful, and therefore that propagation by cuttings is greatly preferable. Take cuttings of the young spring wood, with a small heel of the older wood attached to it; divest it of all the buds excepting five of the uppermost and those of the heel; dibble holes six inches deep in a shady bed or border, and fix a cutting firmly in each hole, by pressure and watering. They succeed perfectly if planted in August, provided they be kept moist and entirely shaded, or in a north aspect; but the season extends thence to the beginning of March. The soil should be rich and light. Cuttings may be placed at first where they are intended to remain, or they may be transplanted after they become rooted plants, cutting away all but the upper whorl of roots: in either case, cut back to two or three buds the shoots made the first spring, and subsequently prune on every side at an outside bud, to make the bush spread at top, and render it open towards the centre.

Prune for fruit just after the buds begin to swell—never before February, or the birds will reduce the expected crop; and in pruning, shorten all the leaders and spur in the laterals, till the bushes appear like deformed masses of scrubby twigs. The long pruning is comparatively worthless. By these spurrings and shortenings, the trees progress somewhat slowly, but the fruit is produced in massive clusters from the numerous spurs. The skeleton of each bush ought to consist of nine, twelve, or fifteen bearing branches, diverging at equal distances from three lower short limbs, which emerge from one main central stem; this is the best form of a neat bush, and the knife should be exercised to keep it open in the middle. If the spring shoots push very vigorously, the first high wind generally breaks down more than half of them; but this natural pruning is frequently advantageous. The black currant requires a still more moist and cool site, and that the wood be kept young, but never pruned or spurred. Whatever shoots become black and scaly must be cut entirely out, leaving those bearing branches only which are of a delicate brown colour. The trees require frequent renewal, by taking vigorous cuttings, for old wood produces small berries. If the soil and site be congenial, and the trees be young, the berries are frequently as large as small black cherries.

The Gooseberry.

This universally known shrub is a native of Britain, and therefore much more easily cultivated than exotics; it is indeed so hardy, and suitable for even keen climates, that remarkably little fostering is required to keep it in perfection. After a long course of culture, there are now hundreds of varieties of gooseberries; still, the kinds which keep their place in public estimation are few in number. The following is Mr Johnson's list of good-flavoured and very large sized, those of each colour being placed in the order of ripening:—*Reds:* Keen's seedling, Melling's crown Bob, Leigh's rifleman, Boardman's British crown, red Warrington. *Whites:* Taylor's bright Venus, Wellington's glory, Saunder's Cheshire lass, Woodward's whitesmith, Cook's white eagle. *Greens:* Parkinson's laurel, large smooth green, Collier's jolly angler, Massey's heart-of-oak, Edward's jolly tar. *Yellows:* Didon's golden yellow, Prophet's regulator, Prophet's rockwood, Brotherton's golden sovereign and pilot. The following are small, but of very good flavour:—*Reds:* red champagne, red Turkey, rough red, ironmonger, and Rob Roy. *Whites:* white champagne, white crystal, early white, Taylor's bright Venus, and white honey. *Greens:* early green hairy, Pitmaston green gage, and green walnut. *Yellows:* yellow champagne and rumbullion. For *bottling* the best variety is the rumbullion; for *preserving*, the best are the red champagne and the white eagle. The first gives a deep red to the syrup; the latter a slight pink, but imparts as good a flavour, and requires less sugar.

Although the gooseberry can be grown in almost any garden soil, yet if excellence of fruit is desired, the soil must be a rich loam, not less than twelve inches deep, and resting on a well-drained yet cool subsoil. The plantation should be near the bottom, yet on the side of a hill, and be unshadowed by trees; for if these intercept from them the light, the fruit will be neither large, nor full coloured, nor high flavoured. Whether to form an entirely new soil, or to improve that in which the plantation is to be made, the following compost, recommended by Mr Haynes, may be advantageously adopted:—Of fresh or maiden earth from a light loamy rich pasture, take one whole spit-deep, with all the turf; to which add one-fourth of rotten stable litter, preferring that from an old hotbed made in the previous spring, which, from its softness and greater readiness to intermix with new soil, will be found preferable to every other; add one-fourth of the finest soft and black bog earth, or, in default of this, either the same quantity of the darkest-coloured leaf or vegetable earth, preferring that from hard-wooded trees. Mix the whole regularly together, laying it into one narrow heap or ridge, about a yard high, in any situation exposed to the sun and air, there to remain for six, nine, or twelve months, as circumstances may admit; turning over the whole every three weeks, when the weather is favourable. The longer the compost remains in this state, the more advantageous it will prove.

To propagate, take cuttings of any chosen sorts eight inches long, of the last spring's wood, having a small piece or heel of the older wood; they are inserted about the end of October to the depth of three inches. The situation should be shady, the earth rather sandy, and each cutting should be fixed firmly in the soil. It is customary to remove all the buds excepting four or five at the top, which are left to form the head, produced from one central stem; but we prefer to secure the rooting of the cutting by retaining the lowest, and planting it four or five buds deep. It is from these buds that we expect roots; and though none may be developed till spring, nature will not be idle; and whenever the eyes break and shoots elongate, it will be time enough to select the strongest and best as a leader to form a stem, obliterating all the others both below and above the surface. Should three or four eyes break at the upper part of a cutting, it will be desirable to remove all others lower on the stem, as soon as it shall be manifest, from the vigour of growth, that there are good and sufficient roots to support them. A central stem is most desirable, and people think to obtain one, and to prevent the growth of suckers, by destroying the lower buds in the first instance; we believe that the want of success and the loss of the cutting are to be traced to this practice, and therefore we disclaim it. When the head is formed, gooseberry-bushes can be spurred as directed for currants, avoiding to shorten the leading branches; or at each pruning in February, a certain quantity of the last year's wood should be retained, and a corresponding portion of the two and three years' old wood cut out; thus, as it were, renewing the trees annually. Larger berries are thus obtained from strong young wood than by the spurring system. Propagation by seed is the mode for obtaining new varieties; but it is seldom resorted to in ordinary culture.

When the fruit has fully set, the smaller berries may be cut away for tarts, and the fine berries left for dessert. If some of the reds, as the Warrington, and the thick-skinned yellows, as the Mogul, be matted over when the fruit is ripe, it will remain good till nearly Christmas.

The Raspberry.

The raspberry is a native of some counties in England, but has been greatly improved by culture. The choice sorts are—1. Red Antwerp, fruit large, of high flavour, ripe in July; but by being planted behind a north wall, can be retarded, and the season thus protracted some weeks. 2. Yellow Antwerp, light coloured, very bristly wood, of luxuriant growth; fruit admirable in flavour, luscious; peculiarly adapted to the dessert. 3. New double-bearing; it is rather an autumnal raspberry than strictly a double bearer; still, by due and timely pruning, a second crop is frequently obtained in autumn.

The raspberry is propagated by suckers taken up from among those which rise in abundance from strong plants. The fruitful shoots or canes bear but once, and should always be cut down in August, to admit air and light to the young shoots of the summer; and from these suckers (of which four or five are amply sufficient) some should be selected to renew the stock every five or six years, changing the soil or situation. Care should also be taken to remove the disorderly suckers which rise from the wandering roots. The soil for this plant should be a light loam well manured; an occasional dressing of lime-rubbish produces fine canes and very fine fruit. The plants, if placed in row, should stand a yard or four feet asunder. They may be supported by strong stakes, made to slope to the north; and, confining the bearing shoots to them, the successional shoots will rise perpendicularly, without interfering with the others.

To procure a sound and abundant crop in the autumn, Mr Mearns gives the following directions, which he has practised with success:—' Early in, or as late as the end of May, cut off, or even slip off all the young fructiferous shoots from the former years' canes; and in a brief period they will spring again from the same eyes, and instead of one shoot, they will produce two, and if the canes are strong and healthy, three, and often four shoots from the same eye, each equally as fruitful as the former, with the fruit upon all, as fine as upon the earlier single cane, and continue to produce plentifully through the months of August and September. The double-bearing varieties are generally valued for the purpose of late fruiting upon the strongest canes of the same season; but the fruit is inferior, both in size and flavour, to some of the new scarlet varieties. But to improve the strength of the canes, consequently its fructiferous powers, in the pruning season cut away every one of the canes of the former season, as they are not required, as there will be plenty of the choicer kinds at the same season those would be ripe, and they only rob and keep the light and air from benefitting the younger canes intended for autumnal bearing, and if well attended to, will produce fruit till the frost checks them. In the growing season, it is of importance to select only a few of the finest and best placed canes, and clear the ground of all the rest, or any superfluous matter, so as not to obstruct the light, heat, and air.

The Strawberry.

The strawberry is one of the few fruits indigenous to Britain, and is found, like the bilberry and juniper, in a wild state in uncultivated spots, chiefly in woods and on tangled shrubby banks. It is likewise found in all the other northern countries of Europe, particularly in Norway, among whose rocky mountains it grows in great abundance; it prevails also in the temperate regions of South America, and abounds in the colder climate of Canada and Nova Scotia. This delicious small fruit is, in short, very generally scattered over the earth, and was the delight of ancient as well as modern times. In Latin its name is *fragaria*, which is supposed to be significant of its fragrance; and the French, perhaps from this source, call it *fraise*.

The strawberry is one of those plants to which nature has given the means of extensive multiplication. From the main bush or stems there spread forth tentacula or suckers over the surface of the ground, and these fastening themselves by a root at every joint, as many new plants spring up as there are joints. A single bush will in this manner, if not kept within bounds, soon spread over a moderately-sized garden. From this abundant growth of the strawberry, it has been inferred that the fruit is of essential importance as an article of food in summer; but this is scarcely philosophical; for to what plant has nature given the means of propagation more abundantly than the dandelion, and what is so little used or held in less esteem by mankind? Be this as it may, the strawberry is universally acknowledged to be exceedingly wholesome and refreshing as an occasional summer diet, and it is also allowed to possess certain medicinal properties, which give it a still higher value.

In most parts of England strawberries are eaten alone, or dipped individually in sugar before being put into the mouth; and to suit this mode of consumption, they are brought to table with their stems, which form shanks to hold by. But in Scotland they are consumed in a far more wholesale manner. There they are brought to table stripped of their stems, and are ladled out and eaten with a plenteous infusion of cream and sugar. 'Strawberries and cream' is, in fact, one of the grand national treats which strangers may reckon upon seeing set before them in the early weeks of July, and to which generally full justice is done. In the neighbourhood of Edinburgh there are a number of suburban villages, deriving celebrity from their extensive strawberry grounds, and to those parties proceed from town to enjoy the fruit in perfection; that is to say, along with the richest and most delicious cream. In the vicinity of Dublin, the celebrated 'Strawberry Beds' in the same manner attract immense crowds of persons in the summer evenings, when the fruit is in its prime. Those who are accustomed to see strawberries only in the small potties in which they figure at Covent Garden, can form but a feeble idea of the consumption at either the Scotch or Irish metropolis.

Of late years, there have been many changes and improvements in the strawberry world. Fifty or sixty years ago, only about a dozen sorts were known, those of the largest size being called *hautboys*, from the *haut bois*, or 'high woods,' of Bohemia, where they were originally found. According to horticulturists, there are now some hundreds of select varieties, produced by crossing, change of situation, and other circumstances. An old and respectable strawberry, known as the Old scarlet, was introduced from Virginia in 1625, and has been the prolific source of several varieties. The Austrian scarlet, the Roseberry, the Scotch scarlet, the Aberdeen seedling, the Grove-End scarlet, the Downton, Sir George Mackenzie's late scarlet, Nova Scotia scarlet, prolific hautboys, and Keen's seedling, may be noticed among hundreds of others. Latterly, some poor sorts have been banished from the market, and given place to Keen's seedling, which combines good flavour with largeness of size, and is an excellent bearer. The object in cultivating so many varieties is to obtain a succession of fruit through the season, some sorts ripening and being ready for market in May, while others come to maturity in the course of June and July. It should be understood, however, that it is only in the neighbourhood of London that the successive cropping of strawberries, or the forcing of them at particular seasons, is methodically conducted on a large scale. In most parts of the country, the vicinity of Edinburgh included, the fruit in its different varieties comes almost at once into the market, the season lasting about three weeks, and then all is over. The exceeding precariousness of the crop, from the chance damage of rains, makes the rearing of strawberries a business of little profit, and lately it has been abandoned by a number of our market gardeners. This is a circumstance to be regretted; and we should hope that, by a greater attention to the cultivation of *late* sorts, which would not arrive at maturity till late in July and in August, a greater degree of success in rearing might be secured.

The following comprehend the general directions for culture:—The seasons for planting are March or September. The soil that all affect is a rich unctuous loam, trenched to the depth of two feet. The best and strongest-rooted runners of July are always to be preferred; and these should be planted at the periods above-named, with all their roots, into beds or borders recently prepared. Many persons retain their beds or rows, during an indefinite number of years, in a tolerable state of fertility; but the triennial system appears to combine every advantage, while it avoids the two extremes of annual renewals, and of protracted duration. When a bed is formed and in full bearing, it will require an annual surface-dressing of loam and manure, two parts of the former to one of the latter, early in the winter, to protect the plants and receive the new roots, which always are emitted just below the lowest leaf-stalks; in March the old leaves ought to be all cut off, leaving the hearts untouched; and the beds should be cleared of litter by a wooden rake. Prior to the fruit becoming ripe, the mowings of a lawn or of any soft grass laid over the surface will prevent the berries from being soiled.

Triennial System of Planting.—1. A plot or border of earth being trenched, as before directed, select, after the first rains of September, a quantity of strong and well-rooted runner-plants, and with a garden fork or trowel, set them one by one, fresh from bed, in the new ground; if in single border row, a foot apart; if in a bed, at the same distance plant from plant, but the rows two feet asunder. Fix each plant firmly, and give water over it from the rose of a watering-pot. If a set of plants be thus merely transferred without much disturbance, and watered three times, few will fail. Hoe the ground occasionally; and prior to or during the first frost, sprinkle some manure over and around the plants, and lightly pass the wooden rake over them. Suffer no blossom to expand in the following spring, but leave the plants to acquire strength. Stir the ground occasionally, and cut off all runners.

2. In the second September, prepare and complete a corresponding plantation. Manure and dress the plants during winter, and those of No. 1 for the second time; and in March trim off the old leaves, and rake the surface. Let the plants of No. 1 bear their full complement, the fruit of which ought to be early, abundant, and of first-rate quality.

3. In September, repeat the work, and thus complete the plantations. Treat this and No. 2 exactly as directed for No. 1. In the following spring, suffer No. 1 to bear a second crop, No. 2 its first crop, and obliterate the blossoms of No. 3. In the September of the fourth year, dig up all the plants of No. 1, turn the ground, manure, and replant it. Thus the routine will be completed; and thus, year after year, there will be a plot progressing in one of the three stages; and if, with each approved variety, a similar routine course be adopted—and especially if a plantation be formed in the three aspects, east, south, and north, the last under a hedge or fence, to screen it from the south sun—the season of strawberries can be extended between the latter end of May and the middle of August. For the latter period, Knight's Elton is peculiarly adapted; and they who can at that time command a supply of a fruit so fine and beautiful, will have ample cause for self-congratulation.

The Cranberry.

There are two species of this plant, the fruit of which is now so very largely employed as a kitchen article for tarts, and as a cheap and effective antiscorbutic among seamen. The common cranberry (*Oxycoccus palustris*) grows wild in upland marshes and turf-bogs both in England and Scotland, and generally over the northern parts of Europe. It is a trailing plant, with slender shrubby shoots, which are clothed with small linear leaves; the fruit is an austere red berry, about the size of the common currant. It flourishes by the sides of little rills, and not among stagnant water, as its botanical name would imply; hence the difficulty of making it an article of culture. The American cranberry (*O. macrocarpus*) closely resembles the common species, but is a larger and more luxurious plant. Its fruit is also larger, and of a longish shape; hence the term *macro-carpus*, long-fruited. Though growing wild in great abundance, it is a plant of easy culture; and in some parts of the United States, barren wastes, meadows, and coarse herbage are converted into profitable cranberry fields at little expense. The plant grows well on sandy bogs; and if these are covered with brushwood, the bushes should be cleared away; but it is not necessary to remove rushes, as the strong roots of the cranberry soon overpower them. Some old cultivators plough the land previous to planting; the latter process being performed by digging holes, four feet distant each way, to receive the roots of the young plants. In three years the whole ground is covered with the vines; and an acre in full-bearing will often produce two hundred bushels, which bring about one dollar per bushel.

The cultivation of the American cranberry in our own country was first recommended by Sir Joseph Banks, and several gardeners have been so successful in the attempt, that this berry may now be regarded as one of our cultivated fruits. 'Wherever there is a pond,' says Neill, 'the margin may, at a trifling expense, be fitted for the culture of this plant, and it will continue productive for many years. All that is necessary is, to drive in a few stakes, two or three feet from the margin of the pond, and to place some old boards within these, so as to prevent the soil of the cranberry-bed from falling into the water; then to lay a parcel of small stones or rubbish into the bottom, and over it peat or bog-earth, to the depth of about three inches above, and seven inches below, the usual surface of the water. In such a situation the plants grow readily; and if a few be put in, they entirely cover the bed in a year or two, by means of their long runners, which take root at different points. From a very small space, a very large quantity of cranberries may be gathered, and they prove a remarkably regular crop, scarcely affected by the state of the weather, and not subject to the attacks of insects.' Although a moist situation is best suited to the plant, yet, with a due mixture of bog-earth, it will flourish, producing abundant crops, even in a comparatively dry soil.

The Grape Vine.

The vine, from the juice of whose fruit wine is made by a process of fermentation, is a plant of Eastern origin, which, in the course of ages, has been introduced into all the countries of southern and central Europe, also England. Requiring a fine climate, it will not bear fruit in the open air farther north than York; and it is only in fine seasons, and in good exposures, that its fruit is worth eating even in the southern parts of Britain; in general, the grapes grown in gardens about London are small, and not presentable at table. In the north of France and Germany they are little better, and we do not really get fine grapes of a proper size till we reach Italy or Portugal. In England, however, grapes produced in hothouses surpass in size and flavour the fruit of the Portugal vines.

Throughout the continent, the practice is to grow vines in large fields, either on plains or the sides of hills, which are fully exposed to the sun. They are trained in rows, tied to stakes, and are pruned to a height of about four or five feet; on the Rhine, they seldom exceed three or four feet; and at a distance the ground has somewhat the appearance of being covered with staked beans or peas. In Italy, the vines are trained to a greater height, and are made to cling to horizontal palings, as if from the roof of a hothouse.

To those in the southern parts of England who desire to rear the vine in gardens and on walls, we offer the following directions:—The varieties most suitable for culture are—1. The white sweet-water, with round berries, somewhat tinged with yellow, and faintly streaked with red on the sunny side. 2. The white muscadine, bunches rather loose, berries not very large, yellowish, and abounding with saccharine juice. 3. The small black cluster, with berries between red and purple, closely packed, very sweet, and luscious in flavour. 4. Turner's hardy, or the esperione, a fruitful tree, and very certain bearer; berries of medium size, varying from dark-red to deepish purple.

Mr Hoare's treatise on the vine has added importance to the culture of this graceful tree, and has thrown great light upon the treatment it requires. Our limits forbid us to recur to the statements therein given, and we can only observe, that no one who possesses a gable-end, a brick-walled house, or indeed a wall or fence of any kind, need be without a vine; it affects no richness of soil, but will grow on the shallowest ground, over and in chalk or rock of any description; yet if a border can be formed with a dry and well-drained bottom, the tree will be rendered more vigorous though the fruit may not be exalted in flavour.

A sound turfy loam, to the depth of eighteen inches, rendered open by small fragments of old lime-rubbish and a portion of crushed bones, will support any vine, and promote its fertility; and these materials can be introduced by degrees, first near the roots, then at a greater distance, to replace a corresponding quantity of old soil; thus little expense will be incurred, and still less labour. But if a new border be contemplated, and outlay be not considered, it will of course be best to complete the work in the first instance.

Vines are propagated by single eyes, by cuttings, and by layers, placed in pots when it is intended to remove the plants to borders or vineries. The soil should be a light, rich, sandy earth, or perfectly decayed manure and sand in equal parts; but they who wish to raise vines without loss of time, should plant cuttings taken from vines of known fertility, and of the yearling shoots which are themselves actually fruitful. Each should have three bold eyes on the young wood, and each should retain at its base a small piece of the previous year's wood. The season for planting is the month of March, and the method very simple. Dibble a hole from four to six inches in front of the wall or fence, deep enough to receive the entire cutting. Mix together equal parts of black leaf-mould and white sand; put in the hole enough of this to raise the bottom one inch, and ram it hard with a blunt stick; then insert the cutting, and hold it firm in the centre of the hole, while that is filled brimful with the compost, which is brought into still closer contact with the shoot by pouring water into it two or three times. Make the ground quite even, and its surface level with the uppermost bud, then cover the cutting with a small hand-glass. If the ground is kept moderately moist, not two cuttings in a dozen will fail. If more than one shoot break, and attain the height of five or six inches, the stronger only should be retained, slipping the other off below ground. This shoot must grow till its point become spindling, when it should be nipped back; and all future growth should be thus stopped above its lowest leaf, as also the laterals that appear during the growth of the main shoot. Great care must be taken to keep the vine regularly nailed and secured by soft and roomy ties, to prevent accident, and the danger of being snapped by the wind.

As the aspects suitable to the vine are confined between south-east and a small point to the west of south, the cuttings, if not duly supplied with water, may be droughted and perish before they become completely furnished with roots; but when once established, the main shoot will grow rapidly, perhaps attaining the height of a common fence, and ripen their wood early. In the end of September, let each be cut down to an inch above the three lowest buds; mulch the ground around the stems and over the roots as winter approaches, and watch the spring progress of the eyes. If possible, obtain and secure two equal shoots; and if the wall or fence be from eight to ten feet high or more, lead these shoots horizontally right and left about six inches above the soil, and secure them by shreds and nails. If the wall be six feet or under, retain but one strong shoot, and train it perpendicularly. In September, cut back according to the strength; thus if the wood of the single rod last-mentioned measure from one-third to half an inch in thickness, and the eyes be full, and from four to six inches apart, cut the shoot at the top of the fence, removing also the remains of all laterals and tendrils. The two horizontals will perhaps be rather slighter, yet if they be fully ripe, and furnished with bold eyes, they may be left three or four feet long on each side of the short main stem, but all the buds on the under side of each must be cut away; mulch the ground as before, and in March following carefully fork in the manure.

Bearing Condition of the Vine.—The fourth spring will find the vines in a fruitful state; but previously, the trees prepared for a dwarf fence should be so pruned as to retain but three horizontal branches on each side of the main stems, about eighteen inches asunder, the intermediate branches being cut back to their lowest bold eye beyond the stem. This eye is designed to produce a new shoot, to take the place of the bearing shoot, which, after the fruit is taken, must be cut away. Thus the vine will henceforward produce, year by year, two systems of branches, one of which will comprise year-old bearing wood, the other a corresponding series of green wood, which will produce the fruit of the following year. This description would almost suffice to elucidate the habits of the vine; yet to leave no doubt on a subject which involves the entire theory of pruning, it will be understood that this tree bears its fruit solely upon the green shoots of the present year, which spring from the eyes of the pale-brown wood of the previous year. When, therefore, a vine is of age, and has acquired sufficient strength to support a crop of fruit, it will generally be wise to provide a new series of bearing wood every year, because the fruit of new wood (in the white varieties particularly) is always superior. In this horizontal alternate system for low fences, each new branch may safely be permitted to extend itself at least two joints beyond its predecessor, always remembering to cut back, early in the autumn, to a short distance above a bold eye seated on perfectly ripe wood; for thus the tree will acquire strength and extent at the same time; and experience proves that, in ordinary circumstances, the fertility of a tree should be moderated, and kept below the supporting power.

The trees on the second system of training for high walls must be pruned in a similar manner, and upon corresponding principles. In the autumn of the third year, three out of four branches will be cut down to the lowest bold eye, and a few vertical shoots, from thirty inches to a yard apart, will remain; and these also must be pruned to a strong eye situated on mature wood. This system will furnish new bearing wood every year, increasing in length as the power of the tree augments; while also the low horizontal stems will extend gradually in due proportion. At first one, or at most two bunches, must be permitted to remain upon each upright branch. In the fifth season, a greater crop may be taken, always, however, remembering to restrict the fertility of the vine; for by so doing, its vegetating power will keep in the advance, till, in the end, the entire fence will be filled with vigorous branches, annually renewed, from which a very heavy crop may be gathered without tasking the vine in any degree that shall produce debility.

The spur system of pruning back the bearing shoot annually may occasionally be adopted with black grapes, and not without advantage; yet the system of yearly renewal leaves the vine at the entire command of the pruner, and procures large clusters of fruit. The few remarks above offered enter little into minutiæ, but they elucidate general principles; and if applied practically, will, we believe, lead to improvement in grape-growing. We again profess to be much indebted to Mr Hoare, and recommend his treatise to every cultivator of the vine.

The fruit of the vine grows in clusters or bunches, as many, perhaps, as a hundred grapes in the bunch. It is not desirable that so many should cluster together, for when numerous they are apt to be very small, and to be so compact in the mass, that those within do not ripen. Bunches with many grapes, therefore, should be thinned, by clipping out those of the smallest size, which will allow the others to grow to the proper dimensions. In very many instances, grapes grown on walls in gardens are spoiled by vermin, the interstices in the bunches being often filled with spiders' webs and insects of different kinds. All this is a result of carelessness in not keeping the walls clean, and pruning and otherwise attending to the bunches. As a preventive, let the walls in winter be lime-washed, including all branches of the vines, and take some pains to remove all vermin which appear in the fruit season.

Forcing.—Of the growing of vines in hothouses or vineries it is not our intention to speak; but for the class of persons whom we address, the following account of a method for forcing vines in humble edifices, given by Mr M'Intosh, in the 'Orchard,' seems so suitable, that we take leave to offer it:—' In many parts of the continent, and even in some few instances in this country, vines are forced in very humble edifices. The Dutch, Flemings, and Germans use pits, often not exceeding three or four feet in depth. These are sometimes heated by dung or tan being placed within them, which give out a mild, humid heat, serviceable to the vine while the buds are breaking; and this, with the proper husbanding of the solar heat by judicious ventilation, is often found sufficient to produce ripe grapes at an early period. Other instances occur of such pits being heated by a smoke flue, to which very moderate fires are applied. But what is most novel in these pits is, the vines being planted outside—the wood that is to produce the fruit is trained under the glass within, while the young wood for succeeding crops is allowed to grow without, where, under a brighter sunshine than we enjoy, the wood becomes perfectly ripened; and when the crop is gathered, the old wood, or that which produced fruit this year, is entirely cut out, and replaced with the young wood hitherto growing without the pit. Vines are also ripened on the continent by having glass frames placed against the wall on which they grow, about the time the fruit is half or three parts swelled, at which period those glasses are not in use which have been employed in forcing early crops of melons, salads, &c. The solar heat collected by this contrivance ripens the fruit well, and fully matures the wood for the following season. We have it in contemplation, founded upon the success of this mode, which we have often witnessed on the continent with admiration, to erect a portable structure in the new gardens now preparing for his Grace the Duke of Buccleuch, at Dalkeith Palace, and of which the following brief description will convey a sufficient idea:—Supposing a south wall, built hollow, and heated with hot water (as all our walls are to be), be planted with the early ripening sorts of grapes, late peaches, and some of the best late ripening plums, such as Coe's golden drop, &c. The trees not to be excited in spring (which should never be attempted with hot walls), but rather retarded in their blossoming, by keeping the branches as far from the wall as possible till they begin to blossom, at which time they are to be laid in to the wall, and the blossom protected with thin canvas awnings, particularly during night. In July, at which period the roof-sashes of the early forced peach-houses and vineries will be removed, these are intended to be employed to cover the above wall in the following manner:—A permanent stone curb, twelve inches high or more (or a wooden plank of the same height will answer as well), is laid along parallel to the bottom of the wall, and at two feet distance from it. This curb is furnished with a groove an inch and a half deep and three inches wide, to receive the bottom rail of the sashes, the top rail to run in a corresponding groove, in a batten of wood fixed to permanent brackets near the top of the wall, the distance between the top and bottom grooves to be equal to the length of the sashes, the bottom rail of each sash to be furnished with two brass rollers, to facilitate their movement. The glasses, it will thus appear, will stand perpendicular to the wall, and at two feet from it, and ventilation, and the necessary operations of pruning, gathering, &c. can be carried on from without, the lights being made to pass each other in the grooves, as in the manner of what is called barrack windows. The concentration of solar heat in August, September, and October, with the power of applying fire-heat by means of the hot-water pipes in the walls, which may be safely used as soon as the glasses are put, will not only ripen our best autumn fruits, but also mature the wood and buds for succeeding crops. Grapes and plums may be prolonged by this mode, we think, till Christmas, or indeed until the glasses be required to be again put on the early forcing-houses; and our finest Flemish pears, late peaches, and nectarines, which do not often ripen well in England on the open walls, and never in Scotland, will be brought to the highest perfection. Hot walls we have long ago proved to be of little or no value in spring, but their efficacy in autumn no one can doubt, and their utility will be greatly increased by having this covering of glass before them.'

For information respecting the construction and management of hothouses and greenhouses, we refer to Loudon's 'Encyclopedia of Gardening,' also to the beautiful works of Mr M'Intosh.

MISCELLANEOUS FRUITS.

The following are fruits which cannot be strictly ranked among the preceding sections, and are grown almost exclusively in gardens of a high order:—

The Fig.

The fig-tree is a delicate exotic like the grape-vine, and great care is required to bring crops of the fruit to maturity in the open air. There are many kinds of the fig-tree, but the greater number are adapted to culture only under glass. The following are four excellent kinds:—The brown ischia; fruit large, rather globular; brown pulp; purplish-red; very rich in flavour, and melting; ripens in August. Brown Naples; colour brown without and within; a hardy fruitful tree. The large blue or purple fig, like the brown Naples, ripens about August. It is one of the best fig-trees; fruit long, and of regular figure; pulp red; of rich and fine flavour. Lee's perpetual bearer, which is well qualified for gentle forcing in pots. The best soil for fig-trees is a light fresh loam; but the chief essential to promote fertility is a hard and dry bottom of chalk, gravel, or artificial pavement; a dry substratum and little depth of soil (that is, from one foot to eighteen inches) are therefore what the gardener must provide, if he expects to render the trees permanently fruitful.

As to culture and training, both are extremely simple. Rogers says, and very justly, 'that the knife is seldom wanted' [that is, in shortening; though, from the extreme luxuriance of the wood, it is frequently necessary to cut out many entire shoots]; 'pinching off the points of the young shoots during the months of May and June with the thumb and finger is the most effectual pruning.' Mr Knight restricted himself to compressing the points of the green shoots till the substance was felt to yield under the finger and thumb, by which pressure a check is given to luxuriance, and the milky sap is diverted to the embryo, which lies embedded at the base of each leaf-stalk.

But to secure fruit in due season, the pruner must recollect that in Italy and the south of Europe two crops of figs are produced yearly. Those large figs which are seen on fruitful trees here late in summer, are developed in spring, and would ripen early in a warm climate; but our winters check their progress, and generally destroy them. The crop which ripens in August is developed late in the preceding summers, and is extremely minute, almost invisible, in September; it is situated near the terminations of those green shoots which have been pinched or compressed; therefore the large green figs (which have properly been termed *sterilising incumbrances*) should be displaced by mid-August, and then it will frequently be seen that two minute embryos form in lieu of the one; and these, if the tree be protected, will ripen at the season mentioned. As to protection, it will be proper to unnail and bend down the upper shoots, so as to bring them into moderate compass, then to pass a few straw bands among and across them, and finally to cover the whole with a mat or canvas sheet.

In April, train in, straight and regularly, all the bearing wood; and as the trees grow, suffer the breast wood to curve forward at its pleasure, pinching the points as directed. Not one shoot is to be cut shorter; but if the wood become redundant, branches which obscure the fruit should be removed, reserving those which will manifestly be fertile, and which can be duly trained in the following spring.

The Filbert.

The filbert is believed to be an improved variety of the common hazel-nut. Both plants are monœcious; that is, they produce male and fruitful blossoms very early in the year, on the same tree, but separate from each other: the catkins that become visible in autumn are the males or pollen-bearing flowers: the *crimson threads* are the pointals of the fertile nut-bearing flowers. As the trees are pruned—spurred, as it is termed—in autumn, care must be taken to reserve a number of catkins, otherwise the crimson pointals will fail to perfect the nuts. The chief varieties of the filbert are the red-skinned, the white-skinned, and the cob or Barcelona-nut. The following are the methods of culture:—Strong suckers, taken in autumn, are either planted in the nursery, or at once in the places where they are to remain; and these grow three or four years, and are then cut down within a few inches of the ground. From the stems several strong shoots are produced, which, in the second year after cutting down, are generally shortened by one-third of their length. Regular figure and an open head are procured by placing a small hoof within the branches, to which the shoots are fastened at regular distances. In the third year, as the bush approaches maturity, short shoots (spurs) spring from the eyes, and are suffered to grow till the autumn, when they are cut back nearly to their origin, whilst also the leading shoots of the previous year are shortened two-thirds.

In the following spring, several small shoots arise from the base of the small branches which were cut off the preceding autumn, in consequence of the curtailment of the leading trained branches, and upon these secondary spurs the fruit may be expected; these shoots augment in number yearly, insomuch that many must be cast away. The largest are removed; the lesser remain, being more fertile in their habit. Many decay yearly; but whether they do so or not, those which have borne filberts are always cut away, and a fresh succession provided as future bearers. The leading shoot is every year shortened two-thirds or more, if the tree be weak, and the whole height of the branches must not exceed six feet. In order to strengthen the tree as much as possible, the suckers of the roots are eradicated, by exposing the roots, at a moderate distance from the stem, to the frost. The excavation is, in the spring, filled with manure.

The crops thus produced are sometimes enormous, followed, however, by intervals of barrenness. We have not heretofore adopted the method of pruning, leaving the trees more to the order of nature; but it is right to try experiments; and when a row of young trees exists, a comparison might readily be obtained, by pruning alternate trees, or one of every three trees, by the 'spur system;' always, however, observing to keep the head of every tree open, and to cut away its upright central leader.

The Mulberry.

The mulberry is a native of Italy, introduced in 1548. The structure of its flowers and fruit is very singular; like the nut and filbert, the males are distinct from the females; the latter do not always expand at the same time as the males, and therefore are not fertilised. The calyx swells and becomes fleshy; each individual contains one or two seeds; and a congeries of these swollen organs form what is supposed to be a single mulberry. There is but one known species of the black mulberry, and this thrives best in loam, of the quality so often named; but the bed ought to be deep, and to rest on a dry sandy subsoil. The fruit sometimes fails; and on this subject Rogers observes, that fertility may depend very much on the warmth of the weather at the time of blossoming, and on the circumstance of both male and female flowers coming forth at the same time; sometimes also the male catkins drop before the fruit-blossoms expand. Williams of Pitmaston suggests 'that no tree receives more benefit from the spade and dunghill than the mulberry; it ought therefore to be frequently dug about the roots, and occasionally assisted with manure.' Others consider a velvety piece of turf as the best site. When the buds expand in the third spring, it is desirable to obtain four shoots on each side of the upright stem, and all the shoots that will break from the two horizontals, which latter are to be led upright, and secured as they advance.

ARBORICULTURE.

Scientifically, as well as popularly, the term *Trees* includes all those plants which attain a considerable stature, and possess stems more or less solid. They are, as all must know, by far the grandest objects in the vegetable world, and they are not amongst the least elegant. The timber produced in the stems also renders them of very great importance in many of the industrial arts, and in none more so than in that which has enabled man, from ages beyond historical record, to transport himself across the bosom of the deep, and communicate from one land to another the various productions of the earth.

PHYSIOLOGY OF TREES.

Trees are divided, with a regard to their structure, into two great sections. Some, which spring from seeds of more than one lobe, and grow by additional layers on the outside of the stem, are for these reasons respectively called *Dicotyledonous* or *Exogenous* trees, as the oak and beech; others, which spring from seeds of one lobe only, and grow by additions in the interior of the stem, as the palm and sugar-cane, are called *Monocotyledonous* or *Endogenous* trees. As our treatise regards the practice of arboriculture in our own country, where there are few of the latter kind, we must be understood in all general descriptions to refer to the former only, unless the contrary is mentioned.

Referring to Vegetable Physiology for details respecting the organisation and functions of vegetation in general, we may here merely remark that a tree consists of four principal parts—the root, the trunk, the branches, and the leaves. The *root* is that portion which grows downwards into the soil from the vital knot or collar; this dividing it from the stem or ascending portion. It consists of two parts—the body or *caudex*, and the long branch-like fibres, great and small, which disperse themselves abroad into the soil. The structure of the body of the root corresponds in a great measure with that of the stem, with the exceptions that no pith exists in roots, and that there are no regular joints or nodes for the production of buds. The rootlets terminate in slender spongy threads (spongioles), fitted for absorbing the sap of the earth, and sending it up by the fibres, whence it ascends into the trunk; and it is observed that the soil is exhausted of its nourishing matter only in the neighbourhood of those soft extremities of the roots. When the main root descends perpendicularly, it is called a *tap-root*; and when it divides just below the collar, it is called a *branching-root*. A tap-root is always set down first by a seedling plant; but as the plant increases in size and strength, the tap-root seems to disappear, as it either changes its form, or is surrounded by other roots, which soon attain such a size and thickness as to render the original tap no longer distinguishable. This is the case with trees and shrubs which, after the first few years, have in most cases branching-roots.

The *trunk* is called by Linnæus *caudex ascendens*, or root above ground, an illustration perhaps more fanciful than real. In common language, the trunk is often named the *bole*; and it is this part which affords the timber for which most trees are reared. The trunk, and also the branches, are covered with *bark*, consisting of a series of thin layers, one of which is formed (next the timber) every year; while in the outside of all is a very thin layer of a different substance, called the epidermis or cuticle, analogous to the outer skin of the human body. The new inner layer which is formed every year receives the name of *liber*; it was on this substance that the ancients, before the invention of printing, were accustomed to write; and *liber*, it is well known, is the Latin word for a book. Within the bark is the wood, consisting chiefly of vessels, great and small, which may be torn asunder from each other, and which are employed in conveying sap to the upper extremities. In the centre of the trunk is a small space filled with a soft substance called *pith*, which is supposed to be a reservoir of nutritious matter for the development of buds in spring.

The growth of a true exogenous bole is as follows:—The stem of a seedling consists at first only of cellular tissue, surrounded by an epidermis; but as soon as the leaves have expanded, some bundles of woody fibre are deposited, so as to have the appearance of a dotted circle just within the skin. As the tree advances in growth, the cellular tissue in the centre becomes pith, and rays of it extend to the epidermis between the bundles of woody fibre. A membrane, or rather layer of vascular tissue, then forms round the pith or *medulla*, so as to separate it entirely from the bundles of woody fibre, and the pith takes the form of a star with rays diverging from a centre. In the second year of a tree's life, the rays and the central pith both contract as fresh layers of woody fibre are deposited, and they continue to do so every year till the tree is full grown. In the second year's growth of a seedling tree, a complete layer of wood is formed round the pith just within the epidermis, and this is called the *alburnum* or *sapwood*. Another layer of vessels, like those in the medullary sheath, afterwards forms round the sapwood, so that when a second layer of wood is deposited, a distinct ring of vessels remains between the two. This process is continued every year, and as the layers of vascular tissue have always a different appearance from the tissue of the wood, the rings of vessels between the layers of wood, which are called *concentric circles*, and the medullary rays diminished to fine lines, may be always traced in a section of the trunk of a tree. The medullary rays become changed in time into thin hard plates, which still radiate from the centre to the outer circumference of the tree, and which form what is called by the carpenters the *silver grain* of the wood. The central pith in the meantime has diminished to a mere speck in the middle of the tree, or, as is frequently the case, it has entirely disappeared. The layer of wood, which is deposited every summer, always appears soft and white for the first year; and it is called the *sapwood* because the ascending sap rises through it the following spring. This wood is of no value as timber; and carpenters, in their contracts for houses, always agree not to use it, promising that their wood shall be free from sap, &c. The inner layers of wood in the tree form what is called the *heartwood* or *duramen*, which is extremely hard and durable. As the layers of wood are thus distinct, and as one is generally deposited in temperate climates every year, it has been supposed the age of a tree may be found by counting the number of concentric circles; but this rule does not always hold good, for the reasons hereafter explained. The sapwood of regularly-formed wood is always white, but some secretions are conveyed by the returning sap through the medullary rays into the heartwood, which changes its colour to brown of various shades, dark red, or even black, according to the specific character of the tree.

The *branches* require no further notice than that they precisely resemble the trunk in every respect, except that they are upon a minor scale in point of size. The *leaves* consist principally of tissue, like the trunk, with vessels throughout, and an external cuticle enveloping the whole; and they are connected with the branch by a foot-stalk or *petiole*. The leaf is one of the most important parts of the whole tree. By a most curious process, not perfectly known to us, the crude sap rises through the wood, in the manner just described, and is elaborated or prepared into juice of a more nutritious sort by the leaves. That process, according to some, is effected by means of an alternate contraction and dilatation of the sap-vessels, and still more by a respiration, perceptible and imperceptible, through the pores or stomata of the leaves, and by the action of heat, light, and air; but according to others, it is rather the exhalation from the leaves, than what are properly their respiratory functions, that effects the ascent of the crude sap. It is then converted into proper sap or *cambium*, and being fitted for the nutrition of the whole tree, it descends by the returning vessels of the leaf-stalk and the longitudinal vessels of the rind or inner bark. At length it reaches the roots, which originally supplied the crude sap itself. This elaborated sap is, like human food, digested into chyle; and as it forms the only real nourishment of the tree, it becomes apparent that the plant must decay if stripped of its leaves.

It has been already mentioned that the trunk of a tree (of the exogenous kind) consists of a number of cylinders enclosing one another like so many layers or concentric circles disposed round an axis; and that, as a circular layer is deposited every year, it is possible to ascertain the age of the tree by counting the number of the layers. M. Decandolle, one of the most celebrated botanists of modern times, has, as appears from a work on the subject, paid great attention to this method of ascertaining the age of trees. He observes that the method of reckoning now alluded to is not liable to much error, but the inspection must be conducted with the greatest care; for the older circles become condensed into a mass, and their number can only be guessed at by measurement. 'My plan,' says he, 'is as follows:—When I have got a section of an old tree, on which I can see the circles, I place a sheet of paper upon it, extending from the centre to the circumference. On this paper I mark every circle, showing also the situation of the pith, the bark, the name of the tree, the country where it grew, and any other necessary observations. I also mark in a stronger manner the lines which indicate every *ten years*, and thus I measure their growth at *ten years'* intervals. Measuring from centre to circumference gives me the circles, doubling this I have the diameter, and multiplying by six I have the circumference.'

The learned professor then presents a table of the periods of increase in the diameter of various trees, an inspection of which proves that every tree, after having grown rapidly when young, seems at a certain age to take a regular march of growth, which may perhaps be accounted for by supposing that young trees have more room to expand in, are less pressed by the roots and branches of their neighbours, and may not have penetrated down to a hard, arid, or otherwise unfavourable soil; and also that as trees advance in age they still continue to form layers as thick as they previously did subsequently to the period of rapid growth. If such tables were multiplied to a sufficient extent, as we have no doubt they will be in course of time, they would form data from which, by ascertaining the circumference of a tree, its age might be known without having recourse to the destructive process of cutting deep into the growing timber. 'If,' says our author, 'one cannot get a transverse section of a trunk, then one must seek for old specimens of each kind, the date of whose planting is known, measure their circumference, deduce their average growth, and calculate from them the age of other trees of the same kind, always keeping in mind that young trees grow faster than old ones.' Decandolle cites numerous instances of trees whose ages have been ascertained according to the rule here laid down. Some of these appear to be many centuries, if not thousands of years old; and what is remarkable, still exhibit symptoms of verdure and vitality.

The fact that trees of such vast age continue to bear foliage and fruit, affords indubitable proof of a very remarkable circumstance connected with the vegetable kingdom. In man and all other animals we find an organisation and a process of life going on which are destined to cease at a certain period. But it is otherwise with trees. They appear to possess the power of growing on for ever without exhibiting any symptoms of decay, unless from accidental or extraneous causes. We shall quote the words of Decandolle on this point:—'As there is formed every year a ligneous deposit, and generally new organs, there is not among the vegetable creation place for that hardness or rigidity, that obstruction of old and permanent organs, which constitute properly the *death of old age*, and consequently, that being the case, trees can only die from accidental causes. Trees do not die from age in the true sense of the word: they have no fixed period of existence; and consequently, some may be found that have arrived at an extraordinary age.' But although a tree thus possesses in itself the elements of continual strength and youth, numerous causes step in to interrupt or destroy its existence. In corroboration of what we state, we need only allude to the facts, that soil is of limited depth—that below the soil there are usually hard strata, which the feelers of a plant cannot penetrate—that roots intercrossing encumber each other, and check vegetation—besides which, there are other destructive and obstructive causes which we need not occupy the reader's time by specifying. Consequently, although what the French philosopher says is quite true, that 'some trees may be found that have arrived at an extraordinary age,' yet, every circumstance considered, we are not to be surprised if the number of such vegetable patriarchs should prove exceedingly small, compared with the immense extent of the earth's surface which is covered with forest growth.

CLASSIFICATION OF TREES.

In a view of arboriculture, trees may be classified according to their uses; for example—1. Trees which produce straight timber for masts and long planks—as the various tribes of pines. 2. Trees which afford crooked timber for knees or bends in the ribs of ships, &c.—as the oak, sweet chestnut, broad-leaved elm, &c. 3. Trees which give tough pieces of timber—as the yew, holly, thorn, ash, hickory, maple, laburnum, &c. 4. Hard-wood trees—as the oak, beech, plane, walnut, box, and holly. 5. Soft-wood trees—as the poplar, large willow lime, horse-chestnut, &c. 6. Wood grown for flexible suckers and spray, to form hoops, baskets, besoms, poles, &c.—as the dwarf willow, birch, &c. To these may be added woods of foreign growth—as rosewood, satinwood, and mahogany, which are employed for ornamental purposes.

According to another classification, trees are arranged as of three kinds—resinous, hard-wooded, and soft-wooded. Those which are resinous are also termed coniferous, from their producing seeds in cones. For the sake of clearness we will adopt this simple arrangement, confining ourselves to trees which may be propagated under the climate of Britain.

Resinous or Coniferous Trees.

There are three tribes of these trees, one of which, the Abietinæ, has four genera cultivated in the British islands—the Pinus, Abies, Larix, and Cedrus. Of each there are several species, all distinguished by their spicular leaves, their cone-like seed-vessels, and their resinous wood. Any of them may be easily raised in nurseries from seed. The more common species is the

Scotch Pine (*Pinus sylvestris*).—This is a tall and generally straight tree, with few branches on the lower part of the stem, the leaf apparatus being confined to the top of the plant, these forming a massive clump. It is indigenous to the Highlands of Scotland; but the little that is generally used comes from the forests in that quarter, the greater proportion being imported from the north of Europe, where a variety of it attains great perfection. For strong beams and spars required by house-builders, this timber is exceedingly suitable; but for smoothness and whiteness of fibre, it is excelled by a tree of much inferior strength—the Canadian pine (*P. resinosa*). On account of the heavy import duties levied on foreign pine, much of Canadian timber is employed in its stead, being thus devoted to purposes for which its properties no way qualify it. 'With reference to the common Scots fir,' says Brown (of Arniston), 'the best timber-trees for general purposes are raised where they are standing pretty close in one mass; but the most picturesque form of this tree is found when standing singly, and has room to spread out its branches. When grown in one mass close together, the trees are found clean-stemmed, and drawn up to a great height; consequently such trees are available for many purposes, whereas, when standing singly, the tree is generally found short-stemmed, thick, and branchy. No tree, a native of Britain, can with more safety be planted out into any soil and situation, provided only that soil be a dry one. I have seen a crop of good Scots fir taken off almost every sort of soil of an earthy or stony nature, but upon a mossy soil I have never seen good Scots fir timber grow.'

Spruce Firs constitute a well-known genus (*Abies*) of the Coniferæ, the more common being the Norway fir (*A. excelsa*), a tree which attains great height, but no great bulk, and furnishes white deal and spars of inferior size; it is also very suitable for masts and poles of all kinds. North America produces three species of spruce—the white, red, and black—each esteemed for particular uses connected with ship-building. The Norway spruce is now widely planted throughout Britain, particularly in the Lowlands of Scotland, and when enjoying a favourable situation, soon grows to a useful size. It is a hardy tree, and though its timber is softer and less durable than the Scotch pine, yet from the rapidity with which it grows, and its adaptation to a soil rather damp, it is frequently preferred.

The *Silver Fir*, called also the Pitch Fir (*Picea pectinata*), displays a greater depth of branches than the other firs, and becomes a majestic tree on arriving at full age. In this country the silver firs are only seen as objects of ornament on dressed ground; but how they would answer if planted closely together, and pruned up to form clear butts of timber, is uncertain, this having never, we believe, been tried in these islands. The quality of the silver fir timber of British growth is yet to be tested. The common silver fir, the balm of Gilead, and the hemlock spruce, have been long in our pleasure-grounds; but the yew-leaved, Fisher's, Douglas's, and Fraser's double balsam, are seldom seen beyond nurseries or pine preserves. The common silver fir is a hardy tree, even more so than the spruce, and is deserving of wider cultivation in our forests and plantations.

The *Larch*.—Of this valuable genus (*Larix*) there are several species grown in Britain and other countries; the more common is the *L. Europea*. The larch is the most beautiful in figure of any of this class of trees; shooting straight up, its elegant stem tapering to a point, is furnished with pendulous branches, ornamented with delicate drooping spray. Its qualities are rapid growth, flexibility, and durability in situations between wet and dry—a circumstance perhaps attributable to the quantity of resin in its fibre. In many parts of the country it is gradually superseding the common fir, over which it possesses a great superiority in point of ornamental effect. 'There are,' says the authority already quoted, 'two varieties of the larch generally cultivated in Britain—the white and the red. The white is the variety which attains the greatest dimensions of timber, and is the sort most generally cultivated, although they are both often seen growing together in the same plantation, and that by mere accident. It is said that upon the Athol estates the red larch does not contain above one-third the cubic contents of timber which the white larch of the same age does; and this is observable in every plantation where the two varieties are found growing together. No timber-tree at present cultivated in our woods begins to repay the expense of culture so soon as the larch does. It is a rapid growing tree, and is well adapted for almost every country purpose. It generally sells at nearly double the price per cubic foot that Scots fir brings; and besides the price of the wood, the bark is available for tanning. The circumstances which are found favourable to the healthy development of the larch are—as to soil it is not particular, but the roots must have a constant supply of water, in order to keep the earth in which they grow in a pure state, as is the case upon all rugged mountain-slopes where there is a continual descent of water from the higher ground to the lower.' On very arid soils the larch never grows freely, and soon dies off with a stunted lichen-clad bole; and on flat ground, where water is liable to stagnate, though the young trees may succeed for a few years, yet they are never found to prosper, but die away as soon as the mere surface turf is exhausted of its nutritious properties by the radicles.

The *Cedar* (*Cedrus Libani*) is remarkable for its long horizontal and often crooked branches, and the great mass of dark-green spicular foliage with which it is covered. It is a native of the mountains of Libanus and other high adjacent regions, where it attains great bulk, and grows to a very long age. From its solemn aspect, it forms a suitable accompaniment to cemeteries or ecclesiastical buildings, and also for sequestered glens in mountain scenery, or for extensive lawns. Cedars were introduced into Britain as far back as 1683; and there are but few old country seats which do not possess some specimens. Many majestic ones are met with in different parts; but in no situation have they thriven more prosperously than at the celebrated residence of Moor Park, in Hertfordshire. So numerous and large were they upon this estate—according to the British Cyclopædia—that about 1798 scores of them were felled for sale, containing four and five loads of timber in their butts only. These fine trees were mostly purchased by London builders for quartering, at a low price, the timber being found far inferior to the common Scotch fir. Cedars are trees of very striking character, and give an air of grandeur to every scene in which they appear. There are two or three varieties: some assume the conical figure of the other coniferæ; others extend their branches horizontally from the top of a short thick trunk, forming a dense canopy overhead; while others, again, are very much divided, near the ground, into many upright stems, which, with their horizontal spray, form, in the course of years, a vast bush.

Cedars may be raised from seeds which ripen in England, or from seeds imported from the Levant. When got from the cones, which is a work of some difficulty, they are sowed in deep seed-pans, or boxes; and when fit for removal, the seedlings are nursed and placed in pots, until they are large enough to be planted out in the open ground. While nurslings, many of them require a stake, to which a leader must be constantly kept trained, in order to insure a regular growth.

The *Yew* (*Taxus baccata*) is more frequently grown as an ornamental than a forest-tree, and, like the cedar, it forms a plant suitable for places consecrated to solemn feeling. Its timber is very tough, and is adapted for making bows and staves; hence it is commonly ranked among hard-wooded trees. As an ornamental tree, it should be fenced round, or otherwise placed beyond the reach of cattle, as its foliage is highly poisonous; and being evergreen, is very apt to be browsed upon during the winter.

Yews are believed to be the most ancient trees of Great Britain; and no doubt can exist that there are individuals of the species in England as old as the introduction of Christianity, and there is every reason to believe very much older. It is the opinion of Decandolle, that of all European trees, the yew is that which attains the greatest age. The following are some of the more remarkable British specimens to which the attention of the curious has been directed. Those of the ancient Abbey of Fountains, near Ripon in Yorkshire, which yews were well known as early as 1155. Pennant says, that in 1770 they were 1214 lines (a line is the tenth of an inch) in diameter, and consequently, according to Decandolle's method of computation, were more than twelve centuries old. Those of the churchyard of Crowhurst in Surrey, on Evelyn's authority, were 1287 lines in diameter. There are two remarkable yews still in the same cemetery, and if they be the same which Evelyn refers to, they must be fourteen centuries and a half old. The yew-tree at Fortingal in Perthshire, mentioned by Pennant, in 1770, had a diameter of 2588 lines, and consequently we must reckon it at from twenty-five to twenty-six centuries old. The yew of Brabourn churchyard in Kent has attained the age of 3000 years; but that at Hedsor in Bucks surpasses all others in magnitude and antiquity. It is in full health, and measures above twenty-seven feet in diameter; thus indicating the enormous age of 3240 years! In all likelihood this is the most ancient specimen of European vegetation.

Hard-wooded Trees.

In this class are included a large number of trees with which every one is familiar. The list embraces—the oak, ash, elm, beech, chestnut, walnut, common sycamore, mountain ash, whitebeam, acacia, birch, wild cherry, Scotch laburnum, holly, hazel, box, elder, and hawthorn. The following are the principal:—

The *Oak* (*Quercus*) is the most valuable of all the timber-trees grown in Britain, not only because it is a hardy native, but for the many important purposes to which its durable timber, its astringent bark, and even its nutritious fruit, are applicable; and, moreover, for the delight which it gives to the eye in sylvan landscapes, the oak being the most picturesque tree of the forest when it has arrived at its mature age and form, and is still clad with foliage.

There are two species in our woods, whether natural or planted—namely, the *Q. robur*, whose acorns grow singly and with long stalks; and the *Q. sessiflora*, whose fruit grows in clusters, with short acorn stalks. The former is said to be the old Druidical British or naval oak, though the latter is more frequently met with, especially in woods which have been planted by the hand of man. The stalked-fruited is also of quicker growth, and is altogether what may be called a more elegant tree when full grown. The quality of the timber of both, when any difference is observable, is more owing to the difference of soil they have grown on perhaps than to any specific difference of the trees. Besides these two common sorts, which are natives, there are thirteen other species, which are exotics—namely, the willow-leaved, the evergreen, ash-leaved, cile-cupped; ilex, of which there are six shrubby varieties; chestnut-leaved, scarlet, velanida, white, Italian, durmast, Lucombe, and the Turkey, of which there are four varieties. This last is a fine free-growing tree, and deserves a place in every plantation. The other exotics are chiefly planted for ornamental purposes, not being yet considered as forest-trees.

All the species are readily raised from their acorns (oak-corns) when they can be procured; and in default of these, most of the foreign sorts may be grafted on the common. The young plants are transplanted twice or thrice in the nursery; and when four or five years from the acorn, may go to their final stations. Any kind of clayey loam is suitable for the oak; but a good gravelly loam, upon a subsoil of blue ferruginous clay, produces the finest timber in the shortest time. 'The largest oaks I have ever seen,' says J. Brown, 'grew upon a dry sandy loam, with a free exposure to air: however, although the oak may attain its greatest dimensions under such circumstances as these, we find it growing to the size of useful timber wherever it has the advantage of a soil with a dry bottom, and not too much exposed to storms—as, for instance, upon the top of a bare hill. The oak will not thrive nor live long in a damp mossy soil.'

England, as well as Scotland, at one period possessed many noble and remarkable oak-trees, the remains of which are in some instances still to be seen, while in others they are only remembered in tradition. Thus every reader has heard of the Fairlop, the Worksop, Damory's, the Great Oxford, the Skeleton, and other oaks. The first, for example, stands in a glade in Hainhault Forest, in Essex, about a mile from Barkingside, and has been known through many centuries by the name of Fairlop. The tradition of the country traces it half way up the Christian era. It is still a noble tree, though it has now suffered greatly from the depredations of time. About a yard from the ground, where its rough fluted stem is thirty-six feet in circumference, it divides into eleven vast arms, yet not in the horizontal manner of an oak, but rather in that of a beech. Beneath its shade, which overspreads an area of 300 feet in circuit, an annual fair was long held on the 2d of July, and no booth was suffered to be erected beyond the extent of its boughs.

The *Ash* (*Fraxinus excelsior*) is also a very valuable hard-wood tree, its timber being useful for many rural purposes, and particularly for implements and machines. The common ash, being prolific in ripening seed, is dispersed pretty generally over the face of the British isles; it is nevertheless much better managed when planted for timber or for underwood, unmixed with any other sort of tree. It should never be allowed a place in a hedgerow, nor on pasture-land, as its numerous surface-spreading roots engross to themselves every particle of nutritive moisture, to the destruction of all other surface-plants. According to the authority just quoted, the circumstances which are found favourable to the healthy development of the ash are, as regards soil, a good strong loam, rather rich than otherwise, and rather moist than dry—that is, the ash does not disagree with a little moisture, provided that this moisture have free and ready access away from the roots, and is not liable to remain in the least degree stagnated. The ash is also rather fond of shelter, and therefore, to grow it well, it is an advantage to plant it in a hollow or glen, or in the interior of a large plantation.

An ash-tree is in its prime when, by free and vigorous growth, it has attained a diameter of about twenty inches; for though on rich gravelly loam it will continue to increase until it is four or five feet in diameter, it has probably begun to rot at the core long before it has arrived at that vast bulk. Therefore, in order to raise ash-timber of the most valuable description, it is necessary to sow or plant a piece of land of the above character thickly, placing the trees about two feet apart. These will rise rapidly; and as soon as they appear to be choking each other, one-half of the poles may be drawn, and the rest allowed to stand till they arrive at a marketable size, which is when they are from eight to twelve inches diameter, and from forty to sixty feet high. When *ground-ash* is of these dimensions, it is suitable for every mechanical purpose where flexibility and extreme toughness are required. From its upright habit of growth, the ash forms one of our best forest-trees; and what is especially deserving of notice, its timber is better—that is, more tough, elastic, and durable—the more rapidly it is grown.

Seed should be gathered in the autumn, and immediately sown in nursery-beds; or the sowing may be deferred till spring. Some of the seeds may not rise till the second or third year; but as soon as the seedlings are five or six inches high, they should be rowed out to gain strength till finally transplanted. There are several varieties of the common ash, one of which is the creeping-branched, but which, by grafting it high on the tall stem of the common one, is made a rather ornamental weeping-tree. Other species are the yellow-barked, curled-leaved, various-leaved, and a great many other exotic species.

The *Elm* (*Ulmus*) is a lofty tree, valuable both for its use in the arts and its ornamental appearance. The small-leaved or English elm is generally preferred for planting, particularly in hedgerows, avenues, and the like. This tree is not a forester, never being seen but about dwellings, or where dwelling-houses have formerly stood. It is probably an exotic, as its seeds never ripen in this country, and is therefore propagated by suckers, which rise abundantly from the old roots, which circumstance makes the tree so eligible for hedgerows; for where once planted, fell the principals as often as wanted, a succession of young stems constantly appears. They are also propagated by layers, and often by grafting on the common wych-elm, especially when wanted for dressed ground, or for avenues where it is desired that no suckers should be seen.

Besides the common wych-elm (*U. campestris*), found wild everywhere in the hedges of Britain, and which grows, where allowed, to a large size, yielding large butts of coarse-grained but useful timber, there are several other sorts raised in nurseries—namely, the cork-barked, smooth, declining-branched (a truly picturesque tree), spreading-flowered, the white, and several others. All the elms delight in a gravelly loam, or in any soil which is not too wet, and they are well worth the planter's attention. No tree bears lopping or shredding better than the elm, it being hardly possible to hurt it by dismemberment. It is raised from seed when produced. In the forest, it requires considerable space, as its natural habit is to throw out on every side broad spreading branches. When confined, it grows up with a slender weakly trunk, the timber of which is of little use to the carpenter.

The elm attains a very large size, and has a very rapid growth, both in Europe and America; but the elm of the latter country has a much more majestic appearance than that of Europe. Michaux characterises it as 'the most magnificent vegetable of the temperate zone.' A specimen mentioned by Decandolle, which grew near the town of Morges in Switzerland, measured 17 feet 7 inches in diameter, and was estimated at 335 years of age.

The *Beech* (*Fagus sylvatica*) is a native forest-tree, occurring most commonly on the chalky districts of the kingdom. When full grown it is a beautiful and stately tree, and its timber is convertible into many kinds of domestic articles, very durable when polished by the cabinetmaker, and equally so if kept constantly under water. The beech is a very fruitful tree; and its mast or nuts, together with acorns, used formerly to fatten vast droves of swine and herds of deer, the then common food of the feudal lord and his vassals.

Young plants are readily raised from the seed sown on beds, and covered with loose soil about an inch thick. Like other seedlings, they are, when five or six inches high, rowed out on fresh ground, till large enough to be transferred to their final stations. The beech is not at all fastidious as to soil, so as there is some portion of calcareous matter present; but a subsoil of chalk or limestone is most congenial. According to Mr Brown, few trees suffer less from mismanagement than the beech; and upon thin, poor soils, and even in high and exposed situations, no hard-wooded tree is so worthy of a place. He has seen the beech grow well upon a soil and situation where almost no other tree could have existed, not even the Scots fir. There are several species: the white-American, the dark-purple, and the iron-coloured-leaved, are ornamental, and are propagated by grafting on the common. As a forest-tree, none of the species are now extensively planted, in consequence of the comparatively little value set upon beech timber.

At Newbottle Abbey, the seat of the Marquis of Lothian, a few miles south from Edinburgh, there are some remarkably fine large trees, most probably planted by the monks prior to the Reformation. 'Professor Walker measured a beech at this place in 1789; its trunk, where thickest, was 17 feet in girth, and the span of the branches was 89 feet. He thinks that it must have been planted between 1540 and 1560. It was blown down a short time before the year 1809. It contained upwards of 1000 measurable feet of timber (twenty loads, or twenty-five tons), and it is with reason reckoned among the largest beeches that have ever grown in Scotland. Another at Taymouth, of a like size, and seemingly coeval with this, was blown down when it had reached above 16 feet in girth. The large beech at Ormiston Hall, in Haddingtonshire, the bole of which we remember to have seen scooped artificially out into a shelter-house, was measured on the 10th of May 1762, and found to be 18 feet 10 inches. We believe it was quite entire when it was destroyed by a high wind. A large beech near Oxenford Castle, in Edinburghshire, was measured on the 6th of June 1763. At the height of three feet from the ground it was 19 feet 6 inches. This fine tree was then decaying. From the state of the Ormiston Hall and Newbottle trees, it may be concluded that the beech, if it meets with no accident, will grow with sound timber for at least two hundred and fifty years.

The *Chestnut*, or sweet chestnut, sometimes also called the Spanish chestnut (*Castanea vesca*), is a splendid forest-tree, exceeding all other British plants in its huge mass of foliage; it is also valuable for its timber, which is but little inferior to the oak. In the south of Europe it is chiefly regarded as a fruit-tree; but here, even in the south of England, in the finest summers, the fruit ripens but imperfectly. As a timber-tree, however, the Spanish chestnut deserves to be more generally planted than it has been of late years; and for a coppice or underwood plant it has no superior. For the number, the straightness, and durability of its poles, it excels all others, when a little trouble is taken to keep the growth perfectly regulated with respect to the purpose for which the crop is wanted. When timber or ornament is the object, the trees must constantly be divested of the shoots, which are apt to rise from the collet of the stem. A strong loamy gravel seems to suit this tree best; and young plants are easily raised from the nuts, dibbled in rows in the spring, and, while in the nursery, kept free from bottom shoots. The sweet chestnut requires considerable shelter, in order to permit of its full development; and should always be cut down before arriving at maturity, as the heart-wood is very liable to decay.

The *Common Walnut* (*Juglans regia*) is chiefly regarded as a fruit-tree, but it is no less valuable for its excellent timber, which, from its lightness and durability, is well adapted for gun-stocks. Where its fruit is of no great value, and especially where it does not ripen, if planted among other forest-trees, it would be drawn up into a shapeable single stem, as valuable as many others. Young trees are readily raised from the nuts, like the chestnut, and are similarly managed.

The *Sycamore*, *Great Maple* or *Plane-tree* (*Acer pseudo-platanus*), is a hardy native tree, which attains a large size, and has the property of growing more quickly than most other hard woods. It is employed to form household utensils and objects in turnery. It not only grows to a large size, but lives to a great age. 'There are many sycamores in Scotland at the present time,' says the 'Forester,' 'which I have myself measured, and found nearly twenty feet in circumference and sixty feet high. It is not a tree that carries height along with its girth; but it is, notwithstanding, a magnificent tree, and few, if any other, can vie with it upon the lawn or park. The circumstances which are found most favourable for the healthy development of the sycamore are—a dry sandy loam with a free exposure, as in the open parks about gentlemen's home grounds; however, it may be profitably planted in almost every situation, except in a damp or mossy soil.' The Oriental plane is one of those trees which attain the largest size, but the rate of its increase is not ascertained. In the valley of Bujükdére, about three leagues from Constantinople, there is a plane which recalls to mind one which Pliny has celebrated. According to the Roman naturalist, there was a plane-tree in Lycia which had a hollow trunk capacious enough to accommodate the consul Licinius Mutianus and eighteen followers, who found within its ample cavity a retreat for the night. This living vegetable grotto was 75 feet in circumference, and the summit of the tree resembled a small forest. The plane at Constantinople is 150 feet round, and within it there is a cavity of 80 feet in circumference. This transcends the tree of Pliny. There are other very large Oriental planes mentioned by Clark and others; and one of vast size was lately noticed by Mr Quin in his voyage down the Danube.

The *Mountain Ash*, familiarly known in Scotland as the *rowan-tree*, from its beautiful clusters of red rowans or berries, is a tree of small dimensions, but elegant form, and is grown principally for ornament in shrubberies. It is hardy and of easy growth in dry soils, and makes an excellent skirter or outside tree in ornamental clumps and plantations; its finely-formed foliage and white blossom yielding variety in summer, and its deep red berries as striking a variety in autumn and early winter.

The *Acacia* is not only a highly ornamental, but also a highly valued timber-tree, when allowed to attain a proper size. Though a native of Virginia, and there called the *locust-tree*, it has been recommended as a coppice plant for this country, because of the very quick growth of its young shoots, which rise from roots after the stem is cut over; and for the excellent and durable quality of the poles for fencing, and particularly as props for hops and other trees. But whether planted thickly for underwood, or in more open order for timber, the acacia requires much attention from the pruner during the first five or six years of its growth. It produces large luxuriant lateral shoots, which are but slightly attached to the stem, and which, if not stopped—that is, their points pinched off when they are about one foot long—are very likely to be blown off by the wind. This care may cease after the tree or pole is ten or twelve feet high, for after that height the growth becomes moderate. Young plants are raised from seeds or from layers, and thrive on any light sandy soil. The timber is highly prized by millwrights for cogs and other friction purposes.

The *Wild Cherry* or *Gean-tree* (*Cerasus avium*) is a hardy native, but is seldom cultivated as a timber-tree; nor has it that care bestowed upon it which it really deserves. The best specimens to be met with are those which have risen by accident in woods; but when such are felled, they are readily purchased by the cabinet-makers. As mentioned under FRUIT TREES, the wood is very suitable for boring and forming musical instruments. It is therefore a tree not to be neglected by the general planter, and should have place among others. Young plants are raised from the stones, sown thickly on a bed of good soil, either in autumn or in spring, and afterwards rowed out to receive the ordinary nursery treatment, until fit to be finally planted.

The *Hornbeam* is a forest-tree, but it ranks as an inferior one; its timber, however, is remarkably tough and durable, and consequently invaluable to the plough and cart-wright. It is a scrubbed, tortuous-growing tree, unless it has some pruning bestowed upon it when young. It is also a pretty good hedge-plant, and useful for forming screens or boundaries in gardens. Plants are raised from the keys, or seed, of which plenty are produced every year by old trees.

The *Birch* (*Betula alba*) is another inferior timber-tree, but useful as a coppice plant for many rural purposes. It has a beautiful and elegant contour, on which account it is introduced into ornamental scenery, especially if water be in the composition. Of the common birch there are several varieties, not to speak of the poplar-leaved, the tall, and the black American. Young plants are most conveniently raised from seeds, and the exotic species are raised from layers, or by grafting on the common one. Wherever there are poor thin-soiled stony heights, the birch may be planted as a useful cover; and its timber, if properly taken, is readily bought up for gunpowder charcoal.

The *Holly* (*Ilex aquifolium*) is a remarkably hardy evergreen, with smooth shining leaves furnished with prickly points. It is a native of Britain, and attains a great age, but seldom reaches a large size. Its timber is white and hard, which renders it suitable for veneering, and for making mathematical instruments. Different varieties are grown as ornamental shrubs.

The *Box* (*Buxus sempervirens*) is generally grown as an evergreen shrub, but when planted out with a proper soil and climate, it attains a height of from twenty to thirty feet. It grows to perfection in Turkey, whence its timber is imported for use in all cases in which exceedingly fine cross grain is required. Sawn across and planed, its surface is as smooth and fine as polished metal. Box blocks are on this account employed for wood-engraving.

Soft-wooded Trees.

In this section may be included the horse-chestnut, lime, alder, poplar, and willow.

The *Horse-Chestnut* (*Æsculus hippocastanum*) is only valued for the beauty of its flowers and the majestic port of the full-grown tree in park scenery. The timber is very inferior, and the nuts are only useful for deer. There are several species of this tree—namely, the smooth, Ohio, ruddy, and the pale-flowered. All these have prickly fruit, and are easily raised from their large nuts. They require shelter and good rich soil; grow rapidly under these conditions; and soon form highly ornamental objects. A section of this genus is called *Pavia*, or bucks'-eye, their fruit being round and smooth. (See BOTANY, p. 55.) The flowers of some of these last are magnificent, being of a glowing red, and are most conspicuous in the spring or beginning of summer. Avenues of these trees, as seen in the neighbourhood of Geneva, are of the most splendid description when in flower. The pavias are often propagated by being grafted upon the common horse-chestnut, and some of them are only shrubs.

The *Lime* (*Tilia*), of which there are several varieties, is a beautiful leafy tree, grown chiefly for ornament, and very suitable for avenues. Those which have most effect are the red-twigged and broad-leaved American, the latter possessing elegant pendulous flowers. As all the varieties require a heavy soil and sheltered situation, and their timber being not of corresponding value, they are seldom or never introduced into the forest. The lime is the European tree which, in a given time, appears capable of acquiring the largest diameter. Decandolle has some observations on the rate of growth of this tree, which may prove useful. He says—'That which was planted at Friburg in 1476, on occasion of the battle of Morat, has now a diameter of 13 feet 9 inches, which would give about two lines of annual diametric growth. This is about the rate of the increase of the growth of an oak, and therefore I suppose the tree had not found a favourable soil, and it would be nearer the truth to calculate the annual growth of the lime at four lines. There are in Europe a great number of limes of large size, and it would be interesting to have the circumference of those whose date is known. I shall mention for their size that of the Château of Chaillé, near Melles, in the department of the Deux Sèvres, which in 1804 measured 15 metres round (about fifty feet), and which I suppose was then 530 years old; that of Trons in the Grisons, already celebrated in 1424, which in 1798 measured 51 feet in circumference, and which I calculate to be 583 years old; that of Depeham, near Norwich, which in 1664 was 48 feet in circumference; and that of Heustadt in Wurtemberg, which in 1550 was so large as to have need of props, and which in 1664 was 37 feet 4 inches in circumference.' The largest now known in England grows in Moor Park, Herts.

The *Alder* (*Alnus glutinosa*) requires a peculiar locality—that is, a damp, bog-earthy soil; is but seldom ranked among forest-trees; and, except to occupy a spot where nothing much better will grow, is seldom noticed. It is most profitable kept as underwood; large poles, suitable for the turner, or for piles or planking for bridges, fetching a good price. Of common species there are four varieties, together with the hoary-leaved, oblong-leaved, waved-leaved, glaucous, with several varieties of these, and some shrubby species, the most of which are propagated by cuttings, or by grafting on the common one. (See Systematic Botany, p. 103.)

The *Poplar*.—There are several species of this tree—as the common black poplar (*Populus nigra*), the trembling poplar, the Lombardy poplar, and black Indian poplar. They grow rapidly, and rise to a great height, but narrow in mass, so as to be very conspicuous in hedgerows and landscapes. The timber is soft, but a good deal sought after; and where undrainable spots are wished to be decorated with stately trees, no better kind can be chosen.

The *Willow* (*Salix*), usually called the *Saugh* in Scotland, is an extensive genus, comprehending those shrubby species, the osiers, used for basketwork. A few species of the willow attain to the height and character of trees, the best of which, as yielding very good timber, is the white or Huntingdon (*S. alba*); and the crack-willow make excellent pollards, furnishing every five or six years a large crop of poles indispensable to the farmer. Another of the tree willows is that elegant plant the Babylonian or weeping-branched one, which forms so suitable an accompaniment to pieces of water, whether artificial or natural. The common osier is the sort mostly cultivated for the basket-maker, and the annual crop of rods from established stools pay the owner as well as any other crop on the farm. All the varieties are easily propagated by cuttings.

REARING OF TREES.

Trees grow spontaneously in all countries in which soil and climate will permit, and, as is well known, form forests of many hundreds of miles in extent on the North American continent. Whatever be the peculiar nature of any species of tree, it appears that the dimensions and form of all are more or less affected by their relative situation. If crowded, they have a tendency to grow tall and slender; if left abundance of space, they extend in breadth. The comparative absence or presence of air and light causes those distinctions. In a forest, each tree struggles upward, for its leaves to get a sufficiency of pure atmosphere and sun's rays, and therefore becomes all stem and top; whereas the tree in an open ground shoots out branches nearly from the bottom of the trunk, and attains a grandeur in its mass of foliage. Trees which are freely exposed are also much thicker and harder in the trunk than those in forests. This arises not only from having plenty of air and light, but from being exercised by winds. The well-understood principle in the animal economy, of exercise strengthening a limb—as, for example, the legs of a dancing-master or the arm of a blacksmith—is extended to the vegetable kingdom, in which those plants that are gently moved to and fro by winds, arrive at greater perfection of ligneous fibre than those kept altogether still.

In connection with this remarkable effect in the economy of plants, it is to be observed that all exposed trees have the largest roots; because, being liable to be blown over, they require to take a much firmer hold of the ground than if they were sheltered on all sides; in other words, the action of the tree, and the free air and light, cause numerous branches and a large breathing apparatus of leaves, and the tree must have a corresponding mass of roots for the supply of sap. So exact is this correspondence between the exposed and underground portions of the tree, that the extent of roots may always be judged of by the extent of branches, the one being of the same breadth as the other. The practical lesson acquired from these facts is, that to have trees with large bushy heads, they must be planted widely; and if wanted to be tall and slender, they should be more closely planted.

The generally thin soil and comparatively ungenial climate of Britain render this country unsuitable for the growth of the more delicate and fine kinds of foreign timber; but all the forest-trees already noticed, when planted and attended to with some degree of care, attain great perfection. The business of planting is seldom performed by the unprofessional culturist, being more advantageously left in the hands of nurserymen, who rear the trees from seeds, layers, or cuttings, in grounds set apart for the purpose, and at the proper time transfer them to the locality where they are to remain. For the sake of general information, we offer the following observations on different departments of this interesting subject.

Ornamental Plantations.

Even on the smallest possessions, a sprinkling of forest-trees in the hedges or corners of the enclosures gives a dignity to the spot which otherwise it would not possess. There cannot be a more cheerless object in a landscape than a house—however substantially built and furnished—standing naked and alone, without a sheltering tree or bush to indicate either the taste or competence of the occupiers within. The lowliest hut, environed by two or three aged oaks or hawthorns, is an interesting spectacle, and far more delightful to the eye than the proudest palace standing bare, and unaccompanied by trees.

To secure these embellishments, planting on an ornamental scale is necessary, and much good taste must be brought to bear on the subject. It is now allowed by all who have studied landscape gardening, that in the part surrounding the mansion trees should not be dotted about at equal distances, nor in lines; they should not be placed as blinds to the principal windows, but so arranged as to form irregular glades, diverging in as many directions from the house as can be done with effect and propriety. These glades should always be laid out with reference to some distant interesting object, or some striking feature of the surrounding country. The offices, which are generally in the rear, or at one end of the house, should be hidden by a screen of trees and shrubs; and all eye-sores, visible from the windows or elsewhere, should also be screened by plantation, which has a double advantage—namely, hiding a deformity by a profitable screen.

When it is intended to increase both the beauty and the value of an estate by planting, and whether for the personal interest of the proprietor, or with a view to that of posterity, ordinary prudence will direct him to fix on those parts which are the least valuable for agricultural purposes. The precipitous slopes of an undulating surface, where cultivation is difficult or impracticable—moist swampy hollows—or the ridges of bleak hills lying to the northward or eastward of the superior portions of the park or parks, whether arable or pasture land—will all be found the most eligible for conversion into woodland. And while such plantations yield the finest shelter and covers for game, they keep rapidly adding to the real value of the estate.

Whenever a project of planting is entertained, if only to occupy waste or worthless ground, it is not easy to separate the idea of ornament from the utility of the design, if it be no more than establishing an acre or two of coppice; for even such a feature, especially in a naked country, requires a little attention in the execution. Coppice, when properly stocked with the right sorts of plants, only appears in all seasons as a thicket of shoots of nearly equal height. Consequently the eye of taste would condemn the plantation as too lumpish, and wanting in variety of outline. But this, though but a trifling defect, may be easily obviated by planting tufts or groups of trees, variously disposed, to remain for timber; or the same thing may be effected by leaving at the first fall a few groups of the most promising saplings, here and there irregularly over the area. These permanent groups will not injure much of the underwood, while they will give as much variety to the whole as may be necessary. This point, however, will be again adverted to when describing the manner of laying down underwoods.

As the beauty of many places constitutes their chief value, and as that beauty is mostly if not entirely owing to the tasteful disposition of the plantations, it behoves every improving proprietor to study well the genius and character of his property before he begins planting on a large scale. The safest plan, in order to avoid taking any step which may afterwards be regretted, or to be done over again, is to sketch an idea, or upon the map, a comprehensive design, embracing everything that may be done with propriety. This being well digested and settled in the first place, may be called the general plan, and of which *as much only* as is most obviously called for, and practicably expedient, may be first of all executed, leaving the more distant and less necessary operations to be done as time and opportunity may allow. Such a general plan of planting an estate, whatever its extent may be, requires a considerable acquaintance with the principles of what is termed landscape gardening, and can only be designed and executed properly by the owner himself (who can do nothing wrong in this way, so as he pleases himself) or by a professional adviser.

It has already been observed that some proprietors may think it advisable to plant only the inferior portions of their acres, while others, who are determined to have a tastefully-planted park or a highly-embellished estate, place their groves, or groups, or single trees on any eligible spot, without regard to the quality of the soil, whether the worst or the very best. In this case everything is sacrificed to obtain such a disposition of the trees as will produce the most striking scenic effect; and such kinds only are selected as blend harmoniously with each other.

The character of the general surface surrounding a mansion fixes the style of planting and the kinds of trees. If the surface be moderately undulating, having easy swelling knolls and gently falling hollows, without asperities of any kind, such a surface is said to be beautiful, and consequently the plantations should be beautiful also; that is, composed of trees of the finest foliage and most elegant forms. But if, on the contrary, the surrounding country be wild in character, and marked with bold and rugged features, as naked rocks or cliffs, deep ravines or glens, &c. then a different style of decoration must be pursued—as planting in irregular masses all the most grotesque, ragged, and sombre-tinted trees that can be selected, in order to harmonise with the natural features of the country. Scenery of this kind is said to be picturesque; and where such tracts of country are chosen for a manorial residence, and the grounds are laid out and planted by a skilful gardener, the scenery is much more interesting to the eye of taste than any other, especially if water chance to be in the composition.

Great changes occurred in the style of planting during the eighteenth century. Up to the beginning of the reign of George I. all transplanted trees were arranged in right lines, as single, double, or quadruple avenues or vistas, or as boundaries to the enclosed grounds belonging to royal or other palaces, colleges, and other public buildings. But about this time it was discovered that very *few* ranks of trees were to be seen in the works of the great masters in the schools of painting; a new idea was entertained that, in all real scenery about to be created in the parks of the nobility and gentry of the British isles, ranks of trees were inadmissible, as being too stiff, formal, and not agreeable to nature. Thus a sentence of condemnation was passed upon every private avenue in the country, and they quickly disappeared before the axe of the woodman. A few only were saved, but they were curtailed in length; and now very few new avenues are planted. Along with the avenues, all the old regularly laid-out terraces and flower gardens were swept away, to make room for a new style, distinguished by the prevalence *of irregularity* and *curved outlines*.

Soon after this revolution in landscape gardening, a great many ridiculous pranks were played in obtaining *extreme* irregularity and *tortuous* lines; and some of the performers got severely handled by the satirists of the day. Kent, who began the revolution, died without having gained much reputation; but his successor, the famous 'Capability' Brown, became highly eminent, and was universally employed. He did more in altering the gardens and grounds of the country-seats of these kingdoms than any other professor before or since his time. His aim was to produce unmixed beauty by neatness and general smoothness, especially near the house; for which purpose he cleared away every obstruction, whether built or planted, in order to set the mansion fairly out upon a naked grass plot or lawn. Even the kitchen gardens were removed as far off as possible; and every bush, or other appearance of inequality was shaven off, to produce the wished-for smoothness. In this proceeding he and his copyists fell into the opposite extreme; instead of beauty, *baldness* was the result; instead of intricacy, *tameness*; and instead of the embosoming shelter of surrounding groves, complete nakedness and exposure to every wind that blows. This exposure detracted from the consequence of the building, whatever might be its size or style of architecture; because a partial display is always more interesting than a view of the whole at once. Nevertheless, Brown had the honour of laying out many beautiful parks and gardens, which remain to this day as monuments of his good taste and judgment; but many of his immediate followers brought discredit upon his style by their very awkward and unmeaning imitations.

The severe animadversions published against the Brownian style tended to correct some of Mr Brown's most ostensible errors; and the works of Messrs Repton, father and sons, Loudon, and others, have improved the style of English gardening, and brought it much nearer to the principles of real taste. The *clump* and the *belt* have been greatly modified; the first is now expanded into a less formal group, and while the latter has lost its continuity, it has been increased in depth, and its lengthened form as a boundary judiciously broken. Undergrowths, which were swept away by Brown, are again introduced; and the banks of lakes and rivers, formerly smoothed down to the water level, are now left more abrupt, broken, and irregularly fringed with overhanging trees, and aquatic shrubs and herbs.

Forest Planting.

The different methods pursued in establishing or laying down woodland, seem to have been determined by the number of acres or nature of the ground intended to be planted. Nevertheless there are certain points which in every case are worthy of the planter's attention, such as the best form for any given extent, the style of boundary, and the mode of enclosure. On these heads we transcribe the advice of a practical forester of long experience. 'As the future welfare of a plantation is considerably affected by the manner in which it is laid out, no man ought to attempt the laying out of ground for one, who is not naturally possessed of good taste for that sort of landscape scenery which is based upon the laws of nature, which will enable him to lay out the proposed plantation in such a manner as to give the greatest possible effect in ornamenting the neighbouring country. It is also necessary that the person who would lay out ground for a new plantation, should be possessed of a knowledge of the nature of the growth of each sort of tree when planted upon any given soil or situation; which knowledge will enable him to judge rightly as to the effects that certain trees will have when planted in any given spot; and he will also be enabled from such knowledge to say truly whether or not trees will grow well in the situation chosen for a new plantation. And it is further necessary that the party, in the laying out of a new plantation, should be acquainted with, or at least have in view, any local peculiarities of the district relative to cold and destructive winds from certain points. From such knowledge he will be able to lay out the proposed plantation in such a manner that it shall have the greatest possible effect in giving shelter to the surrounding fields, which is the principal end a proprietor aims at in having woods upon his estate.

The larger that any piece of plantation is, the sooner will the trees therein come to useful size, and answer the desired end; and the smaller it is, the more likely are the hopes of the planter to be disappointed. And the reason of this is obvious: for the young trees growing in an extensive plantation, as soon as they rise a little above the surface of the grass or heath, begin to shelter one another; whereas if the plantation be narrow, the young trees can hardly be said ever to come the length of sheltering one another—for every breeze of wind blowing through the whole breadth, acts upon every single tree almost as powerfully as if each tree stood singly and alone. Therefore it is most profitable for proprietors always to plant in large masses. Trees planted in a mass of one hundred acres extent will be more healthy, and come sooner to profitable size, both as affording timber and shelter, than they would if planted in a mass of ten acres. From this it follows, that if a proprietor wishes to plant one hundred acres upon his estate, he will raise more healthy timber by planting in *one* mass, than he would do by planting the same extent in four masses of twenty-five acres each. No young plantation, upon an exposed situation, should be less than one hundred yards broad at any given point; and where the soil is of a light, thin, mossy nature, and not apt to raise trees to good size, one hundred yards may even be too little for breadth.'

Again, 'the method of laying out plantations in the form of strips, so often to be met with in Scotland, gives a poor and mean appearance to a gentleman's estate, particularly when found about the home grounds. The form in which they have generally been made is in straight lines, from twenty to thirty yards broad. In such narrow belts of wood the trees are very seldom found in good health; and, upon a little consideration of the matter, this is not to be wondered at—because, from the narrowness of such strips, the proprietors were always afraid to thin them, wishing to keep them in a thick state, in order to give as much shelter as possible; and the natural consequence is, from being left too thick, the one tree soon kills the other. And even where such strips have been well managed, it cannot be expected that they could produce either good healthy timber or make a good shelter; for, being so narrow, the trees never come to shelter one another. But it is a happy circumstance in the history of arboriculture that few such strips are now planted: gentlemen are now beginning to see the impropriety of such a method of raising plantations; and now, almost in all cases of good management, we see the old-fashioned narrow strip giving place to the well-defined, extensive plantation, which is, indeed, the only profitable way of rearing trees for any economical purpose.'

Further, 'it is absolutely necessary that every piece of ground laid out for a plantation should be fenced in some way or other, previous to its being planted. A fence not only prevents the inroads of sheep and cattle, but it at the same time tends very much to shelter the young trees, and to bring them on rapidly. It is, indeed, surprising to observe the difference that a very low fence makes upon the growth of young trees, as compared with those which are not protected by one. Any proprietor or forester, upon looking through his several plantations, will observe that, in all young plantations, the most rapid growing, and at the same time the most healthy trees in it, are to be found immediately behind the outer fence; and upon the other hand, in all older plantations, the best grown, and at the same time the most healthy trees, are to be found in the centre of the same, or at least a considerable distance back from the fence. Now, it may be asked, what is the reason that the best wood is found in the inner parts of old plantations, while the most rapid growing trees are to be found, when young, behind the boundary fence? The reason, as proved from experience, is this:—During the first eight or ten years of the age of any young plantation, the boundary fence is the only shelter that the young trees have; and it is evident that those trees which grow immediately behind the fence will receive most of the benefit of its shelter; consequently, from the circumstance of their receiving more shelter than their neighbours further off, they must grow more rapidly, until such time as their tops begin to rise above the level of the fence, when they are considerably checked by the cold winds. At this stage they begin to grow thick and bushy, rather than advance in height; and immediately upon their becoming so, they begin to shelter all their neighbours inside, which, again, begin to have double the advantage of their neighbours outside; for the trees upon the outside had shelter only so long as they were below the level of the top of the fence, whereas those inside have now a shelter which every year increases upon them for their advantage, in height as well as in thickness. All this comes in to prove that a fence is a great means of furthering the healthy development of a young plantation, independent of its protecting from the inroads of cattle at the same time. I always calculate that a plantation with a good fence is ten years in advance of one without such protection.'—*Brown's Forester*.

Seedlings—Modes of Planting.

To secure a full supply of the plants required, and these of the proper sort and age, it is requisite that they be previously raised from seed on the premises, or be easily procured from a nurseryman in the near neighbourhood. Where a great extent of planting is intended to be done, the former plan is most economical; but the latter, in general, is the most convenient. To raise forest-trees from seed is an easy affair: it is only choosing a piece of good mellow soil within some enclosure; this must be trenched or double-digged, laid level, and freed from stones, &c. by the rake, divided into beds four feet wide, with one foot alleys between. In the month of March, sooner or later, according to the forwardness of the season, the seeds may be sown either in drills lengthwise of the bed, and deeper or shallower according to the size of the seed; that is, nearly an inch for small, and an inch and a half for large seeds, such as acorns and chestnuts; or small seeds may be sown broadcast, by withdrawing with the rake towards the alleys about an inch of the surface each way. On the fresh soil, the seeds are thrown as regularly as possible, and covered by having the removed soil again drawn over regularly and smoothly. The seed-beds must be guarded from birds and mice; and if the weather be warm, and parching winds prevail, they should be covered occasionally with mats, and also watered, if necessary. Seedling trees are usually transplanted into rows in nursing beds, some in the second, others in the third year; and there to stand till planted out for good, which should be done when they have arrived at a proper size—the nature and condition of the ground intended for them, as already observed, determining this point.

The surface to be planted may either be in a state of nature, and covered with heath, or with a turf of some kind or other; or it may have received some kind of preparation, as paring and burning; or ploughed, digged, or deeply trenched. It is almost unnecessary to add that the first is in the worst, and the last in the best condition for the reception of young trees. There are many cases, however, where there is no choice but the first; and yet the success which has attended such undertakings as planting a naked hill or a barren common is a direct encouragement, and proves that such naked portions of the country may be in a few years covered with useful trees.

When a large extent of such description of land is intended to be planted, it must necessarily be executed in the most economical manner. If the enclosed surface be acclivous, and covered with short herbage and thin staple, two or three year old plants of larch, Scotch fir, birch, intermixed with a few oak, beech, and ash, may be inserted by a one-handed tool, somewhat like a cooper's adze. One or two blows of the tool raises a triangular piece of the surface, under which the root of the plant is properly placed, and the raised sod turned back and trodden down with the foot. In this simple and expeditious way of planting, many hundred acres of hilly land have been stocked with trees; and though many of the plants are liable to suffer, if a dry summer follows the planting, a majority are sure to succeed, which well repays the cost. When such ground is level, an opening is made by first cutting the turf in the shape of a cross, and turning back the four corners from the centre, breaking up and making a hollow for the root; when the tree is placed upright, the turf is returned and trodden firmly down.

There is yet another method of planting rough unprepared ground, called *pitting*. The surface covering is first cleared off, the pit broken up with a mattock, and the loose earth thrown out with a spade; the tree is then placed, and planted with the removed soil. This method of planting is expeditiously performed when the ground works kindly; but if wet or clayey, the business is more difficult, the pits requiring to be opened, and the land drained, long before the trees can be planted.

The above methods of planting forest-trees are only had recourse to when the ground cannot be prepared in a superior manner. And notwithstanding the risk of being defeated in such attempts, it is quite certain that in numberless cases they have succeeded admirably; and very valuable woods now ornamenting both England and Scotland have been raised under these simple modes of planting.

When it is intended to plant a field which has been or may be ploughed, it is got in order by receiving a thorough fallow, to clear it of every kind of weed. The ploughings (with a strong team and plough) should be made as deeply as possible. Supposing the land to be got in perfect order by the middle of October, if intended for timber only, the trees may be immediately planted; but if intended for underwood as well as timber, the last ploughing may be deferred till January; and if the ground be then pretty dry and mellow, the whole may be immediately sown broadcast with a mixture of seeds, and harrowed in, after which trees may be planted at the distance of four or five feet. The mixture may consist of the seeds of oak, ash, beech, Scotch fir, and birch; and if a sprinkling of common furze be added, it will be no detriment. If Spanish chestnuts are intended to be a part of the underwood (for which they should always be preferred), the seeds should be dibbled in, as they are too large to be covered by the harrows.

This method of laying down woodland, if carefully performed, is always successful, as there is not only a full number and choice of trees for timber established, but the field answers the purpose of a nursery for many years, from which may be drawn unlimited numbers of young seedlings for planting elsewhere. Some of the finest and most profitable woods we happen to be acquainted with were laid down in this way about the year 1775.

The next successful method of planting forest-trees is placing them on deeply dug ground; for if digging be practicable, it is a proof that the land is in a good condition for their growth. The action of the spade forms a bed sufficiently deep for the generality of the best sorts of timber, and the loosened state of the soil renders the planting easy.

But by far the best preparation of the ground is trenching it eighteen or twenty inches deep. The surface, which is usually covered with vegetation of some kind, or the remains of vegetation, being turned to the bottom of the trenches, forms a fine nutritious stratum for the roots to luxuriate in; besides, the staple being opened and intermixed so thoroughly, admits all atmospheric influences, without which no plant can thrive.

When trees are planted upon either a dug or a trenched surface, seeds may also be sown and pointed in, for undergrowths are always valuable for some purpose or other. This is particularly necessary when the plantations are required as covers for game; and in park scenery, hawthorn, holly, and juniper berries, should always be sown when the trees are planted.

When ornamental plantations are made in a park, and especially if they are in view from the principal windows, they are wished to rise as quickly as possible, for the sake of immediate effect. The trees, therefore, receive extraordinary treatment. The ground is not only carefully and deeply trenched, but a most liberal dressing of good rotten dung and vegetable mould—the first trenched down, and the latter dug into the surface—is bestowed, and which of course excites the trees into much stronger and more rapid growth than if only the ordinary expedients were employed. But this superior and expensive practice is seldom necessary, and much seldomer executed. Indeed, in the rearing of extensive forests for valuable timber, it would be decidedly injurious; for though the young trees might rise rapidly for a few years, as soon as the exciting influence of the manure was over, they would, as all experience teaches, soon fall into a diseased condition, and never attain that hardy robustness which natural forest timber always presents.

Planting on Bad Land.—The preceding directions are sufficient in all cases in which the land is tolerably dry, or which may be rendered suitable by a little preparatory culture; but when the ground is moist, and barren of all useful produce, the following methods of preparation will require to be pursued.

The first thing to be done with a piece of wet land is to drain it, and then enclose it with fences. The draining operations will consist in making wide and deep ditches around the land to receive and carry off the water, and into these smaller cross drains are to be led. (For a minute account of the best methods of draining, see CULTURE OF WASTE LANDS, p. 500.) If the drains be finished in October, so as to allow the water to run off for three months, planting may begin about the middle of February, provided the weather be dry. 'I would recommend,' says a writer on this subject, 'strong plants, three years old; for I have seen many small things stuck in among rank grass, but I have rarely seen any of them grow. The ordinary way of planting does well enough for the firs; it is done in this way:—A cut is made at right angles to the line of the labourers' feet, another is made at right angles to that, and the soil raised; the root of the plant is inserted; and the spade being withdrawn, the soil is, or ought to be, firmly trodden down around it. I say ought to be, for very often it is not. The labourers ought to have the importance of this reiterated upon them; and I would, if possible, always have a big man in preference to a little one to wield the spade. There is an emphasis in the tramp of his foot, which, for the success of the young tree, is invaluable. The other mode of planting is more tedious; but where the proposed plantation is small, I think it is worth while to give all the additional trouble. This method consists in making pits for the reception of the plants. A square piece is dug out, the plant is placed in the middle, the soil is broken and put round the roots, the turf is cut in two, and being turned upside down, the halves are placed one on each side of the stem of the plant, and firmly trodden down all round. This, it will be seen, is tedious. Three plants may be planted by the first method for every *one* by the second; yet, where the plants are large, it is worth while to bestow the additional labour: especially in planting trees of the deciduous kind, this method ought always to be adopted. I have always found it advantageous to plant pretty close; but care must be taken to begin early to thin, otherwise the young trees fall into consumption. Ground treated in the manner now described, be it never so wet, will grow fine trees; that is to say, if there is anything like a soil at all.

Let us next suppose the ground to be planted to consist of a thin, poor soil on a hard close bottom. To plant such ground just as it lies, is a piece of the most consummate folly. Far better burn your young plants at once: they never will grow to anything. The plan which I have now to propose has a most formidable objection against it—it is very expensive. But let the proprietor arrange the matter in this way: instead of planting, say ten acres in one year, let him plant only four. It is far better to have a few trees thriving, than a great many pining out a miserable existence, to the disfigurement of the face of nature and the bitter regret of their owner. The first thing to do is to set about trenching the ground. To the ordinary mode of trenching there is a most decided objection. That part of the soil which is at all good, is mercilessly buried at great labour and expense; and the hard till, which has about as much nutrition for plants as freestone rock, is brought up to form the soil. This will never do. We must keep the soil which is at the top still at the top, and stir the till below. At first sight there is some difficulty here, but the difficulty must be overcome, and that may be done by a little calculation as to arrangements in the matter of digging and filling up the trenches. The cost will be only a little more than that of ordinary trenching, and it is vastly superior to it. It would also be an advantage, as each trench is cleaned out, to give it a rough course of picking along the bottom, which would make the soil, although never so wet before, dry and sweet as a garden. The best time for performing this operation is in the months of February and March, and then only when the weather is dry. It would be well if planting could be carried on simultaneously with trenching; in which case see that the plants be put in *deeper than usual*, and well trodden round the stem.

Ground thus treated will produce the finest trees. They will grow fast, keep free of moss, be healthy in the bark, and straight. It would be advisable, even with this trenching, to open drains throughout the whole that is planted, in order that the surface-water may be carried freely away. Land, when thus dried, becomes richer by every shower that falls. The water, in percolating through the soil, carries down with it a fresh supply of oxygen gas, which the roots of the trees, with their thousands of little mouths, are gaping to receive as their most nourishing food; and being thus fed, is it not natural that they should grow apace and be in good health? In this way you will have in six or eight years fine plantations, forming an ornament to your property and a shelter to the fields. By the other method you may plant thousands of trees; but where the soil is positively wet, you will never see any of them do more than make an ineffectual attempt to grow.

I have now a few observations to make regarding the after-treatment of trees planted in the manner now recommended. They must not be left to themselves; and if hedges be planted, they will require much care, for the first three years especially. They must be kept perfectly free from weeds, at whatever expense of labour. Thin, board-like hedges, cut close upon each side, are not the thing. I never saw any so treated do well. They must have breadth, and should be tapered on both sides to the top. But let us attend to the trees. Exactly a year after they are planted, where the ground has been trenched, it will be requisite to give a partial hoeing—that is, to cut down any tall weeds which may be overtopping any of the trees. Should any of the hard wood, in place of being green, become yellow, there is a plan which, if adopted, will completely restore them. Two years after they are planted, let them, in March or April, be cut over about three inches above the ground; in the month of July a careful person must go through and pinch off all the young buds except one, the healthiest, and the one which offers fairest to shoot into a main stem. This has a most magical effect. It insures a healthy tree, with a free bark, and perfectly straight. I have had oak, ash, and other timber thus treated, which have made beautiful shoots of upwards of two feet in one year. Trees which are on the whole thriving and sufficiently straight, but which are getting hard in the bark, I have generally improved very much by the following process:—You enter the point of a common gardening-knife as near the root as possible, and run it up to the first branches. In a year or two this cut will be covered with new bark, an inch or two in breadth, greatly contributing to a free circulation of the sap, and consequently promoting the health and growth of the tree. I have seen trees twenty and thirty years old materially benefited by this process. A handy labourer will do many hundreds in a day.

If the hints I have now given be followed, I am quite confident that they will save much disappointment to proprietors who are disposed to plant, and that many fine trees will be raised on situations in which, by the common management, they never would have attained to either beauty or value.' To this we need only add, that the young trees should be carefully distributed in the plantation according to the nature of the soils and the situations. In any large area of irregular surface there are generally patches of dry stony ground, of moss soil, of deep loam, or of light gravel; and not only so, but some portions will be more exposed to cold winds and rains than others, some portions will lie favourably to the south, others perhaps to the north or east; and while part of a forest may lie along the banks of a low sluggish river, others may be situated at many hundred feet above. Now as trees have different constitutions and habits, and are differently affected by soil and climate, it is evident that the forester who attends to these habits, and plants accordingly, is far more likely to succeed than he who plants hap-hazard, or with but little attention to these peculiarities. 'I have often regretted very much,' says another tree-cultivator, 'to see larch and Scots firs of thirty years' standing in an unhealthy and dying state, where, if beech or any other of the native sorts of hard-wood trees had been planted, they would undoubtedly have proved both useful and ornamental; and again, as often have I seen stunted-looking hard-wood trees striving for existence, where, if firs or pines had been planted instead, all would have been well.'

Pruning—Thinning—Felling.

When woods are planted as sources of profit, a very material part of their subsequent management is the labour of pruning and thinning the trees. It is not enough that trees grow and be annually increasing in bulk—they should also be assisted to take the finest and most valuable forms. A round straight butt, of moderate length, is far more useful and saleable than a crooked knotty one of twice the size. To have fine timber, it is absolutely necessary to bestow a little trouble to start them fairly off, during the first ten or fifteen years of their growth. The best method of raising a plantation is by using a mixture of different sorts, which may be deemed *principals* and *secondaries*. The first are those for which the land is judged most suitable, the second are nurses or supernumeraries, intended to be drawn out as soon as they press injuriously upon the principals, or when they have attained to a useful or marketable size.

To have tall and straight stems, the trees must be planted thickly at first; that is, only about four feet apart, or even less. In this order they shelter and prompt each other to ascend; and if in the spring the woodman pays his annual visit, armed with a light keen bill and a narrow *turning-saw*, he may direct the growth with the best effect. Every lateral branch which appears to be attracting too much of the powers of the plant, and especially if, as already observed, it be contending for supremacy with the leader, should be sawn off *close* to the bole as soon as it has attained a diameter of one inch. Such a wound will be soon healed up, and present no flaw when the tree is cut up at the saw-pit. All branches of smaller size need not be removed, for they serve to enlarge the trunk, and have no effect in distorting the grain until they attain the size when they should be pruned off. If branches are allowed to remain until they have acquired a diameter of from two to four or more inches, and then cut off either close, or, what is much worse, at some distance from the bole, the timber is sure to be deteriorated. Such wounds, it is true, will be healed over in time, but the timber will be wanting in its best property—namely, soundness and freeness from knots. All branches originate at the pith of the main stem; and whether they are alive or dead when the tree is felled, they are equally objectionable in the estimation of the builder or mechanic. The knots in fir timber are less objectionable, because they are preserved sound by the resinous quality of the sap; but neither are they desirable, if trees can be grown with a clear uninterrupted grain. The most valuable part of a tree is the bole, and the longer and freer from knots this is, the more saleable; and if any or every tree may be made to grow into fine sound boles of fifteen or twenty feet in length by such attention as is recommended above, it is surely worth the trouble and expense.

Trees grown for ornament in lawns require no other pruning than what may be necessary for the removal of rotten or decaying branches; and in general it will be found advisable to leave each kind of tree to assume its own natural form. Ornamental trees are always most beautiful in their proportions when the branches and spray reach towards the ground; but this will not be the case if cattle are allowed to browse beneath and around them. These animals nibble away all the foliage and spray within reach, so as to form in park scenery what is called the *browsing line*—an even bottom of foliage, anything but agreeable to the eye. The only plan of avoiding this inelegance is to exclude browsing animals altogether from ornamental grounds; but this is attended with opposite evils, and takes away that pleasing assemblage of forms which is the great charm of woodland scenery. Where cattle or sheep are permitted to browse, all young trees at least must be protected by circular palings, otherwise they would be disbarked, and generally destroyed.

All species of the hardy pine and fir tribe intended for profit should be planted pretty thickly; the supernumeraries thinned when young, but leaving a full number of principals to grow up to a marketable bulk, or until they cease to thrive, when they will all be ready for the axe together; for such woods cannot bear to be thinned gradually like other trees, being particularly liable to die if they lose the protection of their neighbours. When planted as nurses among deciduous trees, they are easily kept within bounds, and from damaging the other trees, by pinching off, from time to time, the *leading buds* of their branches. This induces a spray-covered, rather than a naked stem, and thus maintaining their character as nurses. By the same means, fir-trees may be formed into impervious screens, or sheltering hedge-like boundaries, very useful in many cases of rural improvement. Respecting the pruning of fir-trees planted for profit, and which are intended to grow up with clear-grained butts, a rule has been laid down by planters which is easily followed: it is this—prune off the lower branches every second or third year, always leaving *five tiers* of branches to form the head. This regular method of keeping the butt divested of its lower branches, and continued up to the highest convenient height, will certainly insure fine butts of clear-grained timber, as all the knots will be small, and all near the centre of the axis. The fine clear-grained butts imported from America and the North of Europe are trees which were never pruned; but having grown up in very close order, the lower spray was consecutively killed by the want of air and light, shut out by the close canopy of branches above. This is gaining sound timber by accident, and which may be done in any country, but by no means in such a short time as may be done by hand pruning.

According to James Brown, 'the distance at which trees in a plantation ought to stand one from another, must in all cases be determined by the nature of the soil and situation upon which the trees grow, and also upon the ultimate object the proprietor may have in view as regards any particular plantation; but as a sort of guiding rule for thinning, I may here state, that if in any particular plantation it should be intended to rear up trees for park or lawn scenery, then in such a case the distance between each individual tree ought at least to be equal to the height of the same; and this rule ought to be kept in view at all stages of the growth of the trees, in order that they may have free room and air to form spreading tops as well as massive trunks, which is the true and natural form of every tree, and which constitutes the great beauty of lawn trees. If it should be intended to rear up a plantation of hard-wood trees principally for the sake of value in timber, and of giving shelter at the same time, then in such a case the distance between each individual ought to be equal to about one-half the height of the same; and this ought to be kept in view at all stages of the growth of the trees, in order that they may not have so much free air and room as to allow the spread of their branches horizontally, nor yet to be so much confined as to be drawn up weakly from the want of air. If it should be intended to rear up a plantation of firs or pines, for the sake of shelter and timber, then the distance between each tree ought to be little more than the third of the height, which is the distance found most favourable to the useful development of the fir and pine tribes, as timber-trees.'

In very many instances trees are suffered to remain in the ground considerably beyond the time they should be felled and put to the proper object of their growth. They are seen to get rotten at the core, or the branches are seen to die; still, from an unwillingness to remove what may be viewed as old friends, they are allowed to remain till accidentally destroyed. Instead of following this practice, we recommend the proprietor of forest timber to have his woods periodically examined by a person skilled in timber, who should mark all the trees that seem ready for removal, and let them be removed accordingly. Unless for particular reasons, every tree should be felled on arriving at maturity, and a new one planted instead.

To insure dryness of timber, it has been found a profitable practice to disbark the oak and larch a year or two before felling. On this point Monteath, in his 'Forester's Guide,' says he is decidedly of opinion that larches treated in this way at thirty years of age will be found equally durable with those cut down at the age of fifty years, and treated in the ordinary way.

Transplanting.

Trees may be lifted from one place to another, or transplanted. The art of accomplishing this exceedingly delicate operation in tree culture was some years ago brought to perfection by the late Sir Henry Steuart of Allanton, whose treatise is the best authority on the subject. The transplanting of a full-grown tree has, in all ages, been deemed next to impossible; and when it was attempted, the operator thought it necessary to cut off a great number of the branches (and consequently the leaves), from an idea that, if suffered to remain, they would require more sap than the roots could supply in their new situation. Of course, just in as far as they deprived the tree of its branches, or, we may rather say, of its leaves, they deprived it of the principal organ of its existence, and it invariably decayed to a corresponding degree. The lopping was like a cutting off of the lungs in a human being; and it would be as absurd to expect a man in that state to be healthy and strong, as it was to hope for vigour in the stripped member of the forest.

Sir Henry Steuart having studied the internal structure of trees, began, a good many years ago, to practise the art of transplanting on what he justly calls the preservative principle—that is, without mutilating either roots or branches, as was universally practised till his time. His seat, Allanton House, is situated on an irregular slope, on the right bank of the river Calder, which is a tributary of the Clyde. The neighbouring ground, though diversified, has no very picturesque natural points; but he contrived, by the removal of large trees, and forming an artificial lake and river, to realise in some measure the miracle of bringing new and picturesque scenery into actual existence, in an almost endless variety of combination.

The following are the rules to be attended to in the transplanting of trees. The best season for transplanting is certainly during the months of October and November; for though trees may be transplanted in any of the winter months when the weather is mild and moist, they never do so well as when removed in the first-mentioned months. Taking up a tree requires as much care as replanting it; the spade and the pick-mattock are both necessary to raise the roots from their seat; and as the most tender fibres are the most active and useful, the greatest care should be taken to preserve them entire. Neither should these delicate fibres be exposed to a dry or frosty air; they should be kept moist and shaded till again put into the ground. The root should be placed no deeper in the new place than it was in the old; and all the ramifications laid as nearly as possible in their natural positions, and imbedded in the breast of the earth.

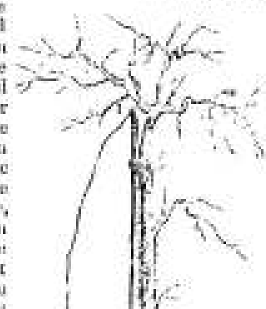
Trees may be transplanted from the age of one up to ten, or even twenty or more years; but when they are from four to six years from the seed, they are, both from age and bulk, in the best condition to be removed successfully. In planting with the one-handed tool, the smallest-sized plants must be used; for pitting, plants from two to three feet high may be chosen; and on digged, ploughed, or trenched ground, the young trees may be from two to six feet high, in which case the tallest may need propping against the south-west winds.

When single trees are to be planted on a lawn, a space of from four to six feet must be stripped off the turf, and rolled back; the soil within should be deeply broken up and excavated, to receive the full spread of the roots. A heap of richer loam or compost is laid in the centre, on which the tree is placed, and the roots are covered with the same, and watered, to consolidate the earth about the fibres. The other soil is then thrown on, and the turf returned to its place and beaten down firmly. Single trees should be staked; and if on a pasture, a cradle will be requisite to defend them from the browsing or rubbing of cattle.

Much has been written on the subject of transplanting large trees, and many successful exploits of this kind have been performed both in past and present times. Shady groves have been formed in the short space of a few months; proving that, with care, skill, and physical force properly directed, any tree of moderate size, say from twenty to forty feet high, may be transplanted with safety and success. One precaution very much facilitates the execution: it is that of digging a circular trench at a proper distance, say six feet, round the trunk, and deep enough to be below, and to cut through all the roots except three or four of the largest, which are left at equal distances to act as spurs for the better security of the tree when placed in its new situation. The trench, after the stumps of the roots are cut smoothly off, is filled with prepared compost for a new fringe of roots to strike into, and after one or two years the tree is in a condition for removal. In doing this, a deeper trench is made on the outside of the last, into which the mould from among the roots is drawn, until the whole is loosened from the soil; the spur roots are also followed out and laid bare. The method of raising the tree by a machine is mentioned beneath. In replanting, much depends on laying out the roots, and firmly imbedding them in moistened earth, and also adding a pretty heavy covering of soil round the stem, to keep the tree steady against wind.

Every tree about to be planted requires a little pruning; broken roots should be removed, and the head may require thinning. The branches should be equally balanced; and if any one appears to be a rival to the stem, it should be cut off close; so those rising with two stems should be deprived of the weakest. These remarks only apply to deciduous kinds; the pines and firs need no thinning when transplanted, unless some of the lower spray is dead.

A machine for transplanting has been formed on the principle of the common timber-truck—being a strong lever attached to the axletree of a pair of wheels. The latter are strongly constructed, at least five feet in diameter, and with a six or nine inch tire. The axletree is correspondingly substantial, and to its middle the pole or lever is securely fixed. The pole should be made of the best ash, seven inches square, with the edges planed off, and somewhat reduced in thickness towards the end. The length should be at least ten feet, for the longer it is, the greater the purchase in raising a tree. The pole is strengthened by side braces let into the axle, and mounted with an iron eye and ring at the point. When used, it is lashed against the tree, and the pole is raised and made fast thereto, as here represented. The wheels rest in the hollow made by baring and loosening the roots, though not upon any of them; and when all is ready, the strength of men, or that of a horse, is applied to the pole chain, which is, together with the tree, pulled to the ground, the root being lifted out of the soil; and, when thus borne on the machine, it is drawn away, root foremost, to its new place, previously prepared for its reception. The wheels are drawn into the new opening, the pole and tree are set at liberty, and if the root be heavy, the tree will resume its former position with but very little assistance. The machine is then loosened from the tree, and removed out of the way; the roots are then laid out carefully, and imbedded in loose soil, well consolidated and watered.



When a machine is made on purpose for removing large trees, the axletree may be made to fit a pair of cart-wheels for a temporary purpose; but the axle should be formed with *straight*, not *drooping*, ends, as they are usually made, because this renders raising the pole much easier. Upon the upper side of the axle there should be a thick block of wood bolted, to give more elevation to the root when drawn along; and on this an old sack, or a thick band of straw, is bound, to prevent chafing the bark of the tree.

Renovation of Decayed Trees.

In favourable circumstances, as respects soil and climate, trees seem to be immortal; but in our own country, these favouring circumstances are afforded on a limited scale, and consequently we can show no trees which are beyond the reach of decay. A time invariably arrives when they begin to show symptoms of decay, and the means to be adopted to prevent, as far as possible, the occurrence of this evil, require now to be noticed. On this delicate and important department of arboriculture we have pleasure in laying before our readers the detail of a process discovered by the late Sir Henry Steuart, communicated in a letter to Admiral Sir T. Livingston, Bart. 'Agreeably to my promise, I shall now give you an idea of my method of reviving or resuscitating old trees, which has often succeeded with myself, and which I have recommended to others; but there is no account given of it in the notes on any treatise on the application of the science of physiology to practical tree-culture, and particularly in removing large trees, for ornament.

The decay of old trees, both in England and Scotland, has been a subject of general complaint during at least a century; and it is observed, with regret, that their place does not promise to be very speedily supplied by existing woods and plantations. The general causes of the decay of trees are twofold: the first proceeds from diseases to which all woody plants are subject; the second from extreme old age, but more frequently from their having exhausted the pabulum within their reach. The pathology of the vegetable tribe, in this respect, differs materially from that of the human species. Among the sons of the forest there are no vicious efforts made by individuals, as among us, by means of disease, to shorten life. There are no gourmands nor sensualists, by fatal indulgences and artificial luxuries, to bring on a premature old age. The laws of nature in trees are allowed fairly to operate, and their existence, therefore, may be reckoned on, and even prolonged by art, to an indefinite period. It has been said that the roots of trees, in a favourable soil, will go abroad in search of their food to a distance from the stem equal to the entire height of the tree, taken from the ground; and wherever this is found to hold good, trees will live to a very great age, especially in a deep and calcareous soil.

Of your two fine old trees at Westquarter, in Stirlingshire, which I lately examined—a holly and a double-flowering thorn—I must say that they appear to me to have declined chiefly from the *latter* of the two causes above-mentioned—namely, their having exhausted the food or pabulum in their immediate neighbourhood; and, in the case of the thorn, in some measure from the ground being overstocked with other plants, that greatly crowd upon it, even to the exclusion of light and air, without which no plant can flourish. As to the holly, it seems stunted and hide-bound, and sends out no free shoots at top, such as a tree in health, in so fine a soil and climate, ought to do. The terminal growths of the thorn, also, have begun to decay; and if some salutary remedy be not speedily adopted to *excite the roots to fresh action*, it is plain that the evil will ere long extend to the greater branches, and, as a necessary consequence, to the trunk itself.

The first thing that I should recommend to be done with this noble thorn is to cut away the ivy that now strongly adheres to it. That parasitical plant has covered nearly the whole external surface of the stem. It already intercepts the kindly influence of the sun and air from the bark of the tree, under which the finer vessels of the descending sap lie, so that it may be said to prey upon the very vitals of the plant. The next object should be to clear the ground, for a considerable space, of overshadowing shrubs and bushes. So venerable a tree standing single would be the most graceful ornament of the verdant turf that surrounded it.

'The second thing that I would do would be to dig a trench round the tree, not exceeding three and a half or four feet out from the stem; which trench should be five feet broad at least, and as deep as to penetrate through both the soil and subsoil, however deep either may be, until you reach the rock, gravel, pure sand, or obdurate clay (*Scotticé*, till) that may lie below. In doing this the workmen may fearlessly cut through all the roots they meet with, leaving only three or four great ones, on the south and south-west sides, to act as *cables* in resisting the severe winds that usually blow from those quarters in every part of the island.

Next, let whatever parts of the trench that consist of good earth, or of earth capable of being easily made so, be thrown aside, and the sand or gravel, if any, be wheeled away; so that you may obtain a depth in the trench of two feet or more, if the soil permit, of well-mixed mould. For this purpose, let good compost or rich garden mould (of which I saw abundance near the spot) be intimately mixed, by two or three times turning, with the better parts of the contents of the trench, adding about a third part of good well-rotted dung, so as that a proper chemical action may be excited throughout the mass, and the whole rendered fit for the food of plants. This done, let the trench be filled up with such compound somewhat higher than the original soil; and let the space which has been left untouched, of four feet out from the stem to the edge of the trench, be covered, eight or nine inches deep, with the same prepared and friable compound, pointing it in with the spade only about three inches deep, so as not materially to injure the roots. In order to complete the process, let all the dead wood be carefully pruned from the branches with a saw—dressing the extremities afterwards with a sharp hedge-bill.

In the following spring, all moss or other impurity should be scraped off the bark, and the entire stem well washed, two or three times during the summer season, with soap and water and a soft brush.

By following the above method, which, however elaborate it may appear in the description, will be very easily reduced to practice, I feel confident that many fine old trees in gentlemen's parks, that are now allowed to decay, might have *another century* added to their existence; because the extension of fresh pabulum at pleasure to greater limits would be a labour well repaid, and attended with little expense, and as little difficulty. There are few persons who would not bestow more labour than this on a favourite tree; and there are perhaps fewer who will not admit that it might easily be applied to purposes of general utility as well as local ornament. The principles on which this process has been instituted are in accordance with the laws of animal as well as vegetable physiology, and will be confirmed by practice, if they be allowed to govern the process. I have uniformly found that the roots, where cut through in the opening of the trench, will send forth an immense body of vigorous ramifications, of from a foot to fifteen inches in length, during the first and second months after the operation, with thousands of capillary rootlets emanating from them; all which will go abroad in search of sap for renovating the vigour of the tree. In a tree of considerable age, such as the two above alluded to at your beautiful place, it is to be observed that much figure cannot be expected to be made during the first year in the elongation of its terminal shoot; and for this plain reason, that effects must necessarily be preceded by their causes, whether they lie on the surface or otherwise; but the leaves will speedily become larger, and of a deeper green colour, than for some years past; and by the autumn of the second year, it will be admitted that the tree is in some sort about *to renew its youth*.

During the early part of the first season, the new mould should be allowed to remain quite undisturbed; but towards the end of the year, the gardener or forester may cautiously look in, and he will observe the wonderful efforts towards the increase of leaves, and, by consequence, towards a fresh supply of sap, that the plant will even then have made. After the second year, the effects of this renovating process will appear still more striking.

Those directions apply equally to both the thorn and the holly at Westquarter, with this difference, that, in consideration of the far greater exposure in which the latter is placed, I should not advise that the trench be opened nearer than within five feet of the stem; also, a greater number of large roots (to act as cables in supporting the tree), say five or six, should be left entire, running across the trench.

The month of February, or beginning of March, according to the season, before the ascending sap begins to stir, would of course be the best time to carry into effect the methods of resuscitation above detailed.'

Coppice.—Live-fences.

Coppice or underwood is either natural or planted. Natural underwoods appear to be the remains of ancient forests, which are kept enclosed, and are felled periodically at long or short intervals, according to the purpose for which the stuff is to be applied. Planted underwoods are either willow holts for the basketmaker, hoops for coopers, hop poles, poles for fencing and hurdle-making, stakes and headers for hedging, broom, hay-rake, and mop handles, spray for birch besoms, fagots for brickmakers and bakers, kindlers, and other firewood, and withes for binding fagots, &c.

Thriving and well-fenced and well-managed underwoods are considered more profitable than timber-woods. The first are very soon a source of income, and as such are subject to tithe, which has caused many acres of them in England to be allowed to grow up into woods, which are free from tithe. But timber and coppice may be united; the standard trees to stand thinly, and if kept pruned up, the undergrowth is not much hurt by their shade. Mixed underwoods are cut every five, seven, or ten years, unless they are entirely of oak, when they are allowed to stand longer, for the sake of having larger poles, together with the bark, which last is a principal part of the value of the fall. When such a fall is made, every superior-looking well-placed pole is left as a standard, if standards be wanting; these at last become fine trees, and are felled in their turn. On the subject of oak coppice, Mr Brown remarks, that the value of the bark has fallen so much of late years, as to render the exclusive growth of this kind of underwood no longer a source of real profit. 'About twenty-five years ago, the price of oak bark was £16 per ton; while this year (1847) the highest price that has been given in Edinburgh is £5, 10s.—making its value at the present time only about one-third of what it was twenty-five years ago, and consequently reducing the value of oak coppice plantations in the same ratio; and upon this consideration, I do think that proprietors should not, at the present time, rear up oak plantations with the intention of converting them into coppice, as has in many instances been done of late. I have seen plantations of healthy oak-trees, about thirty-five years of age, cut down for the sake of the bark they produced, and with the view of converting them into coppice-wood, so as to have a crop of bark every twenty-five years afterwards. Now had those trees which were cut down at thirty-five years of age been allowed to grow for other forty or fifty years, they would of course have attained their full magnitude, and been worth to the proprietor, at the end of that period, more than three times the money that he could get as the produce of the same plants if cut down and disposed of in the form of coppice-wood at periods of twenty-five or thirty years. No doubt where old plantations are cut down, it is right and proper that the stocks of them should be converted into coppice-wood, for this is taking advantage of growths which can be converted into use, and which would otherwise be lost; but to raise up trees to a certain age, and then cut them down prematurely for the sake of their bark, is at best an enormous loss to the proprietor as well as to the country in general.'

The most profitable underwood is that which has been planted, and each sort of tree kept by itself, having regard to the quality of the soil most suitable for each, if there be any difference. For instance, ash and Spanish chestnut should have the driest spots; oak and birch those which are more moist; alder and willow the moistest. All the sorts should be planted very closely together, because this not only increases the length and number, but improves the form of the poles, circumstances which very much add to their value.

The ground should be prepared for underwood in the same manner as for timber-trees, either by the plough or spade. Wet land is usually laid into beds with narrow ditches between, the soil out of which serves to raise the beds, and give the roots more scope. Several wild shrubs introduce themselves among underwood, particularly hazel and hawthorn, neither of which are much objected to, as the first is a useful coppice plant, and the last is always in request about a farm.

Some of our ornamental shrubs arrive at the height of trees, and some of them produce excellent and beautiful timber; such are the cypress, holly, laburnum, and guelder-rose. Large scantlings of the second and third are much prized for veneering.

For live-fences, except in peculiarly bleak and barren situations, hawthorn is the best adapted: care, however, is required both in the planting and trimming. There is a general complaint that thorn hedges do not thrive well; but in most cases the want of success will be found to arise from improper treatment. The preparation of the land for planting hedges requires the greatest care, for if this be not cleared of weeds before the thorns are planted, it will be almost impossible to do it afterwards. Foul land should be well fallowed before the hedge is planted; and it is recommended to plant in the natural soil if it is good; but if poor, it will require to be manured. Old pasture-land should be pared and burned, and the ground otherwise well prepared for the reception of the hedge. If possible, the ground should be trenched to about eighteen inches deep, and four feet in breadth, the surface soil being placed in the bottom of the trench; and this will be found an excellent way of getting rid of weeds. The subsoil, if poor, will not do so much injury on the surface as it would do if left in its natural position; and if opposed to the growth of the thorn, it can be removed. The expense attending a thorough preparation of the soil will be amply repaid by having a clean and well-growing hedge, which is a great ornament to any estate. Indeed so convinced are most landed proprietors of the advantages of a thorough preparation, that the soil is now not only cleaned and trenched, but supplied with a compost of lime and ditch-clearings—a treatment which immensely facilitates the growth of the thorns at the most critical period of their existence. It is in the after-management, however, that the great error generally lies; and were proprietors to impose more stringent obligations upon tenants, or to take the keeping of the live-fences into their own hands, we would have fewer complaints as to the success of the thorn, and a greater degree of rural amenity thrown over the face of the country.

The season for planting depends in some measure on the nature of the ground; for if this be very dry, the planting should take place in the autumn, or early in spring, in order that the plants may have made some root before the heat of summer sets in. The autumn is recommended by some as the best season for planting on all soils, and the month of February by others; but perhaps it is immaterial which period be chosen. If spring is the time fixed upon, it should be as early as possible, so that the plants may not have made any progress in vegetation before transplanting. There are various modes of planting hedges, some preferring the even ground, others forming a mound, with a ditch at one side, and planting either at the top or on a shelf in the side of the mound; others, again, making a ditch on each side of the mound. If the land be good and dry, the hawthorn will grow quite well upon the level ground; but if the soil be of a wet nature, either one or two ditches will be required. In the former case, the land taken up with the fence will not be more than two and a half or three feet; while in the latter not less than eight will be entirely lost to the plough. The most common mode throughout the country, however, is ditch and hedge; the earth taken from the ditch forming the mound upon which the thorns are planted. Some prefer planting on the top of the mound, others on the slope; and when the last method is adopted, care should be taken not to put the plants too far down the ditch, which may prevent them from getting the necessary light and air. The hawthorn does not naturally sink deep into the ground, its roots rather spreading to a distance near the surface. A stunted hedge will generally be found to be overloaded with earth at the roots, while a free-growing and vigorous hedge has been allowed in some measure to follow its own natural habit. The thorns should be planted at the distance of about three or four inches apart, and about the same depth as they stood in the seed-bed. Some cut the plants before they are put in, others cut them after they are planted, to insure regularity; but this is an immaterial point, as the after-cutting will make the hedge uniform. The plants should then be covered with the finest mould, the points little more than projecting from the front of the mound. If the land is in tillage when the thorns are planted, and to remain so for some time, it will not be necessary to raise a fence for their protection; but if cattle are to graze upon it, this precaution must be taken, to prevent them from eating the buds.

After being planted, the ground should be carefully gone over two or three times a year, to cut up weeds. This operation must be performed until the plants have reached some height, and the weeds are completely eradicated, after which the usual cleaning at the roots once a year will be quite sufficient. The plants should never be cut till after three years old, for if cut when younger than this, the hedge is stunted, and never so healthy. The operation of pruning or cutting is frequently intrusted by landlords to their tenants, who seldom perform it in that efficient way in which it ought to be done. Hawthorn hedges, when well planted in good soils, will grow, even if they should be improperly pruned; but in poor soils and exposed situations they cannot thrive under the negligent treatment they are frequently subjected to. When a sufficient number of branches can once be made to rise from the bottom of the main stem, either in the first or second year, the main stem should never be cut until it has attained a considerable strength, which will generally be in the third or fourth year.

When hedges get bare and thin at the bottom, they ought either to be cut over by the root, or to have their sides dressed up close to the principal stems. In cutting off the side branches, it is advisable to make one or more notches in the main stem, by the hatchet, one stroke up, and the other down, so as to take out a piece of wood about half the thickness of the stem. By this method young shoots come out in great abundance immediately below the notch, which may be made at any height; and a complete and impervious hedge is formed much sooner than by cutting the stem over by the roots. There is another method of repairing thorn hedges, which is called *plashing*. It consists in cutting half through the stems adjoining the gap to be repaired, and then bending the upper portion over the vacancy, fastening them down by stakes, or by warping them into each other. By this means a live hedge is formed more speedily than by planting young shoots, and more effectually than by inserting dead branches. The bent stems soon send out shoots; and if the plashing has been done with care, and that on moderately young and pliant branches, it will be found to be a cheap, and, on the whole, a very efficient system.

When thorn hedges are cut too close by the ground, the decayed stocks should not only be taken out, but the earth where the stocks stood should be removed also, and replaced with good fresh soil, in which thorns have never previously grown. The thorn plants intended for filling up blanks should be carefully selected from such as have been transplanted two or three years, have stood thin in the nursery bed, are well rooted, and free growers. It is likewise advisable in all cases to set the young plants into the vacancies, with their tops entire, as they stood in the nursery ground, and not to be cut, as is too frequently the practice. Particular attention should also be paid to keeping their roots moist before planting; and when planted, the earth should be kept low round the stems, so that moisture may be drawn towards them, until the roots are firmly established in the soil. When either crab or beech plants are used for filling gaps in thorn hedges, it is not necessary to remove the earth as for thorn plants, but it should be well loosened and pulverised; and when the plants are set, a hollow space should be left round the bottom of the stems, as recommended for thorn transplants.

In high exposed situations, having thin moorish soils, or on hilly land composed of decomposed granite, thorn hedges are seldom if ever found to thrive. In such situations, the beech has proved itself superior to every other plant, either as an assistant or a substitute for thorns. It retains possession of the soil, and continues to thrive when thorns decay or die out; and when regularly and judiciously cropped, it forms a compact fence, which few animals will attempt to break through. Indeed experience has proved that, as a hedge plant, the beech will thrive in any climate or soil; and what is of essential importance, it retains its leaves during winter, giving a genial warmth and shelter, besides being highly ornamental.

A very durable hedge for high situations with a light soil, may be formed by an admixture of thorn and beech plants in the proportion of two of the former to one of the latter. Such a fence not only looks well, but lasts well, if trimmed with due care and regularity. Latterly, furze or whins have been employed with much advantage as fences; but this hardy native shrub will grow only where there is great freedom of air, and succeeds best in northern climates.

Many other shrubs and trees are used in live-fencing; but more for garden and ornamental than for field purposes. Among the most common of these are the holly, the privet, the sweetbrier, the yew, and the *Pyrus japonica*, all of which bear pruning and training almost to any degree. The thorn has also been occasionally trusted after the Dutch fashion — that is, training it along stakes, and keeping the hedge at a thickness of six or eight inches; but as shelter is as much the object of the British landholder as enclosure, this mode is not likely ever to be extensively followed.

In training any sort of hedge, attention should be paid to the form and manner of cutting. Main stems or trunks should always be cut upwards, and never by a descending blow of the hedge-bill, as the latter produces a jagged and splintery wound, which causes the wood to die much farther down than the up cut. Young shoots will spring from the very verge of an up cut; they never spring within several inches of, nor so readily from, a cut in the opposite direction. In cutting hedges for field use, all fantastic forms should be avoided, and the easiest and most effective shape preserved. Straight or slightly-inclining sides, with a tapering or pointed top, is the easiest form, and the one best adapted to the growth of the shrub. Rounded or pyramidal forms are not economical, as they require longer time for their execution; straight sides with square tops should never be allowed, as snow lodges on the top, and splits up the hedge when the load accumulates. Fantastic forms require not only more time from the hedger, but are injurious to the plant, and nothing looks so ill when badly executed. Hinds and common labourers ought never to be permitted to wield a hedge-bill; a thorough-trained hedger or forester should alone be employed.

THE HORSE.

The horse is universally acknowledged to be one of the noblest members of the Animal Kingdom. Possessing the finest symmetry, and unencumbered by those external appendages which characterise many of the larger quadrupeds, his frame is a perfect model of elegance and concentrated energy. Highly sensitive, yet exceedingly tractable, proud, yet persevering, naturally of a roaming disposition, yet readily accommodating himself to domestic conditions, he has been one of the most valuable aids to human civilisation—associating with man in all phases of his progress, from the temporary tent to the permanent city.

In ordinary systems of zoology the horse is classed with the *Pachyderms*, or thick-skinned animals—as the elephant, tapir, hog, hippopotamus, and rhinoceros. Differing from the rest of the class in many respects, he has been taken as the representative of a distinct family, known by the name of *Equidæ* (*equus*, a horse), which embraces the horse, ass, zebra, quagga, onagga, and dzeggetai. All these animals have solid hoofs, are destitute of horns, have moderately-sized ears, are less or more furnished with manes, and have their tails either partially or entirely covered with long hair. The family may, with little impropriety, be divided into two sections—the one comprehending the horse and its varieties, and the other the ass, zebra, and remaining members. In the former, the tail is adorned with long flowing hair, the mane is also long and flowing, and the fetlocks are bushy; the latter have the tail only tipped with long hair, the mane erect, and the legs smooth and naked. The colours of the horse have a tendency to *dapple*—that is, to arrange themselves in rounded spots on a common ground; in the ass, zebra, and other genera, the colours are disposed in stripes or bands more or less parallel.

By his physical structure, the horse is fitted for dry open plains that yield a short sweet herbage. His hoof is not adapted to the swamp; and though he may occasionally be seen browsing on tender shoots, yet he could subsist neither in the jungle nor in the forest. His lips and teeth, however, are admirably formed for cropping the shortest grass, and thus he luxuriates where many other herbivorous animals would starve, provided he be supplied with water, of which he is at all times a liberal drinker. Delighting in the river-plain and open glade, the savannas of America, the steppes of Asia, and the plains of Europe, must be regarded as his head-quarters in a wild state. There is doubt expressed, however, as to the original locality of the horse. The wild herds of America are looked upon as the descendants of Spanish breeds imported by the first conquerors of that continent; those of the Ukraine, in Europe, are said to be the progeny of Russian horses abandoned after the siege of Azoph in 1696; and even those of Tartary are regarded as coming from a more southern stock. Naturalists, therefore, look to the countries bordering on Egypt as in all likelihood the primitive place of residence of this noble animal; and there is no doubt that the Arabian breed, when perfectly pure, presents the finest specimen of a horse in symmetry, docility, and courage. Regarding the horse as of Asiatic origin, we now find him associated with man in almost every region of the habitable globe. Like the dog, ox, sheep, and a few others of the brute creation, he seems capable of accommodating himself to very different conditions; and assumes a shaggy coat or a sleek skin, a size little inferior to that of the elephant, or not larger than that of an English mastiff, just as circumstances of climate and food require.

In a state of nature, the horse loves to herd with his fellows; and droves of from four to five hundred, or even double that number, are not unfrequently seen, if the range be wide and fertile. The members of these vast droves are inoffensive in their habits, and when not startled or hunted, are rather playful and frolicsome; now scouring the plain in groups for mere amusement, now suddenly stopping, pawing the soil, then snorting, and off straight as an arrow, or wheeling in circles, making the ground shake with their wild merriment. It is impossible to conceive a more animated picture than a group of wild horses at play. Their fine figures are thrown into a thousand attitudes; and as they rear, curvette, dilate the nostril, paw in quivering nervousness to begin the race, or speed away with erect mane and flowing tail, they present forms of life and energy which the painter may strive in vain to imitate. They seldom shift their stations, unless compelled by failure of pasture or water; and thus they acquire a boldness and confidence in their haunts which it is rather unsafe to disturb. They never attack other animals, however, but always act upon the defensive. Having pastured, they retire either to the confines of the forest, or to some elevated portion of the plain, and recline on the sward, or hang listlessly on their legs for hours together. One or more of their number are always awake, to keep watch while the rest are asleep, and to warn them of approaching danger, which is done by snorting loudly, or neighing. Upon this signal the whole troop start to their feet, and either reconnoitre the enemy, or fly off with the swiftness of the wind, followed by the sentinel and by the older stallions. They are seldom to be taken by surprise; but if attacked, the assailant seldom comes off victorious, for the whole troop unite in defence of their comrades, and either tear him to pieces with their teeth, or kick him to death.

There is a remarkable difference in the dispositions of the Asiatic and South American wild horses. Those of the former continent can never be properly tamed, unless trained very young, but frequently break out into violent fits of rage in after-life, exhibiting every mark of natural wildness; while those of America can be brought to perfect obedience, and even rendered somewhat docile, within a few weeks, nay, sometimes days. It is difficult to account for this difference in temper, unless we suppose that it is caused by climate, or rather by the transmission of domesticated peculiarities from the original Spanish stock.

SUBJUGATION AND DOMESTICATION.

As in South America we have the most numerous herds, and the most extensive plains for their pasture, so it is there that the catching and subduing of the wild horse presents one of the most daring and exciting engagements. If an additional horse is wanted, a wild one is either hunted down with the assistance of a trained animal and the *lasso*, or a herd are driven into a *corral* (a space enclosed with rough posts), and one selected from the number. The latter mode is spiritedly described by Miers, whose account we transcribe, premising that a *lasso* is a strong plaited thong, about forty feet in length, rendered supple by grease, and having a noose at the end:—' The corral was quite full of horses, most of which were young ones about two or three years old. The chief guacho (native inhabitants of the plains are called peons or guachos), mounted on a strong steady animal, rode into the enclosure, and threw his lasso over the neck of a young horse, and dragged him to the gate. For some time he was very unwilling to leave his comrades, but the moment he was out of the corral, his first idea was to gallop off; however, a timely jerk of the lasso checked him in the most effectual way. The peons now ran after him on foot, and threw a lasso over his fore-legs, just above the fetlock, and twitching it, they pulled his legs from under him so suddenly, that I really thought the fall he had got had killed him. In an instant a guacho was seated on his head, and with his long knife cut off the whole of the mane, while another cut the hair from the end of his tail. This they told me was a mark that the horse had once been mounted. They then put a piece of hide in his mouth, to serve for a bit, and a strong hide halter on his head. The guacho who was to mount arranged his spurs, which were unusually long and sharp; and while two men held the horse by the ears, he put on the saddle, which he girthed extremely tight. He then caught hold of the animal's ear, and in an instant vaulted into the saddle, upon which the men who held the halter threw the end to the rider, and from that moment no one seemed to take any further notice of him. The horse instantly began to jump in a manner which made it very difficult for the rider to keep his seat, and quite different from the kick or plunge of our English steed: however, the guacho's spurs soon set him agoing, and off he galjopped, doing everything in his power to throw his rider.

Another horse was immediately brought from the corral, and so quick was the operation, that twelve guachos were mounted in a space which I think hardly exceeded an hour. It was wonderful to see the different manner in which different horses behaved. Some would actually scream while the guachos were girthing the saddle upon their backs; some would instantly lie down and roll upon it; while some would stand without being held, their legs stiff, and in unnatural positions, their necks half bent towards their tails, and looking vicious and obstinate; and I could not help thinking that I would not have mounted one of those for any reward that could be offered me, for they were invariably the most difficult to subdue.

It was now curious to look around and see the guachos on the horizon in different directions, trying to bring their horses back to the corral, which is the most difficult part of their work; for the poor creatures had been so scared there, that they were unwilling to return to the place. It was amusing to see the antics of the horses; they were jumping and dancing in various ways, while the right arm of the guachos was seen flogging them. At last they brought the horses back, apparently subdued and broken in. The saddles and bridles were taken off, and the animals trotted towards the corral, neighing to one another.'

To hunt down the horse in the open plain requires still greater address, and greater strength of arm. According to Captain Hall, the guacho first mounts a steed which has been accustomed to the sport, and gallops him over the plain in the direction of the wild herd, and circling round, endeavours to get close to such a one as he thinks will answer his purpose. As soon as he has approached sufficiently near, the lasso is thrown round the two hind-legs, and as the guacho rides a little on one side, the jerk pulls the entangled horse's feet laterally, so as to throw him on his side, without endangering his knees or his face. Before the horse can recover the shock, the hunter dismounts, and snatching his *poncho*, or cloak, from his shoulders, wraps it round the prostrate animal's head. He then forces into his mouth one of the powerful bridles of the country, straps a saddle on his back, and bestriding him, removes the poncho, upon which the astonished horse springs on his legs, and endeavours, by a thousand vain efforts, to disencumber himself of his new master, who sits composedly on his back, and by a discipline which never fails, reduces the animal to such complete obedience, that he is soon trained to lend his whole speed and strength to the capture of his companions.

The subduing of wild specimens in America, the Ukraine, Tartary, and other regions, must be regarded as merely supplementary to that domestication which the horse has undergone from the remotest antiquity. A wild adult may be subjugated, but can never be thoroughly trained; even the foal of a wild mother, though taught with the greatest care from the day of its birth, is found to be inferior to domestic progeny in point of steadiness and intelligence. Parents, it would seem, transmit to their offspring mental susceptibility as well as corporeal symmetry; and thus, to form a just estimate of equine qualities, we must look to the domesticated breeds of civilised nations. At what period the horse was first subjected to the purposes of man we have no authentic record. Trimmed and decorated chargers appear on Egyptian monuments more than four thousand years old; and on sculptures equally, if not more ancient, along the banks of the Euphrates. One of the oldest books of Scripture contains the most powerful description of the war-horse; Joseph gave the Egyptians bread in exchange for horses; and the people of Israel are said to have gone out under Joshua against hosts armed with 'horses and chariots very many.' At a later date, Solomon is said to have obtained 'horses out of Egypt, and out of all lands,' and to have had 'four thousand stalls for horses and chariots, and twelve thousand horsemen.' Thus we find that in the plains of the Euphrates, Nile, and Jordan, the horse was early the associate of man, bearing him with rapidity from place to place, and aiding in the carnage and tumult of battle. He does not appear, however, to have been employed in the useful arts of agriculture and commerce; these supposed drudgeries being imposed on the more patient ox, ass, and camel. Even in refined Greece and Rome, he was merely yoked to the war-chariot, placed under the saddle of the soldier, or trained for the race-course.

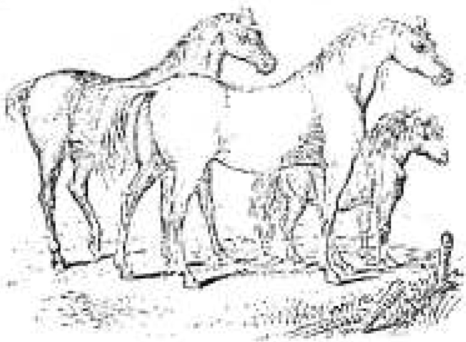
As civilisation spread westward over Europe, the demands upon the strength and endurance of the horse were multiplied, and in time he was called upon to lend his shoulder indiscriminately to the carriage and wagon, to the mill, plough, and other implements of husbandry. It is in this servant-of-all-work capacity that we must now regard him; and certainly a more docile, steady, and willing assistant it would be impossible to find. But it is evident that the ponderous shoulder and firm step necessary for the wagon would not be exactly the thing for the mail-coach; nor would the slow and steady draught, so valuable in the plough, be any recommendation to the hunter or roadster. For these varied purposes men have selected different stocks, which either exist naturally, or have been produced by a long-continued and careful system of breeding. In a state of nature, the horse assumes various qualities in point of symmetry, size, strength, and fleetness, according to the conditions of soil, food, and climate which he enjoys. It is thus that we have the Arabian, Tartar, Ukraine, Shetland, and other stocks, each differing so widely from the others, that the merest novice could not possibly confound them. Besides these primitive stocks, a thousand *breeds*, as they are called, have been produced by domestication, so that at the present time it would require volumes even for their enumeration. In our own country, for example, we have such breeds as the Flanders, Norman, Cleveland, Suffolk, Galloway, Clydesdale, and Shetland; and of these numerous varieties, as may be required for the turf, the road, the cart, or the carriage. All this exhibits the wonderful ductility of the horse, and proves how admirably he is adapted to be the companion and assistant of man, as the latter spreads himself over the tenantable regions of the globe. It is to the character, training, and management of the horse thus domesticated that we devote the following pages.

DOMESTICATED VARIETIES.

Horses exist, as we have said, in numerous varieties, distinguishable by size, strength, colour, and other qualifications, the result most likely of peculiarities of climate, food, and artificial treatment. The following is a brief notice of the leading varieties or breeds now common in Britain:—

The Arabian.

The Arabian horse is considered to occupy the highest rank among the numerous cultivated varieties, and embodies that qualification in its purest condition known by the term *thorough-bred*. The pure Arabians are somewhat smaller than our race-horses, seldom exceeding fourteen hands two inches in height. Their heads are very beautiful, clean, and wide between the jaws; the forehead is broad and square; the face flat; the muzzle short and fine; the eyes prominent and brilliant; the ears small and handsome; the nostrils large and open; the skin of the head thin, through which may be distinctly traced the whole veins of the head. The body may, as a whole, be considered too light, and the breast rather narrow; but behind the arms, the chest generally swells out greatly, leaving ample room for the lungs to play. The shoulder is superior to that of any other breed; the scapulæ, or shoulder-blades, incline backwards, nearly in an angle of 45 degrees; the withers are high and arched; the neck beautifully curved, and the mane and tail long, thin, and flowing; the legs are fine, thin, and wiry, with the pasterns placed somewhat oblique, which has led some to suppose that the strength was thereby lessened, which is by no means the case; the bone is of uncommon density, and the prominent muscles of the fore-arm and thigh prove that the Arabian is fully equal to all that has been said of his physical powers.



English Hunter—Arabian—Shetland Pony.

The Arabs of the Desert have made the breeding of horses their sole occupation for ages bygone; and from their strict attention to certain rules, they may be justly regarded as the first breeders in the world. They take infinite trouble in grooming their steeds, and are extremely regular in their hours of feeding them morning and evening. They get but little drink, and that is supplied to them two or three times a day; they conceive that much water not only destroys their shape, but also affects their breathing. In spring, they are pastured on dry aromatic herbage; and during the rest of the year they are fed on barley, with a small quantity of straw; and they are the hardiest horses in the world. The Arab trains his horse by kindness, and never on any occasion strikes it; the consequence is, that the animal shows a degree of affection and tractability in which most British horses are quite deficient. The pure Arab horse is employed only for riding, and possesses great fleetness.

The following interesting account of the hardihood of the Arabian is given by M. Chateaubriand, in his travels in Greece:—'They are never put under shelter, but left exposed to the most intense heat of the sun, tied by all four legs to stakes driven in the ground, so that they cannot stir. The saddle is now taken from their backs. They frequently drink but once, and have only one feed of barley in twenty-four hours. This rigid treatment, so far from wearing them out, gives them sobriety and speed. I have often admired an Arabian steed thus tied down to the burning sands, his hair loosely flowing, his head bowed between his legs, to find a little shade, and stealing with his wild eye an oblique glance of his master. Release his legs from the shackles, spring upon his back, and he will "paw in the valley, he will rejoice in his strength, he will swallow the ground in the fierceness of his rage;" and you recognise the original picture as drawn by Job.'

The Arabs are exceedingly particular regarding the pedigree of their horses; and they have amongst them a breed which they declare has descended from a horse of King Solomon. It must not, however, be supposed that all the horses of that country are of the finer kinds; for the Arabs have three distinct breeds: the two inferior kinds, they allege, were introduced from India and Greece. The superior kinds they call nobles; and they are never sold without a pedigree, which is most scrupulously attended to.

The British Racer.

The British race-horse is a cultivated breed, originally sprung from the Arabian, and to which is traced the quality of being *thorough-bred*. The skins of race-horses are delicate, with short hair, usually tending to the bright brown or bay generally characteristic of the horses of the East, and sometimes to the gray, prevalent likewise amongst the Arabs and Barbs. They are frequently chestnut, which may be looked upon as a mixture of the dun or tan colour of some of the races of Northern Europe with the finer brown or bay; and sometimes, though very rarely, they are of the bright black common to the great horses of the plains of Germany. They are of medium height, rarely exceeding fifteen hands. Their form is that which an almost exclusive attention to the property of speed has tended to produce. They have the broad forehead, the brilliant eyes, the delicate muzzle, the expanded nostrils, and the wide throat, characteristic of their Eastern progenitors. Their light body is comparatively long, and suited to the extended stride. Their chest is deep, so as to give due space to the lungs, but comparatively narrow, preventing the fore extremities from being overloaded, and the limbs from being thrown too far asunder in the gallop. Their shoulder is oblique, to give freedom of motion to the humerus; and their haunch is long and deep, beyond that of any other known race of horses, indicating the length of those bones of the hinder extremities on which the power of progression essentially depends. Their limbs are long and muscular to the knee and hock, and below tendinous and delicate; and their pasterns being long and oblique, give elasticity to the limbs.

The pedigree of race-horses is always a matter of consequence to the breeder and purchaser of these animals, and is preserved with the same degree of care as the genealogy of many a noble family. By jockeys and others, therefore, a list or stud-book is kept of the sires and dams of their horses, which can be exhibited if required. The pedigree of many fine racers of the present day is traced through stud-books to the Darley Arabian, a horse purchased by a Mr Darley at Aleppo, from which it was imported to England. One of its immediate descendants was the celebrated Flying Childers, bred by Mr Childers of Carr-House. This beautiful racer is reputed to have been the fleetest runner ever known in England, or perhaps in the world. On one occasion he ran (carrying nine stones two pounds) round the course at Newmarket—which measures 3 miles, 6 furlongs, and 93 yards—in six minutes and forty seconds.

Horse-racing—which, in the opinion of competent judges, is unnecessary, as far as keeping up serviceable breeds of horses is concerned—is usually spoken of as the *turf*, from its being performed on stretches of turf-ground at Newmarket, Epsom, and various other places. Among an idle, and in many instances a profligate class of persons, this *sport*, as it is termed, affords scope for a most extensive system of fraud, betting, gambling, and general dissoluteness of behaviour; in a word, this cruel pastime may be described as a great canker lying at the root of society in England; and, countenanced by the high in rank, is at the present moment not the least effective of the many drags on social advancement.

Hunters—Saddle-Horses.

The hunter is a combination of the thorough-bred race-horse and half-bred horses of greater strength and bone; but changes are continually taking place in its character. The older race of hunters has been giving place to one of lighter form and higher breeding, and even the thorough-bred horse is now employed by numerous sportsmen. In his improved state, the hunter may rank as a saddle-horse of the first class, combining strength with fleetness. The prime qualities of a hunter may be briefly summed up—head small, neck thin, crest firm and arched, a light mouth, broad chest, body short and compact, the hocks well bent, power behind to push him over difficulties, and broad well-made feet turned outward. He is prepared for his duties by physic, air, and exercise. To do him justice, the hunter should not work above three days a week; and after a hard day's run, he ought certainly to have two or three days of rest. We cordially coincide in the following remarks of Mr Youatt on the cruelty of abusing this noble animal:—'It is very conceivable, and does sometimes happen, that, entering as fully as his master into the sports of the day, the horse disdains to yield to fatigue, and voluntarily presses on until nature is exhausted, and he falls and dies; but much oftener the poor animal has intelligibly enough hinted his distress: unwilling to give in, yet painfully and falteringly holding on. The merciless rider, rather than give up one hour's enjoyment, tortures him with whip and spur until he drops and expires. Although the hunter may be unwilling to relinquish the chase, he who "is merciful to his beast" will soon recognise the symptoms of excessive and dangerous distress. To the drooping pace, and staggering gait, and heaving flank, and heavy bearing on hand, will be added a very peculiar noise. The inexperienced person will fancy it to be the beating of the heart; but that has almost ceased to beat, and the lungs are becoming gorged with blood. It is the convulsive motion of the muscles of the belly, called into violent action to assist in the laborious office of breathing. The man who proceeds a single mile after this, ought to suffer the punishment he is inflicting.' The charger or cavalry-horse partakes of the qualities of the hunter—great strength and spirit, without which he would be unable to endure the toil of warfare in a rough country.

The proper kind of saddle-horse is only a variety of the hunter, possessing less or more *blood*, according to the nature of the work required of him, and the taste of the breeder. Of the great varieties of saddle-horses, there may be said to be a chain of connection, as respects spirit and form, from the racer to the cart-horse; and therefore the station which any individual occupies is almost undefinable. The saddle-horses of England are celebrated for their beauty and action; and nowhere are seen so many of elegant forms as in London. Latterly, the breeds have been tending to greater lightness, the state of the roads not now requiring the strength of limb which was at one time necessary.

Coach-Horses—Hackneys.

The better kind of coach-horses owe their origin to the Cleveland bay, and are principally bred in Yorkshire, Durham, and the southern districts of Northumberland, and some few have been produced in Lincolnshire. The coach-horse is produced by a cross of the Cleveland mare with a three-fourth or thorough-bred horse, which is possessed of sufficient substance and height. The produce of these is the coach-horse of the highest repute, and most likely to possess good action. His points are advantageously placed, with a deep and well-proportioned body, strong and clean bone under the knee, and his feet open, sound, and tough. He possesses a fine knee action, lifts his feet high, which gives an elegance to his paces and action: he carries his head well, and has a fine elevated crest. The full-sized coach-horse is, in fact, only an overgrown hunter, too large for that sport. The carriage-horse, reduced to drawing stage-coaches, is generally used in a very disgraceful manner. Urged with a heavy draught to the height of his speed, almost incessantly wrought, whipped unmercifully, and poorly groomed, his fate is often melancholy in the extreme. It ought to be recollected, that in proportion as the load or draught is increased, so is the animal's power of speed lessened; and therefore to make him both draw a heavy weight and run also, is to put him beyond his natural powers, and his muscular energy suffers accordingly. We shall afterwards advert to the principles which ought to regulate both draught and speed.

The term *Hackney*, in common use, is employed to denote a kind of horse fitted for general services, and is therefore understood to exclude the horses of the highest breeding, as the thorough-bred horse and hunter; and there is further associated with the idea of a hackney, an animal of moderate size, not exceeding fifteen hands, and possessing action, strength, and temper. Our present breed of hackneys have a considerable portion of racing blood in them, varying from a half to seven-eighths. The latter are too highly bred for the general purpose of a roadster, as their legs and feet are rather tender; and their long paces and straight-kneed action are ill adapted for the road, being more fitted for cantering and running than the trot, which is the distinguishing characteristic of a good hackney. Indeed they should never be permitted to go at any other pace than a trot, which is undoubtedly much better adapted for the road than for cantering.

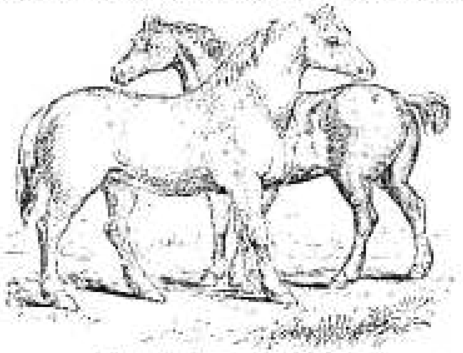
Nothing is more essential in a hackney than sound strong fore-legs, and also well-formed hind ones; his feet must be quite sound, and free from corns, to which hard-ridden horses are very liable; and he ought only to lift his fore-legs moderately high. Some are of opinion that he cannot lift them too high, and conceive, while he is possessed of this quality, he never will come down. There is a medium, however, in this, as a horse that raises his fore-legs too high in trotting is always disagreeable in his action, which greatly shakes and fatigues the rider; besides, he batters his hoofs to pieces in a few years. The principal thing to be attended to is the manner in which the hackney puts his feet to the ground; for if his toes first touch the road, he is sure to be a stumbler. The foot should come flat down on the whole sole at once, otherwise the horse is not to be depended upon in his trotting. A hackney should be particularly even-tempered, and not given to starting. The thorough-bred hackney ought to possess two qualities, indispensable to the safety of the rider—he should never shy at anything on the road, and his motion at a trot should be much more smooth than that of a half-bred horse.

The Cart or Draught-Horse.

The cart-horses of Great Britain are extremely variable in point of size as well as in shape, differing in almost every county. One principal character, however, is weight, to give more physical force in the draught. They should not be above sixteen hands high, with a light well-shaped head and neck, short pointed ears, with brisk sparkling eyes: their chests should be full and deep, with large and strong shoulders, but rather low in front than otherwise. The back should be straight, and rather long, but not too much so, as this always impairs his general strength; the animal should stand wide on all his four legs, and considerably wider behind than before; he ought to have great pliability in the knee-joints, and be able to bend them well, which assist in producing a brisk and active step in walking, a quality of much consequence in a cart or wagon-horse. The height to be desired in a draught-horse, however, will depend upon the purpose for which he is to be employed.

In the midland counties of England—Warwickshire, Derbyshire, Leicestershire, Lincolnshire, and Nottinghamshire—there is a very large breed, called the great cart-horse. It was bred in the lowland rich alluvial pastures of the plains of these counties, from the Flemish and Dutch horses, with the larger English breed. Mr Bakewell introduced horses, and also mares, from the Netherlands, and thus produced those fine animals with Belgic blood both on the side of the sire and dam. The very large horses of seventeen hands and upwards are only useful for the purposes of brewers' drays, wagons, and the slop-carts of London. It is, however, doubted if they answer the better for their gigantic size; and all who have written on the subject, consider that they are inferior in point of strength, on account of their bulk; for by the feeding which is required to increase their dimensions, little of muscular fibre is produced, the growth being principally in the cellular tissue and fat; and the additional quantity of food required to keep up their system must more than counterbalance any advantage to be reaped from their size.

Latterly, considerable pains have been taken to improve the qualities of ordinary cart-horses, among which we include those required in agriculture. A breed called the Clydesdale is highly valued for either cart



Clydesdale Horse—Suffolk Punch.

or plough. Animals of the Clydesdale breed reach to a large size, and are not unfrequently to be met with sixteen and a half hands high. These animals are strong and hardy, but their heads are somewhat coarse, and they are rather flat on the sides and hinder quarters. The usual colour of these horses is gray or brown. This breed is supposed to have originated about one hundred and thirty years ago, between the common Scotch mare and the Flanders horse. As a breed, the Clydesdale is rapidly rising in estimation, and is now undergoing considerable modifications and improvements chiefly for farm purposes.

Ponies.

A horse beneath thirteen hands is called a pony, but this definition is not very strictly attended to, and the same thing may be said of the *galloway*. The old Scottish galloways, which took their name from the district of Galloway, in the south-western extremity of the country, are now nearly extinct. They were stout, compact animals, sure-footed, and of great endurance, and on these accounts invaluable in travelling over rugged and mountainous districts. The beauty and speed of the galloway were supposed to have arisen from the breed having been the produce of the Spanish jennets that escaped from the wreck of the Spanish armada; and these, crossed with our Scottish horses, gave rise to this esteemed breed. But we apprehend they were famous at a date long prior to that event, as this district is known to have supplied Edward I. with great numbers of horses. This breed seldom exceeded fourteen hands in height: their colour was generally bright bay or brown, with black legs, small head and neck, and their legs peculiarly deep and clean. A compact stout-built pony, of from thirteen to fourteen hands high, and possessing some of the qualifications of the galloway, is called *a cob*, which is valuable as a steady pacer, at an easy rate.

The small ponies of the Highlands of Scotland and Shetland (usually called *shelties*) may almost be termed wild animals; for they go at large in herds on the hills and wastes, and are not shod till caught and put into training. They are docile and tractable, and being very sure-footed, are the best adapted for boys' riding. The Welsh pony is more handsomely formed than that of Shetland; has a small head, high withers, deep round body, and excellent feet. The Exmoor and Dartmoor ponies are also a hardy sure-footed race, well adapted for riding in wild districts. The ponies of Norway and Sweden, which are of a dingy cream colour, and of which there are now occasional importations to Britain, are considerably larger than the Shetland or Welsh breeds, but also hardy and very docile.

REARING OF HORSES.

The breeding and rearing of horses are carried on professionally in England; chiefly in Yorkshire; but many private gentlemen and farmers also address themselves to it as a means of pecuniary profit and the improvement of their animal stock. We do not pretend here to offer any specific directions on this branch of our subject, it being one in which the public at large are not particularly interested; and a few observations seem all that is necessary.

The circumstance which the breeder of horses requires to keep most in mind is, that the qualities, good or bad, of the animal are hereditary. Finely-made horses produce finely-made descendants, and *vice versâ*: heavy cart-horses never produce animals possessing the qualities of racers. Thus the bone, blood, and general make are directly transmissible; and, in the case of crossing, the produce is found to possess a proportional share of both sire and dam. Cross-breeding between extremely different horses is not found advantageous: it is a generally recognised principle that the nearer the resemblance between the parents, so will the produce be more satisfactory. Mr Smith, in his 'Observations on Breeding for the Turf,' remarks, that 'the stock of some mares will frequently partake most of the dam, and that of others most of the sire; and sometimes one foal will partake most of the mare, and the next perhaps most of the horse, &c. It also occasionally happens that the produce bears some resemblance to its grandsire, grandam, or other distant kindred; and although this does not perhaps often occur, so as to be very perceptible, yet as their qualities must, in a lesser or greater degree, descend to their progeny, it has always had its due weight; hence the value and partiality to blood, or ancestral excellences, transmitted through many generations.' He further observes, however, 'that he is disposed to attribute more in general to the dam than to the sire, inasmuch as he is decidedly of opinion that a good mare put to the worst thorough-bred horse would be much more likely to produce a runner, than a bad mare put to the most fashionable stallion in England; and therefore a person possessing good mares may bring any stallion into repute.' The grand aim of the breeder must be the propagating of excellences, and avoiding defects; but this is not to be accomplished, as respects important alterations, all at once; improvements in this, as in everything else, being the work of time and a judicious experience. Breeding *in-and-in*, as it is called, or between close relationships, is decidedly pernicious, and should by all means be avoided.

The season for mares is about February and March, but in some cases it continues later; and the term of gestation is generally over eleven months. The foal remains with the mother till weaned, which takes place earlier or later, according to the quantity of milk, the strength of the animals, and the season of the year. On removal, it requires to be carefully attended to, and provided with soft nourishing diet. Few things contribute more to the health and perfection of young horses than a sweet, sound, and hard-bottomed pasture range.

The operation of cutting is seldom performed on thorough-bred colts, but with all others it is common. It is an operation which ought by all means to be left to the veterinary surgeon or skilful farrier. The best authorities recommend it to take place with young cart-horses when four or five months old, but if for carriage or light work, it may very properly be postponed till the animal is twelve months old. The use of the operation is to render the horse more submissive than if left in an entire state, and to devote him altogether to the work he is required to perform. The advantages, whatever they are, are in some measure lessened by the lowering of spirit. The practice, however, is universally recognised in Britain, as one indispensable where numbers of horses are congregated, and required to be kept in good condition.

Breaking, or reducing the young animal to obedience, is a most important point in the education of the horse. If previously accustomed to handling, the difficulty of breaking will be much lessened. Racing colts are now begun to be broken at one year old, and saddle colts at two years, and are finally and fully broken and trained, some at three, and few later than four years old. Breaking horses is a regular business, and is best left to the person who is well accustomed to it, provided he follow a judicious course of treatment. As in the training of children, gentleness, yet firmness, ought to be a prevailing principle of management. The chief apparatus of breaking is a powerful bridle or head-tackle, with boots or pads strapped on the legs, to prevent them knocking against each other. The young horse is to a certain extent trained before his back is mounted; all the preliminary part of the process of subduing being accomplished while he is led by the bitted tackle. His back is not to be mounted till he is evidently able to endure the load without injury to his figure; too early mounting is apt to make him hollow-backed for life. In putting on a saddle for the first time, great caution should be taken; let the girths be drawn loosely, the crupper smooth, and keep the stirrups from dangling. In short, the animal requires on this trying occasion to be treated with as much kindness as it is possible to employ.

Having, by the various means which are adopted, brought the animal into subjection, and in effect taught him that he must in future act the part of a dutiful servant to an indulgent but firm master, the next step is to teach him his paces. These are partly artificial. Commence with slow and regular walking; whenever he is inclined to bolt, bringing him back to the steady pace you desire. After he has been accustomed to slow paces on a methodic plan, go on to the slow trot, then the quick trot, and lastly the canter and gallop. By no means allow him to mix these paces—that is, half-canter and half-trot—which would be an ungainly hobble; but let him know that he must, for the time being, keep to one kind of pace. The skill of the breaker consists in enforcing these lessons, and teaching the animal to change readily and neatly from one pace to another by little more intimation than a twitch of the rein. Lawrence recommends that 'a graceful canter should be encouraged, commencing with the proper or off-leg foremost, and the nag accustomed to be pulled up from the canter to the trot without unseemly and unpleasant blundering. The lessons should not be too long or fatiguing, but the young animal kept in as cheerful and easy a state as possible.' The first shoeing ought to be performed with great care, so as to alarm the animal as little as possible.

In connection with the breeding of horses we may say a few words respecting *mules*, or the hybrid offspring of the horse and ass. The mule proper is the produce of a male ass and mare; when the parents are the horse and she ass, the produce is called a *hinny*. The mule is the superior animal, partaking to a larger degree in the qualities of the horse; it is more robust, plump, and hardy, and better adapted for all the ordinary purposes of riding and draught. The hinny is more thinly made, has a longer head, and is altogether more like the ass than the horse. Mules of both kinds live to a very old age, and when properly trained, they are tractable, and very serviceable animals. There are comparatively few mules in Britain; but in Spain, and some other countries of southern Europe, also in Spanish America, they are numerous, and are used in carriages of people of the highest rank. According to a well-known principle in natural economy, by which intermixture of kindred species is not allowed to go beyond a single step, and only for one generation, mules do not breed; and the stock requires to be kept up by a recurrence to the common parentage.

The Teeth—Age.

The horse attains maturity at five years old, and he is in his prime till eight or nine. If no unfair play be used, his age may be judged of from his teeth, or, as it is called, *mark of mouth*. At five years old, when the teeth have been fully developed, the horse possesses six teeth in the front of each jaw, called the incisors or *nippers*; it is with these teeth that he bites. At a short distance from each end of the row of incisors, and in each jaw, there is a solitary canine tooth; these canine teeth are technically named *tushes*. At a greater distance inward in each jaw, and on each side, there are six grinders—the whole apparatus being designed to bite or crop the herbage, to tear, and to chew. At five and a half years old, the nippers are marked by a natural cavity formed in the substance between the outer and inner walls, and it is the presence or absence of these darkish marks that certifies the age of the animal. When the horse reaches six years, the marks in the two front nippers in the nether jaw are filled up, and the tushes are blunted. At seven years, the two nippers next the middle ones are also filled up; at eight, the two outer ones are filled up also, and the tushes are round and shortened. The lower nipper teeth are now all smooth; the marks are gone; but in the teeth of the upper jaw marks remain a year or two longer. At eight years, the disgraceful practice of *bishoping*—a term given from the name of the inventor—is often resorted to, for the purpose of imitating the obliterated marks. An engraving tool is employed to cut the surface, and a hot iron is then applied to give a permanent dark stain. This infamous trick may impose on the ignorant; but a person skilled in horses can easily detect the imposition, from the stains being diffused around the marks, and other appearances.

As a horse, if well treated, remains in excellent working condition till twelve, and even later, the disappearance of the marks on the teeth is often of little consequence. Some horses are as valuable to their owners at fifteen years as they are at eight; and for ordinary saddle-work, ten to twelve may be considered an age sufficiently young. It is important, however, that the teeth are capable of mastication; for if the animal is unable to chew his food properly, he cannot be kept in good condition, or fit for the performance of his duties. In consequence of the very general abuse of horses, few live till twenty-five years old; and the instances of any living till above thirty are rare.

Technical Terms.

Horsemen employ terms to horses which are not strictly adhered to in ordinary language. A male horse left uncut is said to be an *entire horse*, to distinguish it from the *gelding*, or cut animal. A female horse is always spoken of as a *mare*. A young male horse is called a *colt*, and a young female a *filly*. *Thorough-bred*, as already noticed, is applied only to animals whose pedigree can be traced to an Arabian origin, without stain or any common intermixture. When the pedigree of the racer is to a certain degree stained, the animal is called a *cocktail*. The term *blood* is of more loose signification; but what is generally understood by it is a horse which is thorough-bred, or of the blood of the Arabian, and consequently shows a fine spirit and action. A horse may be half-bred, three parts bred, and so on, according to his pedigree. The half-bred is produced from a racer and a common mare. Some of the best riding-horses are of this stamp. The term *welter horse* is applied to racers who are able to carry the highest weight.

Horses are measured by *hands*, four inches being reckoned to the hand; the measure is taken at the fore-leg and shoulder. To all the more prominent parts of the body and members certain technical names are applied; for example, to take the four extremities first:—the *muzzle* includes the lips, mouth, and nostrils; the *withers* are the sharp protuberance over the shoulders between the back and neck; the breast is the *counter;* the *arm* is the upper part of the fore-leg, but enveloped in the muscle of the shoulder; beneath it is the *fore-arm*, which is the higher part of the visible leg, and extends downward to the *knee;* below the knee we have another stretch called the *shank*, which extends to the *pastern*, or, as we might call it, the ankle; the *fetlock* is behind the pastern; beneath are the feet. A few of the hinder extremities are named as follow: the *croup*, which extends from the loins to the root of the tail or rump; the *flank*, extending from the ribs to the haunches; and the *leg* or thigh, which reaches down to the *hock* or middle joint of the hind-leg, corresponding to the knee in the fore-leg. The left side of a horse is called his *near* side; and his right the *off* side.

The greater number of British horses are of a dark colour, inclining to black or brown, but of innumerable shades. One kind of brown is called bay, and another the chestnut; a yellowish chestnut is termed the sorrel. The roan is a blending of red and whitish tones. The gray is a mixture of white and black hairs, and in old age, becomes altogether white. The dark colours are the most esteemed for their physical qualities, and patches of white on the legs are considered defects or foul markings.

STABLE MANAGEMENT.

The horse, as has been already mentioned, possesses very delicate senses, and is nice in his habits, in which respect he differs very materially from black cattle. In a state of nature, the animal seems to be best adapted for a mild and genial climate, and to rejoice in freedom and space. When reduced to domestication, care should be taken to violate as little as possible his natural tastes and habits. His delicacy of constitution, augmented in no small degree by an artificial mode of life, should warrant the best attentions of his keepers; and whatever be the nature of his work, he should be treated with kindness, regularly fed and supplied with pure water, allowed a cleanly and well-ventilated habitation, and his body and limbs preserved free from dirt and all offensive matter that may cling to them. The leading features of management may be defined as follows:—

The Stable.

The stable varies in size, according to the number of horses kept. Of whatever dimensions, the situation should be dry and airy; if in any respect damp or fœtid, the animals will assuredly contract disease. When the stable is calculated to contain many horses, it is seldom regular in temperature, from the fluctuation of numbers in it at any one time. To avoid this defect, the best size, in ordinary circumstances, is that which will accommodate six or eight horses, leaving plenty of room to each.

A stable with a row of stalls only on one side is better than one with double rows; if double, the space between should not be less than eight or ten feet wide. Sixteen feet is a proper width for a stable with a single row, six of the feet being allowed for the depth of the stalls; each stall should also be six feet wide, but commonly only five and a half are given. The floor of the stalls should be neatly paved, either with stones or with the new caoutchouc pavement; slope very little from head to feet; and be bounded by a gutter, with gratings to carry off all liquid refuse. The gangway, or space beyond the stalls, should be also paved in a neat manner; and care ought to be taken that rats are effectually excluded from the walls or any part of the flooring. The stalls should be lined with smooth wood. The stable should have only one door, and that not opposite a stall; it ought to be at least four and a half or five feet wide, and eight feet high. A pinchedness in any of these details is far from economical.

The inner walls of stables are often kept shamefully dirty. They ought by all means to be well white-washed, at regular intervals, in order to extinguish vermin and wipe off impurities. The interior ought to be well lighted with windows, which should be kept clean, and never permitted to remain in a broken condition. A little carelessness in this respect may occasion the loss of a horse; for broken windows in stables are about as dangerous to the health of the inmates as broken windows in a dwelling-house.

When we say that the stable should be well lighted, we certainly oppose one of the most vulgar prejudices respecting horse management. In most instances stables are kept as dark as dungeons, greatly to the injury and discomfort of the inmates. It is impossible to understand what can be rationally designed by keeping horses standing during their waking hours in the dark. Nature never intended anything of the kind; and we say the practice should be abolished. Mr Stewart pleads as warmly as we do on this point. 'A horse was never known to thrive better from being kept in a dark stable. The dealer may hide his horse in darkness; and perhaps he may believe that they fatten sooner there than in the light of day. But he might as well tell the truth at once, and say that he wants to keep them out of sight till they are ready for the market. When a horse is brought from a dark stable to the open air, he sees very indistinctly; he stares about him, and carries his head high, and he steps high. Dark stables may thus suit the purposes of dealers, but they are certainly not the most suitable for horses. They are said to injure the eyes. There is not perhaps an animal so liable to blindness as the horse. It cannot be said that darkness is the cause; but it is well known that the eyes suffer most frequently where there is no light. Whether a dark stable be pernicious to the eyes or not, it is always a bad stable. It has too many invisible holes and corners about it ever to be thoroughly cleaned. All these things considered, it is evident that the stable ought to be well lighted.' The preferable plan of lighting is by skylights, made to open when required, for the sake of improving the ventilation.

Hay-loft—Racks—Mangers.

The hay-loft, or place of deposit for hay, ought not, as is usually the case, to be over the stable, but adjacent; and a chamber level with the floor of the stable is preferable. The reason for this is, that the hay may be preserved free from the breath of the animals and effluvia which rise from the stalls. Lawrence strongly opposes the use of hay-lofts over stables:—' According to the good old and present custom, it is the receptacle of all kinds of impurities as well as hay—the excrements of cats and mice, and exuviæ of spiders, and the accumulated and sacred dust of perhaps half a century. Add to these trifles the perpetually-ascending clouds of steam from the stabling below, contaminating, drying, and exhausting the hay of its fragrance, and of every pure and beneficial quality. Hay should remain in the stack, in order to have it in its utmost fragrance and moisture of quality, to be cut often, and taken fresh to the horses, there being a clean and cool hay-room near the stable, to contain small quantities. The gangway and walls of the stable should be perfectly clear of all encumbrance of chests, pails, brooms, shelves, saddles, or lumber of any kind, for which extra rooms are the proper place.' In cases where hay-lofts are used, let them be kept as clean as possible, and allow no opening to the racks. The hay must be brought down in small quantities, and placed in the racks.

Hay-racks of the best material and form are made of iron, the bars rounded, and two inches from each other. The rack need not traverse the whole breadth of the stall, because in such a plan rubbish collects in the corners. A size to hold from a half to a whole stone of hay will be sufficient in most instances; and the form should be that of a convex or bulged grating from the wall, placed a little above the head of the horse. A rack of this or any other shape cannot be kept too clean; the bars should be daily rubbed, and all refuse of hay removed.

The manger, from which the corn and other kinds of food are eaten, is also best made of cast-iron, and need not be larger than a foot in length and breadth, and about nine inches deep. The old-fashioned wooden mangers, traversing the extremity of the stall, are absurdly large, and as they sometimes are splintered, they injure the animal when feeding or at rest. The form and dimensions of the manger, however, are of much less importance than being kept in a high state of cleanliness. All horses are nice feeders, but some are more fastidious than others, and will not partake of food from a foul manger, or one even which has been blown upon. Let the groom, therefore, keep his horse's manger as clean as he would do his own dish, and at all events do not allow it to get dusty or out of order. The manger is commonly used for dry food only; but some attentive stable-keepers also provide a manger for water, and this seems to be highly judicious. Drinking from pails is a slovenly practice, independently of its being inefficacious. It is now allowed that horses, when stalled, should have a little fresh water beside them to drink, if they feel the desire to do so; and it may be doubted if any horse will drink when nature does not need this refreshment. Be this as it may, a good plan is to have, in one corner at the head of the stall, an iron manger shaped like that for corn, and into which pure water can be made to flow from a pipe when the groom thinks proper. A waste pipe beneath should be provided, to run off the water which is left, or which has been rendered impure by the droppings from the animal's mouth.

Bedding—Ventilation—Cleaning.

The good horse sleeps in a lying posture, his legs being partly drawn under him, and his head remaining up. A horse that habitually sleeps standing, or will not lie down at night, is usually reckoned to be of little value; for it is indispensable to doing his duty during the day that he rests well at night. The preparation of a bed for the animal ought to be one of the most pleasing parts of a stable-keeper's duty, and he should perform it well. The best bed is made of wheat-straw, but when that is dear, or cannot be got, the straw of oats may suit the purpose. The more even and less rumpled the litter, the better. The bed should be made level, or sloping slightly from the sides and head towards the centre, and be completely free of hard lumps. All ought to be smooth, clean, soft, and the depth of litter perhaps seven or eight inches. Every morning the soiled litter is to be taken away to the dung-yard, and the clean portion separated and placed at the head of the stall, or in some other convenient situation, ready to be employed again at night.

Ventilation, or a means for the provision of fresh air, is of the first importance in the economy of the stable. Small apertures at different places should be made in the walls, to allow the entrance of pure air, and the escape of such as has been vitiated. A better plan for the removal of the foul air, especially from stables in which a number of horses are kept, would consist in leading it away in a tube from the roof to the flue of a fire. (See VENTILATION.) Architects generally do not make any provision of this nature in stables, and as few stable-keepers think of instituting such an effectual process of ventilation, we can only here state, as a general principle, that means of some kind should be adopted to keep the atmosphere of the stable in an equable temperature, and as pure as possible, both night and day. We invite attention to Mr Youatt's observations on this important point:—'If the stable is close, the air will not only be hot, but foul. The breathing of every animal contaminates it; and when, in the course of the night, with every aperture, even the keyhole, stopped, it passes again and again through the lungs, the blood cannot undergo its proper and healthy change; digestion cannot be so perfectly performed, and all the functions of life are injured. Let the owner of the valuable horse think of his passing twenty or twenty-two out of the twenty-four hours in this debilitating atmosphere. Nature does wonders in enabling every animal to accommodate itself to the situation in which it is placed, and the horse that lives in the stable-oven suffers less from it than would scarcely be conceived possible; but he does not, and cannot, possess the power and the hardihood which he would acquire under other circumstances. The air of the improperly-closed stable is still farther contaminated by the urine and dung, which rapidly ferment in the heat, and give out stimulating and unwholesome vapours. When a person first enters an ill-managed stable, and especially early in the morning, he is annoyed not only by the heat of the confined air, but by a pungent smell, resembling hartshorn; and can he wonder at the inflammation of the eyes, and the chronic cough, and the inflammation of the lungs, with which the animal, which has been shut up in this vitiated atmosphere all night, is often attacked, or if glanders and farcy should occasionally break out in such stables! It has been ascertained by chemical experiment that the urine of the horse contains in it an exceedingly large quantity of hartshorn; and not only so, but that, influenced by the heat of a crowded stable, and possibly by other decompositions that are going forward at the same time, this ammoniacal vapour begins to be rapidly given out almost immediately after the urine is voided. When disease begins to appear among the inhabitants of these ill-ventilated places, is it wonderful that it should rapidly spread among them, and that the plague-spot should be, as it were, placed on the door of such a stable? When distemper appears in spring or in autumn, it is in very many cases to be traced first of all to such a pest-house. The horses belonging to a small establishment, and rationally treated, have it comparatively seldom, or have it lightly; but among the inmates of a crowded stable, it is sure to display itself, and there it is most of all fatal. The experience of every veterinary surgeon, and of every large proprietor of horses, will corroborate this statement.'

The more cleanly the stable is kept, the more easily will it be ventilated. Stables are often kept in a most offensively foul condition. In the first place, they are often ill-paved, and the refuse of the animals, getting imbedded in the interstices of the stones of the stall and gutter, keeps up a constant exhalation. Then there is no proper provision for disposing of the foul litter and urine. It is customary to rake out the used litter and other impurities to a dung-heap immediately outside the door, and there it steams and loses its value, besides being a nuisance to passengers. Instead of this bad economy, let all be raked or shovelled out to a dung-pit covered in from the outer atmosphere, so that every particle of the ammoniacal gases may be preserved. Into this pit let a smooth channel from the stalls convey rapidly and effectually all liquid refuse. Any man who willingly allows the liquid manures of his stable to run to waste, may with great justice be said to be daily picking his own pocket. Should the gaseous odour be intense, and the quantity of litter in the heap incapable of absorbing it, add now and then a spadeful of earth; or, what will be more effectual, a sprinkling of gypsum or dilute sulphuric acid. Any of the disinfectants and deodorisers, now attracting attention, may be used in stables with obvious advantage.

The stable should be clean swept, brushed, and thoroughly ventilated every morning, leaving impurities neither on the ground nor in the atmosphere. Good feeding and regular exercise may partly neutralise the effects of uncleanliness; but in the event of epidemical influenza, glanders, and other diseases, these effects become sadly manifest; and then, as Mr Stewart humanely observes, 'the proprietor begins to look about him. It is time for him to know that God has not given him absolute and unconditional control over his fellow-tenants of the earth. Oppression has wide dominions, but there are limits which cannot be passed; and death reveals the operation of a wise and beneficent law.'

Stable Furniture—Stablemen.

Every stable is to be provided with proper receptacles for hay and straw. The oats, peas, beans, bran, &c. should be kept in one large chest with divisions, or separate chests, and, if possible, be placed in an apartment separate from the stable. For small stables, an adjoining room should be fitted up neatly for the accommodation of the corn chest, the saddles, and other apparatus; all saddles, bridles, and small articles being properly hung on hooks on the wall, or placed on other appropriate supports. A cupboard for combs, brushes, &c. will be an advantage. If the stable be not supplied with water in pipes, a well should be at hand.

Horses require to be under the charge of persons who understand the business of attending to them in all their varied wants. Some individuals seem to imagine that any boy or lad will do for taking care of a horse. This is both inhumane and bad policy. Where only one horse is kept, a steady lad, under the directions of his master, and instructed in the line of his duty, will often be found sufficient; but he requires constant looking after, for all young persons, and some old ones too, are disposed to play pranks with horses, and rob them of their food. The ordinary class of ostlers are not regularly instructed in the qualities and wants of the horse. All they know is empirical, and their prejudices are frequently absurd. Let all such persons, therefore, be estimated at their proper value; and on committing your horse to any of them at an inn, see that he does his duty to the animal both as respects cleaning and feeding.

In stables in which two or more horses are kept, a regular groom should be employed; and this person should reside close by the stable, so as to be always at hand. The qualifications of a groom ought to be steadiness of conduct, promptitude in a case of difficulty, openness to advice or instructions, experience in well-managed stables, taste for cleanliness; and he should be as desirous of making his charge comfortable as he would his own person.

In large establishments there are head and undergrooms, strappers, and stable-boys—the latter a kind of loose appendages to the concern, who act as drudges to the superior officers, and look forward to promotion. In establishments of moderate size, the groom and driver, or coachman, are the only functionaries. It is the duty of the groom to attend to the horses in every particular, when in or about the stable, and when taking exercise. The duty of the driver is more particularly to keep the chaise or other vehicle in order, and also to clean the harness.

If all horses were good-tempered, or rendered docile by kind treatment, they might be advantageously left at liberty in their stalls; circumstances, however, require that they should be restrained; but this should be done with as little pain to them as possible. The halter or rein from the head-gear should be led to a ring at the head of the stall, leaving the animal at liberty to lie down in an easy posture. The rein, whether of rope or chain, should not be tied to the ring. It should go through the ring, and drop down with a plummet at the extremity to keep it down, yet allowing the animal to pull it up or allow it to sink at pleasure. A shorter halter may be employed during the day than at night, so as to keep him from straggling backwards into the passage or gangway. Some horses are most restive in restraint, and commit tricks to loosen themselves; and others, by awkwardness of movement, get cast—that is, benumbed or cramped—when lying; and it is often necessary to employ skill and force to raise them to their feet. A soft level bed and abundance of room are the best preventives for this kind of accident.

Grooming—Dressing—Trimming.

The skins of horses are liable to become clogged with a scurf of dried perspiration, along with particles of dust and mud, which collect and lodge among the hairs. It is of great importance to remove these impurities by currying and brushing, for the sake of the health of the animal, independently of the value of the operation as respects the appearance of his coat. The degree to which this species of grooming is carried will of course very much depend on circumstances; but as a general rule, it should take place every morning before the horse is led forth to the labour of the day.

The grooming is commenced while the animal is in his stall, his wrapping-cloth, if he have one, being removed, and the restraining rein being lengthened, to allow his standing a little back into the gangway. If restive, his head must be tied up. All refuse having been previously removed, a little of his bedding may be drawn out for his hind-feet to stand upon. The first thing done is to curry him with a curry-comb—a flat iron instrument, with rows of short blunted teeth and a handle. By being drawn along the surface of the body and limbs, it rakes up the lumps of hair, and generally loosens and brings up all extraneous substances. The groom commences with the neck and shoulders; next he goes to the body, hinder quarters, belly, and legs, both sides being treated alike. The curry-comb must not in any case be used roughly, and with thin-skinned horses its application must be very gentle. If the horse be regularly groomed, and its work not dirty, a gentle scrubbing with the curry-comb will in most cases suffice. In performing the operation, a brush may be held in the other hand, with which to clear out the teeth when necessary. After the curry-comb has gone its rounds, apply the brush in turn, going over the whole surface with it, from head to heels, to remove all raised impurities, and to lay the coat smooth. Lately, a rough hair-glove has been introduced into use as an improvement upon the brush; and it certainly possesses the advantage of being more easily applied to the head, limbs, and flank, than the brush. Should the horse be changing his coat, which he does twice a year, the curry-comb must not be used at all; a rubbing with a straw-wisp being perhaps sufficient.

After the currying and brushing, the groom proceeds to comb the forelock, mane, and tail, so as to make all the hairs lie straight. This finishes the grooming; but if the legs or feet be white, they will perhaps require washing with warm water and soap—to prevent the growth of a yellow appearance—and then dried with a wisp. We have only to add, that if horses are not groomed regularly in this manner, they will inevitably lose their health, or be troubled with parasitical animals lodging beneath the hairs, and never have a glossy and cheerful appearance. Some horses have a great repugnance to being groomed, but this generally arises from harsh treatment while they were young: if treated considerately, they will feel pleased with the friction, and grateful for the attention bestowed on them.

The cleaning of a horse after work is as necessary as the morning grooming. When a horse is brought to the stable in a state of perspiration, it should not be taken in to be at rest all at once, but be walked gently about till it becomes moderately cool. This allows the excitement of the blood-vessels and muscles to be allayed gradually, and prevents any sudden stoppage of the pores of the skin. To assist in drying and cooling down the animal, he may be scraped or rubbed with wisps. Wisping is preferable. After the horse has been walked and wisped, his legs and feet should be washed with water and a brush or sponge, and also his belly, if it be dirty with sparks of mud; but after any such washing, every part should be thoroughly dried with a fresh wisp. Never leave a horse with wet legs or feet. In the country, it is not unusual to walk horses into a river to wash their legs—a practice most detrimental to their health, and which should not be allowed.

When the horse has been cleaned and dried, the cloth may be thrown over him, and tied to his stall. The cloth used in summer should be lighter than that used for winter. It is customary for grooms to exercise horses with the stable-cloths wrapped round them, and then perhaps the next hour they are taken out saddled, and without any cloth at all. This seems an inconsistency. The use of cloths is to protect the animal's loins from cold, and is unnecessary in fine weather. If the horse has to stand still out of doors, and the weather be ungenial, his loins ought by all means to be protected by an oiled cloth. The horse is very susceptible of injury by exposure of the loins; and it will be observed that, to shelter that part, cavalry soldiers wear a long riding-cloak, which falls loosely over the hinder part of the animal.

Nature gives the horse a beautiful flowing tail and mane, for the purpose of whisking off flies, and for other uses; but mankind, in taking the creature under their protection, have in many instances, and for no good reason, as far as we are aware, deprived it of these graceful personal appendages. The most contemptible piece of this rash interference has been the docking of the tail, and causing it to cock up, thus leaving the rear of the animal exposed. The tail should be left flowing to a point, and only trimmed to a limited extent; and the same thing may be said of the mane. Nature has likewise given the animal long hairs on the legs, independently of the fetlocks. These various appendages have likewise not been given unnecessarily; they answer as a kind of thatch to carry off the moisture which trickles down the legs, so as to keep the feet dry and the legs warm. These parts, therefore, should be trimmed sparingly; and the fouler the animal's work, the more should be left on. Any trimming should be executed tastefully with a comb and pair of scissors. It is customary to clip away the long hairs about the ears and muzzle, but this also must be performed with great discretion. These hairs have their uses, those about the ears in particular, and harm is not unfrequently done by their removal.

Management of the Feet.

When the horse has been stabled for the night, it will be the duty of the groom to see that the hoofs, above and below, have been cleaned, particles of sand removed from the crevices of the shoes, and the feet generally in a good condition. The feet have a tendency to harden and crack, and thus a good horse may become lame. The fore-feet are most liable to this serious evil. To prevent hardness and soreness of feet, it is customary to stop them at night with a soft moist material, most commonly pieces of horse-dung, which is crammed into the sole. No special directions on this point can be given; for some thin-soled horses do not require stopping, and the hind-feet are seldom in need of anything of the kind. When the frog is liable to thrush, the feet require to be kept dry, and cleaned and attended to with peculiar care. To prevent over-dryness of hoofs, as well as the undue action of moisture, it is advisable to anoint the horny part of the feet with an ointment made of tar, fish-oil, and bees-wax, melted together in equal proportions; but this should not be done unless it is absolutely required. If well washed, and kept clean, the feet will seldom require any of this kind of varnishing.

When at large in a wild state, horses, as may be supposed, go barefooted, like all the other lower animals. The hoofs grow with a slight curve up in front; but this does not seem to impair their speed. If domesticated horses were always to walk on turf, and not be obliged to carry or draw a weight, their feet might remain unshod; but the circumstances of their condition make it necessary to protect the hoofs from tear and wear by means of shoes. Horse-shoes have been used of many different shapes and materials; but it is needless here to speak of any others than the iron shoes in common use. The shoe must be of weight conformable to the powers and uses of the animal, but exactly to suit the curve of the hoof, flat, and of equal thickness, and be secured by nails to the hoof. The proper paring of the hoof before shoeing, and the shoeing itself, are matters to be left to the discretion of regular farriers. As a general principle, care must be taken not to drive the nails into any tender part, and the hoof should be as little broken as possible. A gentleman's horse should be shod at regular intervals, and a shoe never suffered to come off from too long usage.

Exercise.

Every horse ought to be exercised daily in the open air. The exercise should be in the early part of the day: when not exercised by work, he must be walked out and trotted on purpose. An authority already quoted (*Lib. Use. Know.*) observes:—' The horse that, with the usual stable-feeding, stands idle for three or four days, as is the case in many establishments, must suffer. He is disposed to fever, or to grease, or, most of all, to diseases of the foot; and if, after these three or four days of inactivity, he is ridden fast and far, is almost sure to have inflammation of the lungs or of the feet. A gentleman's or tradesman's horse suffers a great deal more from idleness than he does from work. A stable-fed horse should have two hours' exercise every day, if he is to be kept free from disease. Nothing of extraordinary, or even of ordinary labour can be effected on the road or in the field without sufficient and regular exercise. It is this alone which can give energy to the system, or develop the powers of any animal. In training the hunter and the race-horse, regular exercise is the most important of all considerations, however it may be forgotten in the usual management of the stable. The exercised horse will discharge his task, and sometimes a severe one, with ease and pleasure, while the idle and neglected one will be fatigued ere half his labour be accomplished; and if he be pushed a little too far, dangerous inflammation will ensue. How often, nevertheless, does it happen that the horse which has stood inactive in the stable three or four days, is ridden or driven thirty or forty miles in the course of a single day! This rest is often purposely given, to prepare for extra exertion—to lay in a stock of strength for the performance of the task required of him; and then the owner is surprised and dissatisfied if the animal is fairly knocked up, or, possibly, becomes seriously ill. Nothing is so common or so preposterous as for a person to buy a horse from a dealer's stable, where he has been idly fattening for sale for many a day, and immediately to give him a long run after the hounds, and complain bitterly, and think that he has been imposed upon, if the animal is exhausted before the end of the chase, or is compelled to be led home suffering from violent inflammation. Regular and gradually-increasing exercise would have made the same horse appear a treasure to his owner. Exercise should be somewhat proportioned to the age of the horse. A young horse requires more than an old one. Nature has given to young animals of every kind a disposition to activity; but the exercise must not be violent. A great deal depends upon the manner in which it is given. To preserve the temper, and to promote health, it should be moderate, at least at the beginning and the termination. The rapid trot, or even the gallop, may be resorted to in the middle of the exercise, but the horse must be brought in cool. If the owner would seldom intrust his horse to boys, and would insist on the exercise being taken within sight, or in the neighbourhood, of his residence, many an accident and irreparable injury would be avoided. It should be the owner's pleasure, and is his interest, personally to attend to all these things.'

Watering and Feeding.

A horse should be exercised a little after being watered. He should on no account be allowed to drink when heated, particularly if heated to the extent of perspiring. The only refreshment allowed in these circumstances is a rinsing of the mouth, and the muzzle may be washed and relieved of froth. When not permitted to take water of his own accord in the stall, let him be offered a pail three or four times a day; and after drinking copiously at either a pail or pond, he may be trotted or gently cantered, the motion being generative of heat, and at least prevents any chill.

Horses are fed on different materials in different countries; but principally on the various kinds of grasses and cereal grains. The Germans give them foods of brown bread while on a journey; in India, rice and spices are employed for their diet; in England, the chief articles of food are oats and hay, with inferior proportions of beans, peas, cut straw, and bran. The quantity, and also the nature of the food will depend on the habits of the animal, and the work to which he is put. If the work be hard, he must be fed to a considerable extent on oats, which are more nutritious than most other articles in use; but if the work be light, a lighter diet of hay, with perhaps only a small quantity of oats, will suffice. The stomach of the horse being small, he cannot eat much at a time; and it is always preferable to feed him often, and at regular intervals, than to offer him large feeds at irregular periods. There is another reason for offering small feeds: the horse nauseates food which he has blown upon, or previously touched, and will accordingly reject it if offered a second time, or allowed to stand beside him. For various reasons, therefore, it is better to give him only a little at a time, so as to leave none behind. If the animal be a poor feeder, or apt to waste his food, greater care must be taken in this respect.

Oats ought to be sound, old, and dry. If musty, reject them. In almost all cases it is preferable to have them bruised; for by this they are more easily digested and nourishing than if left whole. It is now customary to mix oats with chaff composed of the cuttings of clover or meadow hay, and the straw of wheat, oats, or barley. In some stables a machine is kept to cut these materials. The length of the cuttings should be about half an inch. Bruised oats have a tendency to scour the animal; but the admixture of chopped stuff counteracts this quality.

Of hay, clover, and meadow-hay, little need be said. They should be sound, and sweet-flavoured, without any mustiness. The hay should, if possible, be a year old, and well saved for use in an adjacent stack. Some horses are fond of peas; but they require to be given with caution, as they are apt to swell in the stomach. Almost all horses are inordinately fond of carrots, which, when administered in small quantities, do not purge the animal, and improve his coat. A respectable authority states, that 'for agricultural and cart-horses, eight pounds of oats and two of beans should be added to every twenty pounds of chaff; and thirty-four or thirty-six pounds of the mixture will be sufficient for any moderate-sized horse [daily] with fair or even hard work.' In this estimate no hay is supposed to be given. When the horse is fed on the two last articles, hay and oats, four feeds, or nine or ten pounds of oats per day, will be a fair allowance during winter, and in the case of moderate work; but in summer, half the quantity, along with a proportion of green herbage, will suffice. Many gentlemen follow a general rule of allowing twelve pounds of oats per day to each riding-horse, and this is given in three or four meals. A pony, having but moderate work, will be well fed on six pounds of oats per day, with a fair proportion of hay. Latterly, sago has come into use as an article of horse diet; and we believe it is highly nutritive, and may be employed to a certain extent to supersede oats, or to be mixed with them. It should be partially softened by preparation.

Several serious diseases arise from improper feeding, particularly at intervals during hard labour; and on this point we refer to our observations on

THE DISEASES OF HORSES.

In consequence of the general mismanagement and ill-treatment of horses, they are exposed to a number of formidable diseases. Those of most frequent occurrence are glanders, inflammation of the lungs, broken-wind, inflammation of the bowels, and certain illnesses of the feet and legs. Referring our readers to larger works on the horse for full information on these diseases, and recommending all unskilled persons at once to hand over their horse to a veterinary surgeon when unwell, we propose only to give a few hints as to the best means of prevention. The institution of schools of veterinary surgery, at which the anatomy, peculiar nature, and diseases of horses are explained by men skilled in this important department of science, has been a powerful auxiliary in improving the qualities of horses, preserving their lives, and saving them from much needless distress.

Glanders.

This is a disease of the nose, in some measure resembling the effects of a cold. It is believed to be occasioned by breathing vitiated air, and takes the form of an irritation of the delicate membranes of the nostrils, accompanied by an offensive discharge. Glanders is highly infectious, and may be communicated hereditarily. When not removed in time, it will perhaps terminate in farcy, a disease of the veins, which causes swellings called farcy-buds. The preventive of either of these dangerous maladies is cleanliness in the stable and pure ventilation.

Inflammation.

The more ordinary inflammation is that of the lungs, and is caused by sudden changes of temperature; it is, in reality, the grand disorder of the horse, and its effects are only paralleled by those of pulmonary consumption in the human species. Already we have spoken of the great impropriety of exposing horses, while heated, to cold draughts. Allowing them to stand any length of time in the open air, in cold or moist weather, is equally objectionable, and positively cruel. Inflammation of the lungs, however, will arise from various causes besides cold, and these have engaged the most serious attention of veterinarians. Some time ago, the Highland Society of Scotland offered a premium for the best essay on the *inflammatory complaints generally* of farm-horses, and the prize was awarded to Mr Matthew M. Milburn, Thorpfield, near Thirsk, Yorkshire, whose paper appeared in one of the numbers of the 'Quarterly Journal of Agriculture.' Some of the parts of the essay appear to us so worthy of being made known to persons who have the management of horses, that we take the liberty of giving them publicity in our pages.

After showing that there is not any particular predisposition to disease in the breeds of horses usually employed in heavy draught, nor in the particular conformation of the animals, Mr Milburn proceeds to say that 'the post-horse, and such as are required to perform fast work, are more liable to attacks of diseases of the brain, the nerves, and the lungs, simply because their work consists of rapid and powerful exertion; the farm-horse, the animal of long and steady exertion, to gripes, inflammation of the bowels, and stomach-staggers—results, as I shall presently show, of a management unsuited to the character of the labour we require from them. The stomach of the horse is remarkably small—smaller in proportion to his size, and the quantity of food he requires, than any other domestic animal. Nature intends for him a supply of nutritious food, and that *at short intervals*; wherein he materially differs from the ox, whose capacious stomach will contain food which will not be digested for hours. The post-horse, the hunter, and the carriage-horse, have food of the most nutritious description, and the time during which they are worked is necessarily short, owing to the extreme exertion required; they return to their food; and although their appetite may for a time be impaired, and their stomach and bowels affected by the general debility of the system, yet they recover their tone as soon as the rest of the frame admits of their taking food. The farmer's horse, on the contrary, has food of a less nourishing nature; his rack is filled with straw, or at best with clover; the ploughman rises early, gives him a feed of corn, and leads him to his work, where he continues for seven, eight, and even nine hours, and his whole day's work is completed before he is allowed to eat. We do not find the ox, worked under similar circumstances, so affected in the stomach and bowels, simply because his capacious stomach, when filled, requires many hours to empty; while, as we have seen, it is different with the horse. Debilitated and hungry, the horse returns, and his rack is plentifully supplied, and a good feed of corn given him, and he is left to himself: he eats voraciously, half masticates his food, loads his debilitated stomach, and his digestive organs are weakened, and permanently injured. This course is repeated—a habit of voracity is acquired; and at no very remote period the food lodges and obstructs the pyloric orifice (the passage from the stomach to the bowels), fermentation ensues, gas is evolved, the stomach is distended, he grows sluggish and sleepy, drops his head upon his manger; or he is delirious, and evinces that the sympathy which exists between the stomach and the brain has excited the latter organ; he rolls, paws, and is seized with convulsions; at length he expires, and he has died of stomach-staggers. The half-masticated food has irritated the bowels, extra exertion of the muscles has been required to propel the fæces to the rectum, and cholic or cramp (spasms) of the bowels has followed; or a course of continued irritation, or of continued cholic, or both, has ended in inflammation of the bowels. I remember a beautiful farm-horse, which, owing to the distance of part of the farm to which he belonged from the buildings, was worked the long hours described, and finished his day's work before his bait. He was constantly subject to attacks of the gripes, which were subdued; but he died of stomach-staggers. The same stable, then so often subject to diseases, is now, by a change in the system, completely free from them. Another case, however, occurred: a beautiful compact little mare was constantly afflicted by cholic; she eventually died of inflammation of the intestines.

There are other parts of the management to which horses employed in agriculture are subject, which induce diseases of the bowels. For instance, a boy returning from work, with heated and sweating horses, to save himself trouble, allows them to drink copiously at some pool or stream he passes. Suddenly one or more of the horses exhibit symptoms of gripes; they suddenly lie down, roll about, look at their sides, rise up, seem relieved, and again speedily relapse; the sudden application of the cold water has produced spasms in the bowels, through which it has passed. This is neglected, or perhaps gin or whisky, aided by pepper, is administered as a remedy, and severe and general inflammation of the bowels is the result: this is mistaken for another attack, and again the poison is administered, and the inflammation increased, and death follows. The horse of heavy work, too, is longer exposed to the inclemencies of the weather than the animal of light work. In the former, the rain is allowed to fall upon him for hours, and it is allowed *to dry upon his back;* the sympathy between the skin and the alimentary organs is known to every groom; obstructed perspiration, and consequent irritability, is conveyed from the one to the other, and disease is the consequence. It is true the latter is also partly exposed to the rain, but for shorter periods, and the wisp and brush are liberally applied when he enters the stable; a determination of blood takes place to the skin, perspiration is promoted, and disease thus prevented.

Of the best means of preventing these diseases in farm-horses we will now treat: we have attributed the peculiar liability to them in farm-horses to mismanagement, with the exception of certain instances of peculiar formation of the animals; and although the farmer must necessarily work his horses longer hours than the horse of rapid work is capable, there is no necessity for depriving the animal so long of food. No horse should work more than five or six hours without a bait. If we examine the history of the stables of large farmers, whose fields necessarily lie at a great distance from the buildings, and where they are worked long in consequence, and compare it with that of small farmers under the contrary circumstances, we shall find a striking difference as respects the health of the animals. The case referred to above strikingly illustrates the truth of this observation. But it may be asked—How is it possible to bait the animals so far from home? The difficulty seems to be in procuring food upon the spot; for if this is not done, the precaution will be neglected, and at anyrate the land will be occupied by it. This, however, may be remedied. In the case, for instance, of a field intended for turnips, which has to be worked during the spring, a part of it, half an acre, or in proportion to the size of the field, may be sown with winter-tares, a few of which may be mown off, and given to the animals green, without carrying them from the field, interfering with any crop, or wasting any time in carrying the horses to a distance. If the field be intended for summer-fallow, the spring tare will answer, and which may be used in the same manner, instead of allowing the poor animals greedily and indiscriminately to crop the leaves of the hedges at every turning, from the impulse of hunger. There is another easy way of baiting, which some carters adopt, and which might be applied to the farmer's horse, especially when carting. It consists in securing a bag containing corn over the animal's mouth and nose, by a string, which passes over the poll, and is locally denominated a "nose-bag," or "horse-poke," and which should be removed when he has finished his food. To prevent the effects of the wet upon the skin, an unexpensive glazed cloth may be thrown over the horse's back, and secured to the collar and traces. This may by some be considered very troublesome; but it will be found that when it is once begun, it will be considered no more trouble than carrying the rest of the harness; and if disease is prevented, the trouble amounts to nothing. To counteract as much as possible any habits of greedy feeding which the horse may have acquired, his corn should be mixed with chopped straw, or chopped clover, which will secure its proper mastication, and prevent many troublesome complaints, as well as render all the nutrition of the food available. These may be substituted by an admixture of clean chaff with corn—a plan which is pursued in a farm stable with which I am acquainted, and is found a useful practice. It would save the animals much time in eating if all their food was chopped, and perhaps steamed; but on this subject we have not sufficient data to determine with accuracy.'

The cure, it has been hinted, must generally be left to the veterinary practitioner, whose chief object should be to empty the stomach. In severe cases, an ounce of laudanum and a drachm of pounded ginger, in a quart of warm ale, may be used with probable success.

Broken-windedness.

When the breathing of a horse is rapid and laborious, it is said to be *thick-winded;* and when it breathes irregularly, the inspiration taking one effort, and the expiration two, it is called *broken-winded.* Inflammation of the lungs from cold is a cause of thick-windedness, the condition of these organs preventing the full action of the air-tubes. This complaint, if not removed, will most likely terminate in the broken-winded condition; but broken-windedness will take place without this premonitory symptom. The main cause of broken-windedness is sharp work after over-feeding—causing the animal to run while the stomach is full. The distended membrane presses upon the lungs, and causes a rupture in the air-cells, by which several cells are thrown into one. Thus the breathing is rendered irregular by imperfect muscular action in the parts.

This disease is almost invariably a result of sheer carelessness in the persons whose duty it is to superintend the feeding of the horse. The case, according to Mr Youatt, stands thus:—'Suppose a horse to be a gross feeder, and to have filled his stomach with straw and hay, or provender that occupies a great bulk, and contains little nourishment, the lungs are squeezed into less than the natural compass. Let the horse be now suddenly and smartly exercised; more blood must be purified, and in the violent effort to accomplish this, some of the cells give way. Therefore we do not find broken-winded horses on the race-course, for although every exertion of speed is required from them, their food lies in small compass, and the stomach is not distended, and the lungs have room to play, and care is taken that their exertion shall be required when the stomach is nearly empty. Carriage and coach-horses are seldom broken-winded, unless they bring the disease to their work, for they, too, live principally on corn, and their work is regular, and care is taken that they shall not be fed immediately before their work. The farmer's horse is the broken-winded horse, because the food on which he is fed is bulky, and too often selected on account of its cheapness; because there is little regularity in the management of most of the farmer's stables, or the work of his teams; and because, after many an hour's fasting, the horses are often suffered to gorge themselves with this bulky food; and then, with the stomach pressing upon the lungs, and almost impeding ordinary respiration, they are put again to work, and sometimes to that which requires considerable exertion.

This disease depends as much upon the cramped state of the lungs, from the pressure of an over-gorged stomach, in the ordinary state of the animal, as on the effects of over-exertion. The agriculturist knows that many a horse becomes broken-winded in the straw-yard. There is little nutriment in the provender which he there finds; and to obtain enough for the support of life, he is compelled to keep the stomach constantly full, and pressing upon the lungs. Some animals have come up from grass broken-winded that went out perfectly sound.

The cure of a broken-winded horse no one ever witnessed; yet much may be done in the way of palliation. The food of the animal should consist of much nutriment condensed into a small compass; the quantity of oats should be increased, and that of hay proportionably diminished; the bowels should be gently relaxed by the frequent use of mashes; the water should be given sparingly through the day, although at night the thirst of the animal should be fully satisfied; and exercise should never be taken when the stomach is full.'

Curb—Bog-Spavin—Bone-Spavin.

The hock-joint is particularly liable to derangement, so as to render the animal unsound. One of these affections is called *curb*, which arises from over-exertion of the ligaments, and takes the form of an enlargement a few inches beneath the joint of the hock. A more serious complaint of the hock is the *bog-spavin*, which takes place from over-exertion, and is an inflammation in the vesicles containing the lubricating material for the joint. This disease is almost incurable; and the poor animal is in general only fit for ordinary and moderate work all the rest of his life. The *bone-spavin* is a still more formidable disease. It is an affection of the bones of the hock-joint, caused by violent action, or any kind of shoeing which throws an undue strain on certain ligaments, and deranges the action of the bones. A bony deposit takes place, the joint is stiffened, and the consequence is a lameness or stiff motion in the hind-legs. Blistering, as a counter-irritant, and rest, are the principal remedies prescribed for this complaint; but the best thing of all is never to overload the horse, or put him to any violent exertion, so as to *prevent* not only this, but all other similar complaints.

Physicking.

Horses that are attended to with the greatest care occasionally get into a condition which requires physic—that is, purgative medicine; as, for example, when they have been too long on hard food, and require a laxative, when they get into a heated state of body from constant work, when their bowels get overloaded or disordered, or when they are getting too fat. The most simple laxative is a *bran-mash*. Bran is put into a pail, and softened with boiling water; when cooled sufficiently, it is given to the animal as the last food at night, instead of corn or hay. About half a pailful is a dose. Horses used by commercial travellers or others during the whole week, and fed on corn, are indulged in a mash on Saturday night; and this, with the rest on Sunday, keeps them in good condition. When a working-horse is lamed, or becomes sick, and must remain idle for a few days, he requires to be relieved by a dose of physic. Generally, this consists of from four to nine drachms of Barbadoes aloes, powdered, and formed into a round moistened mass, fit to be swallowed. It requires to be administered by a skilful groom, who will push it over the throat adroitly, without alarming the animal. Sometimes the powder is mixed with a little Castile soap. An hour or less after taking physic, a bran-mash should be given, and then the horse be gently exercised. On his return to the stable, he may be offered a drink of water from which the chill is taken, or as warm as he will take it.

We should consider it imprudent to offer any further explanations of the materia medica of horses; and again recommend all unskilled or but partially-instructed persons not to attempt doctoring their horses themselves, but to obtain at once the advice of a veterinary surgeon.

ADVICE IN PURCHASING A HORSE.

The purchasing of a horse is ordinarily a matter of very serious difficulty, in consequence of the proverbial trickiness of dealers, and the many defective points in the animal's constitution, which cannot be seen with all the care that may be bestowed. In offering any hints on this important particular, we must refer to the instructions of authorities whose testimony is worthy of confidence. Mr Stewart has written a valuable little manual, entitled 'Advice to the Purchasers of Horses,' which should be in the hands of all who have frequent occasion to make purchases. The following are a few of his admonitions:—

'In buying a horse, one of the chief requisites to be attended to is the degree of nervous energy which the animal possesses; and it is the union of this energy with good conformation that makes many horses invaluable. Its absence or presence, however, is not likely to be discovered by the purchaser without a trial; and to avoid disappointment in this respect, it is therefore advisable to obtain one prior to purchase. The horse should be set to the work he will be called on to perform; and if he is intended for the saddle or single harness, he should have no companion on his trial, for many animals work well in company that are downright sluggards when alone. Some horses have an unpleasant way of going, or are difficult to manage, or have some vice which is only displayed when at work. These are so many more reasons for having a trial prior to striking a bargain. But if that cannot be obtained, some sort of conclusion regarding the animal's spirit may be drawn from his general appearance. The way he carries his head, his attention to surrounding objects, his gait, and the lively motion of his ears, may all or each be looked to as indicative of "bottom," or willingness to work. It is only, however, in a private stable, or in that of a respectable dealer, that these *criteria* can be depended upon; for in a market-place, the animal is too much excited by the cracking of whips, and the too frequent application of them, to be judged off as regards his temper. Neither must the buyer be thrown off his guard by the animation which horses display at an auction, or on coming out of the stable of a petty dealer; for it is a fact, which cannot be too well made known, that there are many unprincipled dealers who make it their business, before showing a horse, "to put some life in him"—that is, they torture him with the lash, till, between pain and fear, the poor animal is so much excited, as to bound from side to side with his utmost agility at the least sound or movement of the bystanders.'

This writer continues, in relation to the head and other parts of the animal:—'The head, as being a part not at all contributing to progression, should in the saddle-horse be small, that it may be light—the nostrils expanded, to admit plenty of air, and the space between the branches of the lower jaw, called the channel, should be wide, that there may be plenty of room for the head of the windpipe. In the draught-horse, a heavy head is not, as far as utility is concerned, an objection, for it enables him to throw some weight into the collar; and hence, excepting its ugliness, it is rather an advantage, if he is used entirely for draught. But it makes the saddle-horse bear heavy on the hand of the rider, makes him liable to stumble, and, when placed at the end of a long neck, is apt to wear out the fore-feet and legs by its great weight. The neck of the saddle-horse should be thin, not too much arched, and rather short than long, for the same reason that the head should be light: and in the draught-horse it may be thick, stallion-like, and sufficiently long to afford plenty of room for the collar, and for the same reason that the head may be large in this animal. The windpipe should be large, and standing well out from the neck, that the air may have an easy passage to and from the lungs. A horse intended to be used for the miscellaneous purposes of carriage and draught should have a head and neck neither too light nor too heavy.

That the saddle-horse may be safe, and have extensive action, it is necessary that the withers be high. This advantage is indicated by the horse standing well up before; and it is usual, in showing a horse, to exaggerate the height of the forehand by making him stand with his fore-feet on a somewhat elevated spot. A horse with low withers appears thick and cloddy about the shoulder. In the ass and mule, the withers are very low, and the shoulders very flat, and this is the reason why they are so unpleasant to ride, and why it is next to impossible to keep the saddle in its proper place without the aid of a crupper. High withers, however, are not essential to the racer or the draught-horse. The former does all his work by leaps, and that is performed best when the horse stands somewhat higher behind than before: neither are high withers necessary to the draught-horse; but in the roadster, they are as important as the safety of the rider is, for a horse with a low forehand is easily thrown on his knees. In the draught-horse, this tendency towards the ground is obviated by the support the collar affords.

The chest should be deep and wide in all horses, but especially so in one intended for quick work, in order that there may be plenty of room for the play of those important organs—the lungs.

The back should not be too long nor too short; for though length is favourable to an extended stride and rapid motion, yet it makes the horse weak, and unable either to draw or carry any considerable weight. On the other hand, if the back be too short, the horse's action must be confined; and short-backed horses, in general, make an unpleasant noise when trotting, by striking the shoe of the hind-foot against the shoe of the fore one: and though they are in general very hardy, and capable of enduring much fatigue, and of living on but little food, yet a back of middling length is better by far than one immoderately short or long. The back should be nearly straight.

In the saddle-horse, and where safety is desirable, the position of the fore-leg is worthy of attention. It should be placed well forward, and descend perpendicularly to the ground, the toe being nearly in a line with the point of the shoulder. The pasterns should neither be turned in nor out. When they are turned inwards, the horse is in general very liable to cut the fetlock-joint by striking the opposite foot against it. The draught-horse may be excused though he leans a little over his fore-legs, but the saddle-horse will be apt to stumble if he does so.'

Minute attention should be bestowed on the examination of the fore-legs and feet: these, in fact, are the great trying points. If the feet be not round and full, so as to stand firmly and flatly on the ground, and if tender or thin in the hoofs, the animal is not to be trusted for saddle-work. Mr Lawrence on this subject remarks—'The feet of saddle-horses, be they ever so sound and good in nature, detract greatly from the value of the nag, unless they stand even on the ground; since, if they deviate inward or outward, the horse will either knock or cut in the speed—that is to say, will strike and wound the opposite pasterns either with his toe or his heel; and if he bend his knees much, and is a high goer, will cut the inside of the knee-joint. Nature has been very favourable in the hinder hoofs, with which we have seldom much trouble; but there is, now and then, a most perilous defect in them—namely, when the horse is so formed in his hinder quarters that he overreaches, and wounds his fore heels with the toes of his hind-feet.' The defect here spoken of will be observed to cause an unpleasant clattering noise in trotting. The fore-legs, from the knees downwards, should be clean made, sound, and flexible at the joints. Bad usage knocks up a horse, or founders him; and his legs, being in a kind of benumbed state, will either wholly or partially refuse to perform their office. By ease and physicking, the horse recovers; but his system has been shaken, and he is apt to come down. This is a fearful defect in a horse; for no one is for a moment safe on his back. Weakness in the fetlock-joint will also cause a horse to stumble and come down, and is therefore an equally serious defect. When the horse stumbles either through weakness or bad management so as to come down on his knees, the likelihood is, that the knees are broken; and it is well known that wounds of this nature never heal over to resemble the original. The horse with broken knees is, in short, damaged for life, at least in as far as he is a marketable commodity.

Horses are sold either with or without warranty. At sales at repositories, the terms of warranty are generally announced in a public manner; but when the sale is private, no warranty is binding which is not expressed in writing in the receipt. The principle that a price above ten pounds warrants a horse sound, is not now recognised as binding. The warranty, to be of any legal value, must be something different from a mere verbal understanding or illusory custom.

DUTY OF HORSES.

Draught.

The horse is equally willing to make himself useful as a beast of burden or draught; but his powers are best adapted for the latter, and particularly on a level road. The formation of his body does not suit him for climbing or going up-hill with a load; and his strength is always exerted to greatest advantage when he can throw his centre of gravity forward as a make-weight. The amount of load which he can draw in a wheeled vehicle depends on the arrangement of the load to the pull. The pulling point is across the shoulders, and the most advantageous method is, to make the line of traction proceed *direct* from the shoulders to the load—in no shape bent or distracted from its course. The load should be placed lower than the line of the shoulders, thus making the line of traction go by a straight slope to the seat of resistance. The load should not be at a greater distance than will allow freedom of motion to the hind-legs. If it be placed too low, a part of the power will be uselessly spent in upholding it. (See LAWS OF MOTION.)

According to the calculations of James Watt, the weight which a horse can draw, called a *horse-power*, is 1,980,000 pounds raised one foot high per hour, or 33,000 pounds raised one foot per minute. The weight is supposed to hang at the end of a rope passing over a freely-moving pulley. This calculation is based on considerations more favourable than those which usually attend horse-labour. There are, in reality, no rules to guide the imposing of loads on horses; for everything depends on the degree of friction on the wheels of the carriage, the nature of the road, and the strength of the animal in question. One thing is certain, that a horse always exerts his power better by himself than when yoked with others. The load which it requires four horses to draw unitedly, if divided, could be drawn with equal ease by three. The following observations referring to the operations of Sir C. Stuart Menteith deserve to be noticed:—

'From the experience this gentleman has had in the use of animal power upon common roads, he is of opinion that the most economical mode of employing horses in draught is to give every horse his own carriage, and that he should solely depend upon his own exertions in drawing the load, as otherwise it is well known that it is difficult to find either man or beast equally willing or capable to make the same exertion, or to have the same spirit or motion; and at the same time never to exceed six miles on one stage, and to be performed twice daily. In a stage of three and a half miles, Sir C. S. Menteith employs wagons weighing eighteen cwt., in which horses draw three tons. The road is in general upon a declivity of one foot of fall for every eight, sixteen, or eighteen feet, with several ascents of one foot in every thirty feet, up which a horse draws the load of three tons, and a wagon of eighteen cwt.; but in order to facilitate the ascent, a continuous line of sandstone railroad is first laid down, upon which a plate of iron, six inches wide by a quarter of an inch thick, is fixed down. In order to enable a horse to bring a load of three tons down any rate of descent, a friction-break has been employed, similar to the one in common use in Belgium, from which Sir C. Stuart Menteith derived this important application. The break is a strong plank, fixed to the back of a cart or wagon, which, by means of a screw, the carter presses against the two hind-wheels of the machine, so as to give a sufficiency of friction to retard the too rapid descent of the carriage. This plan has been employed with great success by Mr Croal, coach proprietor in Edinburgh, from the suggestion of Sir C. S. Menteith, who has now used it more than fourteen years upon his coal-wagons. The mode adopted by Mr Croal is to fix a lying axle to the plank pressing upon the hind-wheels of a coach, and which is turned by an upright shaft, with a bevel-wheel connecting the two shafts, and turned by a winch by the hand of the coach-guard, without moving from his seat. Were this break applied to every coach, the lives and limbs of thousands would be preserved, as the guard would be able to stop horses when running away with a carriage—as it is thought that treble, as it were, of the weight of a coach is to be drawn, if the two hind-wheels are prevented from revolving by the break. This kind of break enables a coachman to drive with perfect security down a descent of any length, and at any rate of speed. If the employment of horse wagons, weighing from twelve to thirteen cwt., were adopted in conveying coal through the streets of London, one horse would do the work of two: at present, four immense horses draw three chaldrons of coal, or four tons one cwt., in a wagon weighing perhaps two tons; so that the shaft-horse is obliged to draw a weight of six tons in turning out of one street into another.'

The larger the size of wheels in a vehicle, within a reasonable proportion, so is the friction in overcoming obstacles on the road less, and so is the draught more easy to the horses. The benefits of large wheels, however, have often been completely lost by not making them run fairly in an upright position. The custom has been to make them *dished* or bevelled outward from the axle, and to cause the axle to lean downward at each extremity to accommodate this peculiar shape. It is of importance to understand that a wheel always runs best when its tire is of equal diameter, when the spokes are at right angles to the axle, and when the axle projects straight out. This is exemplified in the trundling of a hoop: a hoop which is perfectly upright and even on the rim, requires less force to send it forward and keep it moving than if it were bevelled, and inclined to go round in a circle. For the sake of convenience, wheels may be a little dished, though now that the roads are good that is scarcely necessary.

The power of draught of a horse depends on the rate at which he is compelled to proceed. He exerts his power to most advantage at a fair pull, when moving at the rate of from two and a half to three miles per hour. If he go at a greater speed, he is less able to draw. As a general rule, if the speed be doubled, the load should be halved; and if the speed be twice doubled, the load should be quartered; yet this will only hold as correct for short distances. Much work may be procured from a horse if he be impelled only for short stages. A horse in a stage-coach, running only five miles at a time, and then resting for a few hours, will last at least four times longer than another horse of equal power which runs ten miles at a time. This is well understood by all stage-coach proprietors, and short stages have now almost everywhere superseded long ones. Such a fact should also be known to all private travellers. Whether employed in a gig, chaise, or for riding, the horse on a journey should take his day's work in two distinct stages: one in the morning, and another in the afternoon, when rested and refreshened. He should also, to remain in good condition, have a rest during the whole of Sunday. In journeying with light loads, a distance of from twenty to twenty-five miles is considered a sufficient day's task.

Riding.

The art of riding or equitation, forms a regular branch of instruction, and is seldom well performed by those who have not been regularly taught. It is not to be supposed that anything we can say can supersede the instructions of the riding-school; but it may be of use to offer a few hints on the subject from the most esteemed authorities.

Riding should be performed in that manner which is least calculated to oppress the horse and fatigue the rider, and which will be most secure for both parties. The first principle in horsemanship is, that the horse and his rider should act and react on each other, as if governed by one common feeling. To attain this end, the rider must acquire the knack of balancing himself properly on the animal, and establishing the means of making himself understood through certain movements of hand and body. A good horseman will act according to the following directions, given in Walker's 'Manly Exercises:'—'The place of the rider's seat is that part of the saddle into which the rider's body would naturally slide were he to ride without stirrups. This seat is to be preserved only by a proper balance of the body, and its adaptation to even the most violent counteractions of the horse. In relation to the thighs, the rider, sitting in the middle of the saddle, must rest chiefly upon their division, vulgarly called the fork, and very slightly upon the hips. The thighs, turned inward, must rest flat upon the sides of the saddle, without grasping; for the rider's weight gives sufficient hold, and the pressure of the thighs on the saddle would only lift him above it. The knees must be stretched down and kept back, so as to place the thighs several degrees short of a perpendicular; but no gripe must be made with them, unless there be danger of losing all other hold. If the thighs are upon their inner or flat side in the saddle, both the legs and the feet will be turned as they ought to be. Thus turned, they must be on a line parallel to that of the rider's body, and hang near the horse's sides, but must not touch; yet they may give an additional hold to the seat, when necessary, and the calves must act in support of the aids of the hands. The heels are to be sunk, and the toes to be raised, and as near the horse as the heels, which prevents the heel touching the horse. As to the body, the head must be firm, yet free; the shoulders thrown back and kept square, so that no pull of the bridle may bring them forward. The chest must be advanced, and the small of the back bent a little forward. The upper parts of the arms must hang perpendicularly from the shoulders, the lower parts at right angles with the upper, so as to form a horizontal line from the elbow to the little finger. The elbows must be lightly closed to the hips, and, without stiffness, kept steady, or they destroy the hand. The wrist must be rounded a little outwards. The hands should be about three inches from the body, and from the pommel of the saddle, and from four to six inches apart; the thumbs and knuckles pointing towards each other, and the finger-nails towards the body. When the rider is in the proper position on horseback without stirrups, his nose, breast, knee, and instep, are nearly in a line; and with stirrups, his nose, breast, knee, and toe, are in a line. The man and the horse throughout are to be of a piece. When the horse is at liberty, or disunited, as it is termed, the rider sits at his ease; and as he collects and unites his horse, so he collects and unites himself. There must, however, be no stiffness of manner more than in sitting on a chair; for it is ease and elegance which distinguish the gentleman.'

Riding, to one accustomed to it, is best performed with a curb and snaffle bridle; the curb, however, being only employed to bring the animal up by pressure on the mouth when occasion requires. As some horses have a much more delicate mouth than others, the nature of the bridle must depend on circumstances. In holding the reins, a union of firmness, gentleness, and lightness, is the essential requisite. The foregoing authority alludes to the manner in which the reins are to operate on the mouth of the animal:—'The hand being connected with the reins, the reins to the bit, the bit operating in the curb on the bars, and in the snaffle on the lips, the rider cannot move the hand, and scarcely even a finger, without the horse's mouth being more or less affected. This is called the *correspondence*. If, moreover, the hand be held steady, as the horse advances in the trot, the fingers will feel, by the contraction of the reins, a slight tug, occasioned by the cadence of every step; and this tug, by means of the correspondence, is reciprocally felt in the horse's mouth. This is called the *appuy*. While this relation is preserved between the hand and mouth, the horse is in perfect obedience to the rider, and the hand directs him, in any position or action, with such ease, that the horse seems to work by the will of the rider rather than by the power of his hand. This is called the *support*. Now, the correspondence or effective communication between the hand and mouth—the appuy, or strength of the operation in the mouth; the support, or aid, the hand gives in the position or action, are always maintained in the *manege* and all united paces. Without these, a horse is under no immediate control, as in the extended gallop, or at full speed, where it may require a hundred yards to pull before we can stop him. The degree of correspondence, appuy, and support, depends, in horses otherwise similar, on the relative situation of the hand. The act of raising the rider's hand increases his power; and this, raising the horse's head, diminishes his power. Depressing the rider's hand, on the contrary, diminishes his power; and this, depressing the horse's head, increases his power.'

Much may be done to animate a horse, either in riding or drawing, by addressing a cheerful word to him, instead of the lashing and scolding with which he is too frequently visited. If a horse requires correction or urging by the whip, he should only be touched lightly behind the girth and saddle, never on any account on the head, or on a fore part of the body. We have frequently seen riders so lost to humanity as to whip their horses when restive over the head and ears. Should a horse attempt to baffle his rider, he must be pressed by the legs, urged lightly with the spur, and kept in his proper track, but not drawn up with the curb, or terrified by abuse.

The most common pace in road-riding is the trot, which, in effect, is a rapid walk, and most difficult for a rider to perform with address and a small degree of fatigue to himself. In slow trotting, the body should adhere to the saddle, and when it becomes fast or rough, the body may be raised at the proper moments to ease the jolting. This rising of the body, however, is to be a result of the horse's action, not an effort of the rider. The proper method is to rise and fall with the leading foot, the body rising from the seat when the foot is elevated, and falling when it sinks.

In the course of either slow or fast riding, the horse may trouble his rider by plunging, shying, or restiveness. If he kick and plunge, sit upright, hold on by the legs, and do not vex him by any lashing; when let alone, he is not long in coming out of his freak. When he shies, or flies to one side, as if afraid of something, press him on the side to which he is flying, keep up his head, and bring him into his track. Pressing both legs against his sides will generally keep him from running backward. When he becomes restive—that is, turns round, and has a disinclination to go in the way he is required, the rider must keep him in his track by dint of pressure, a touch of the spur, and the hand. If he has been accustomed to spurs, and finds that your heels are not provided with these appendages, your case is very hopeless. We must allow Walker to point out the course to be pursued with a restive horse. If he persists in turning round, the rider must continue 'to attack his unguarded side, turn him two or three times, and let the heel and spur, if necessary, assist the hand, before he can arm or defend himself against it. If he still refuse to go the right way, the rider must take care that he go no other, and immediately change his attack, turning him about and reining him backward, which the horse is easily compelled to do when he sets himself against going forward. In these contests, the rider must be collected, and have an eye to the surrounding objects; for restive horses try their utmost to place their riders in awkward situations, by sidling to other horses, carriages, the foot-pavement, the houses, &c. In this case the rider, instead of pulling him from the wall, must bend his head to it, by which his side next the wall is rendered concave, and his utmost endeavours to do injury are prevented. The instant, therefore, that the rider perceives his horse sidling to any object, he must turn his head to that object, and back him from it. There are some horses who fix themselves like stocks, setting all endeavours to move them at defiance. There, happily, their defence can in no way endanger the rider. It must, however, be converted to punishment. Let them stand, make no attempt to move them, and in a short space—frequently less than a minute—they will move of themselves.' The same author recommends the rider to remain perfectly cool in all these awkward circumstances. 'When passion,' he observes, 'possesses the rider, it prevents that concord and unity taking place which ever should subsist between the rider and his horse. He should always be disposed to amity, and never suffer the most obstinate resistance of the horse to put him out of temper. If the contest does not demand his utmost exertion of strength, he should be able to hum a tune, or converse with the same composure and indifference as though his horse were all obedience. By these means the instant a horse finds himself foiled, he desists, having no provocation to contend farther, and is abashed at his own weakness. It is the absence of passion which, added to cool observation, makes the English the best riders and drivers in the world.'

Neither in the above section nor elsewhere have we said anything of the accoutrements of the horse, as every article of this kind must be left to the taste of the party concerned. The harness made by all saddlers is now both handsome, commodious, and durable, and so well calculated for the comfort of the wearers, that it would be superfluous to say anything respecting it, further than to recommend that it be always kept clean and glossy, and that it do not gall or press unduly on any part of the animal's body.

CATTLE—DAIRY HUSBANDRY.

NEXT to the horse, the cow is justly valued as the most useful animal which man has been able to domesticate and retain permanently in his service. The ox tribe, of which it is the female, belongs to the order *Ruminantia*, in the class *Mammalia*—these terms implying that the animals ruminate or chew their food a second time, and have mammæ or teats with which they suckle their young. In the ox tribe (*Bovidæ*) there are different species, all more or less varying from each other; and of the domesticated ox, the varieties from the effect of cultivation are now very numerous. The ox, in one or other of its varieties, for the sake of its labour as a beast of draught, for its flesh, or for the milk of its female, has been domesticated and carefully reared from the earliest times; in some countries having been raised to the rank of a divinity, or at least held as an object of extreme veneration.

The domesticated species of the family, common to Britain and adjacent parts of Europe, is, in all its varieties, materially altered from its wild parentage. Influenced by climate, peculiar feeding, and training in a state of subjection, its bony structure is diminished in bulk and power, its ferocity tamed, and its tractability greatly improved. Our observations in the present sheet will refer chiefly to the cow, on which very great changes have been effected by domestication; the most remarkable of these being her increased capacity for giving milk. In a wild state, the udder is small, and shrinks into an insignificant compass when the duty of suckling is over; but when domesticated for the sake of its milk, and that liquid is drawn copiously from it by artificial means, the lacteal or milk-secreting vessels enlarge, and the udder expands, so as to become a prominent feature in the animal. In this manner, by constant exercise, the economy of the cultivated species of cow has been permanently altered, and rendered suitable to the demands which are constantly made on it. Yet it is important to remark, that those milk-yielding powers are not equal in the different varieties or breeds of cows. Some breeds, from the influence of circumstances which it is here unnecessary to inquire into, give a large quantity of milk, but of a thin or poor quality, while others yield less milk, but of a good or rich quality. Whether, then, the cow-keeper wish *quantity* or *quality*, is the question for him to solve in making a selection of stock. In general, near large towns, where the demand for milk is considerable, the object of dairymen is to keep cows which will give a large quantity of milk, no matter of what sort. Private families in the country are usually more regardful of the quality of the article; they wish a little milk which is good, some fine cream, and perhaps also some well-flavoured butter and cheese, and on that account are more careful in the choice of their animals.

VARIETIES OR BREEDS.

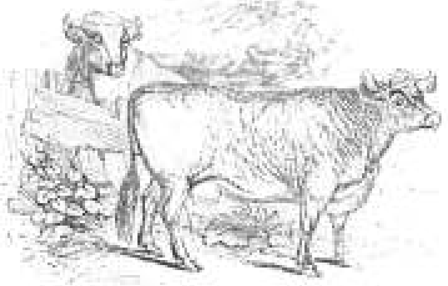
The breeds of cattle throughout the United Kingdom vary in different districts, from the small hardy varieties of the north Highlands to the bulky and handsome breeds of the southern parts of England. It has been customary to classify the whole according to the comparative length of the horns—as the long-horned, short-horned, middle-horned, crumpled-horned, and hornless or polled breeds. Besides these, there are many intermixed varieties or sub-breeds. The middle-horned cows, which are found in the north of Devon, the east of Sussex, Herefordshire, and Gloucestershire, and the breeds peculiar to Durham, Ayrshire, and Fifeshire, are among the most valuable and handsome of those now cultivated.

The intelligent author of the work on Cattle, published by the Society for the Diffusion of Useful Knowledge, thus describes what ought to be the proper form and shape of cattle:—'Whatever be the breed, there are certain conformations which are indispensable to the thriving valuable ox or cow. If there is one part of the frame the form of which, more than of any other, renders the animal valuable, it is the chest. There must be room enough for the heart to beat and the lungs to play, or sufficient blood for the purposes of nutriment and strength will not be circulated; nor will it thoroughly undergo that vital change which is essential to the proper discharge of every function. We look, therefore, first of all to the wide and deep girth about the heart and lungs. We must have both: the proportion in which the one or the other may preponderate, will depend on the service we require from the animal; we can excuse a slight degree of flatness of the sides, for he will be lighter in the forehand, and more active; but the grazier must have width as well as depth. And not only about the heart and lungs, but over the whole of the ribs, must we have both length and roundness; the *hooped* as well as the deep barrel is essential; there must be room for the capacious paunch, room for the materials from which the blood is to be provided. The beast should also be ribbed home; there should be little space between the ribs and the hips. This seems to be indispensable in the ox, as it regards a good healthy constitution and a propensity to fatten; but a largeness and drooping of the belly, notwithstanding that the symmetry of the animal is not improved, are considered advantageous in the cow, because room is thus left for the udder; and if these qualities are accompanied by swelling milk-veins, her value in the dairy is generally increased. This roundness and depth of the barrel, however, are most advantageous in proportion as found behind the point of the elbow more than between the shoulders and legs; or low down between the legs rather than upwards towards the withers: for the heaviness before, and the comparative bulk of the coarser parts of the animal, are thus diminished, which is always a very great consideration. The loins should be wide. Of this there can be no doubt, for they are the prime parts; they should seem to extend far along the back; and although the belly should not hang down, the flanks should be round and deep. Of the hips it is superfluous to say that, without being ragged, they should be large; round rather than wide, and presenting, when handled, plenty of muscle and fat. The thighs should be full and long, close together when viewed from behind, and the farther down they continue close the better. The legs may occasionally vary in length according to the destination of the animal; but shortness is a good general rule, for there is an almost inseparable connection between length of leg and lightness of carcass, and shortness of leg and propensity to fatten. The bones of the legs (and they are taken as a sample of the bony structure of the frame generally) should be small, but not too small—small enough for the well-known accompaniment, a propensity to fatten—small enough to please the consumer; but not so small as to indicate delicacy of constitution and liability to disease. Lastly, the hide—the most important thing of all—should be thin, but not so thin as to indicate that the animal can endure no hardship; movable, mellow, but not too loose, and particularly well covered with fine and soft hair.'

Of the various breeds and cross-breeds now common in Britain, there are a few which enjoy the best reputation. We may name, for example, the *Old Yorkshire Stock*—a cross between the *Teeswater* and *Holderness breed*—the *Long-horned* or *Lancashire breed*, the Short-

horned or *Dutch breed*, the *Middle-horned breeds of Devonshire, Sussex*, and *Hereford*, the *Ayrshire breed*, the *Fifeshire breed*, the *Alderney breed*, &c. Some of these merit particular attention:—

The *Short-horn* or *Teeswater* breed is considered of great value, both for milking and feeding. There are many varieties of it, known by the names of the counties where they have been raised. The best of these varieties are large in the carcass, well proportioned, broad across the loins, chine full, legs short, head small, but handsome, neck deep, but in keeping with the size of the body, colour generally red and white mixed, or what is called flecked, hide thin. The flesh of the true Short-horn is thick, close-grained, retaining the juices well; and from this circumstance is in request for victualling ships going on long voyages.



Short-Horn.

Regarding the milking qualities of this breed, Mr Dickson, an eminent cattle-dealer, who has had the most extensive experience throughout the whole country, says—'It has been frequently asserted that the short-horned cows are bad milkers: indeed, that no sort of cattle are so deficient in milk. But this deficiency of milk does not proceed from the circumstance of the cows being of the short-horned kind. Had the flesh been neglected as much as the milk by the eminent breeders, and the property of giving milk as much cherished as the development of flesh, the short-horned cows would have been deep milkers. Indeed, it is not to be doubted that, where the general secreting powers of the animal system have been increased, the power of secreting milk will be increased with the power of secreting fat; all that seems requisite is, to encourage the power of that secretion which is most wanted for the time. It would be to desire an impossibility to wish the full development of flesh, fat, and milk, at the same time; but there is no absurdity in desiring a large secretion of flesh and fat at one time, and a large secretion of milk at another, from the same cow. Accordingly, this is the very character which has been acquired by short-horned cows. They will yield from six to sixteen quarts a day throughout the season; and they are such constant milkers, that they seldom remain dry above six weeks or two months before the time of calving. I know a Scotch breeder who had a short-horned cow which gave fifteen quarts a day during the flush of the grass in summer, and never went dry for two seasons. A cross between a Galloway cow and a short-horned bull in Berwickshire yielded twenty pints a day during the best of the season, and she had to be milked five times a day to keep her easy.' We have thus considered it our duty to give the opinion of Mr Dickson regarding the value of the short-horned breed of cows as a dairy stock, seeing that the demand for short-horned bulls has of late years been great in many of the counties of both England and Scotland. It seems, however, a well-confirmed opinion, that the breed which of all others appears to be gaining ground throughout the United Kingdom for abundant produce on ordinary pasture, is the Ayrshire kyloe, which is described as without a parallel under a similar soil, climate, and relative circumstances, either for the dairy or feeding for the shambles. But the ever-variable circumstances in climate, soil, shelter, and the quality and quantity of the pasturage, as well as the nature of the winter feeding and general treatment, will always have an effect upon the stock.

The *Ayrshire* breed, which is considered the most valuable in Scotland, is of the small sized and middle-horned race; its origin is unknown, as it has been long settled in the county from which it derives its name. In modern times, the breed has been improved by judicious selection, coupling, and general treatment. The common characteristics of this excellent variety of cows are thus described by Mr Aiton in his 'Survey of Ayrshire:'—'Head small, rather long and narrow at the muzzle; eye small, smart, and lively; horns small, crooked, and set at considerable distances from each other; neck long, rather slender, tapering towards the head, with no loose skin below; shoulders thin; fore-quarters light; hind-quarters large; back straight, broad behind, the joints rather loose and open; carcass deep; legs small, short, with firm joints; udder capacious, stretching forward; the milk-veins large and prominent; teats short, all pointing outwards.' The Ayrshire cow is very docile, feeds well, is easily managed, and, as a dairy cow, is equal to any other. It is said to be inferior, however, for feeding, to the medium-horned Devon and Hereford breeds.

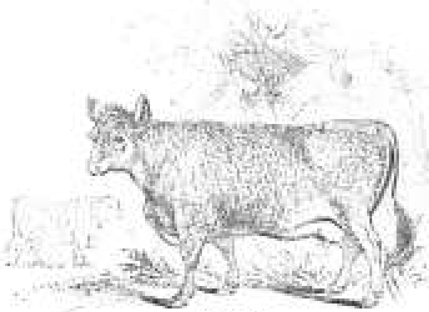
Ayrshire.

Many of the Ayrshire dairy cows, when properly fed, will yield from 6 to 8 gallons per day during a part of the summer. The quantity varies much during the year, from 1½ to 6 gallons, or more; and the highest average of the milk yielded by this breed is 1000 gallons per annum. It is only some of the finest cows that will yield such a quantity as this, and from 500 to 750 gallons may be calculated as the most general yearly produce. Every 2½ gallons of milk will afford 1 pound of butter, of 16 ounces to the pound, or 8 gallons will give 3 pounds. About 25 gallons of milk will give one stone of cheese, 14 pounds to the stone; and a good milch cow will thus produce 26 stones annually, which, at 10s. per stone, is £13 per annum for this article alone.

The *Devonshire* is a handsome breed of cattle, well set upon their legs, straight along the back, small muzzle, generally red in colour, and both as oxen and cows they feed well at an early age. The cow is much smaller than the bull, but roomy for breeding, and is distinguished for her clear round eye and general loveliness and neatness of features. Fed on the fine pastures of North Devon, the cow yields a rich quality of milk, and in reasonable abundance. The North Devon breed prevails in some parts of Somersetshire, and has been introduced into other districts of the country, but is not considered suitable in situations greatly differing in climate and herbage from its native county, which, on the whole, is mild, and rather moist.

The *Hereford* breed is larger than that of North Devon. It is broad across the hind-quarters, narrow at the sirloin, neck and head well proportioned, horns of a medium size, turned up at the points, colour deep red, but with face and some other parts generally white, and countenance cheerful and sagacious. This breed is reckoned among the best in England as respects the abundant production of milk, and when too old for that purpose, it fattens to a greater weight than the North Devons.

The *Galloway* breed of cattle is well known for various valuable qualities, and easily distinguished by the want of horns. It is broad across the back, with a very slight curve between the head and quarters, broad at the loins, the whole body having a fine round appearance. The head is of a moderate size, with large rough ears, chest deep, legs short, and clean in the neck. The prevailing colour is black, those of this colour being thought the most hardy, although this varies. This breed is highly esteemed, as there is no other kind which arrives at maturity so soon, and their flesh is of the finest quality. The milk is very fine, but is not obtained in very large quantities. Great numbers of this breed are sent annually to Smithfield market; and it is remarkable that they are generally in as good condition after the journey as before. The *Suffolk* dun,



Suffolk.

also a hornless breed, is supposed to be a variety of the Galloway, from their general resemblance. 'Some exaggerated accounts,' says Mr Youatt, 'have been given of the milking properties of the Suffolk cow; but nevertheless she is not inferior to any other breed in the quantity of milk that she yields. In the height of the season some of these cows will give as much as eight gallons of milk in the day, and six gallons is not an unusual quantity. The produce of butter, however, is not in proportion to the quantity of milk. The Rev. Mr Aspin of Cockfield had three cows, one of them a heifer with her first calf. They were kept on three acres only of grass, without any change of pasture, until after mowing time, and in the winter chiefly on straw, with very little hay. Both the old ones yielded eight gallons of milk per day during the height of their season, and the quantity of butter made from June to December was 613 pounds. The Rev. Arthur Young, the secretary to the Board of Agriculture, forty years ago, adds, that one Holderness cow would have consumed all the food of the three without returning half of the produce. There are few short-horn cows, although far superior in size to the Suffolks, and consuming nearly double the quantity of food, that will yield more milk than is usually obtained from the smaller polled breed. Fifty thousand firkins of butter are sent to London every year from Suffolk, of which each cow furnishes on an average three firkins, each firkin weighing half a hundredweight; and this independent of three-fourths of a wey of cheese.'

The *Improved Kerry* is an Irish breed, of rather diminutive size, hardy, and which can subsist on scanty pasture. This renders them exceedingly well adapted for hilly pastures, and for cottagers who may not have the best food to offer their stock. Their milk and butter are rich in quality, and for their size they are good milkers. They are quiet enough when let alone, but if the least irritated, no fence can contain them. The Irish cows have improved very much of late years, in consequence of crossing with English stock; and they are now in many respects thought equal to the breeds of either England or Scotland.

The *Long-horned* or Lancashire is distinguished by the length of its horns, the thickness of its hide, and the large size of its hoofs. It is far from being a handsome animal; nor is it held in very general estimation either for milking or for feeding.

The cattle of the *Highlands of Scotland* are of small bulk, and very hardy. The most esteemed are those belonging to the Western Highlands and Isles, called the Argyleshire breed, and frequently *kyloes*. It is thought that this breed might be much improved by judicious crossing, as was seen in the case of the Ayrshire kyloe, formerly mentioned. This breed is rather handsome in appearance; the horns are long and upright, head large, neck short and deep, legs of a good length, and the beef is in general estimation. The cattle of the Highlands and Isles are bred on an extensive scale of farming, for the purpose of sending to the southern markets. Small in size at first, they increase in bulk as they are transferred to a more genial climate and richer pasturage as they proceed southward, till, by annual stages, they reach the neighbourhood of London, when they are large and heavy. These breeds may therefore be considered an object of culture for the shambles rather than for the dairy.

The *Alderney* breed of cattle is awkwardly shaped, with short bent horns, and light-red, dun, or fawn-coloured skins. The appetite of the cow is voracious, and it yields little milk; but that is of an exceedingly rich quality, and the animal is on that account frequently preferred by country families, who do not regard the expense of keep.

We have thus briefly treated of some of the many breeds of cattle considered valuable as dairy stock in Britain; but we pretend not to give any decided opinion as to which is best. The merits of each have been vigorously contested by their respective advocates, and it would be extremely difficult to decide between them. Upon the form and qualifications of a perfect cow, it ought to be observed, that whatever breed is selected, there is a wide difference between the form of one meant for fattening and that intended for the dairy. The first should resemble the ox as nearly as possible; while the latter should be long and thin on the head, with a brisk, quiet eye, lank in the neck, narrow across the shoulders, but broad at the haunches; and there should be no tendency to become fat. The udder should be large and full-looking, but not protruding too far behind; the teats all pointing out and downwards, equal in size, and rather long and tapering. A cow with a high backbone, large head, small udder, and showing an inclination to become fat, will be found to be a bad milker. This description applies to all breeds; and of course the difference between a cow for fattening and one for yielding milk will be comparative.

Mr Aiton mentions the following as the most important qualities of the dairy cow:—'Tameness and docility of temper greatly enhance her value. One that is quiet and contented feeds at ease, does not break over fences, or hurt herself or other cattle, will always yield more milk than those who are of a turbulent disposition. To render them docile, they ought to be gently treated, frequently handled when young, and never struck or frightened. Some degree of hardiness, however, a sound constitution, and a moderate degree of life and spirits, are qualities to be wished for in a milch cow, and what those of Ayrshire generally possess. Some have thought that a cow living on a small quantity of food was a valuable quality, but that will depend on the quantity of milk given by the cow that eats little compared with those that eat much. If the cow that eats little gives as much milk as the one that eats more, it certainly is a valuable quality; but of this I entertain doubts, which forty years' experience and observation have served to confirm. Speculative writers affirm that some cows will fatten as well, and yield as much milk, when fed on coarse, as others will do on rich food. Cows that have been reared and fed on coarse pasture will yield some milk of a good quality, and from which the best butter may be extracted; while a cow that has been reared and fed on much better pasture, would, if turned on that which is bad, give scarcely any milk. But if a cow that has been accustomed to feed on bad pasture be put on that which is better, she will greatly increase in milk, and fatten much faster. If two cows of the same age and condition, and which have been reared and fed on food of equal quality, are put, the one on bad food, and the other on that which is good, the latter will yield four times the milk, and fatten four times faster than the former. A cow need not always be fed on green clover, cabbages, and cauliflower; but she will neither fatten nor yield milk if she gets no better fare than rushes, bent, and sage grass.' A writer in the 'Farmer's Magazine,' some years ago presented the following doggrel lines, as combining what are popularly considered the good points of a cow, such as is common among the short-horned breed of Yorkshire and Durham :—

'She's long in her face, she's fine in her horn,
She'll quickly get fat without cake or corn;
She's clean in her jaws, and full in her chine,
She's heavy in flank, and wide in her loin.

She's broad in her ribs, and long in her rump,
A straight and flat back, without e'er a hump;
She's wide in her hips, and calm in her eyes,
She's fine in her shoulders, and thin in her thighs.

She's light in her neck, and small in her tail,
She's wide in her breast, and good at the pail,
She's fine in her bone, and silky of skin—
She's a grazier's without, and a butcher's within.'

To insure the perpetuation of valuable qualities in cows, it is necessary to breed from good bulls of a variety similar to the cows. The heifer or young cow, if properly pastured, should begin to breed at two years, or not beyond two and a half years old. The cow is at her prime at from four to six years, and declines into old age at ten or eleven years, when it is customary to fatten her for market. Dairymen, in selecting cows, prefer those which have had their third or fourth calf when they have attained their fifth or sixth year. The bull is in his prime at three years, and should not be used after eight or nine years old.

GENERAL MANAGEMENT OF THE COW.

The cow goes with young nine calendar months, or 270 days; but this length of time is liable to variation, from the effect of circumstances. A calf is most likely to survive and be healthy which has been carried exactly the nine months. Cows come into season at different periods of the year, in which state they remain for a few days, after which the affection ceases, but it afterwards returns in three or four weeks. The farmer watches these periods, and permits the company of the bull at such a time as will produce the young at a season of the year when grass is plentiful for the nourishment of the mother. This should generally be an advanced period of spring, for the cow will require nourishing diet some time before she drops her calf as well as afterwards.

A cow may be kept in milk up to the time of her calving, by daily taking a quantity from her; but this is most injurious to the fœtus, and the excitement of the new upon the old milk is apt to produce local inflammation. In towns, where dairymen care nothing for the calf, and must have milk at all risks, cows are often maltreated by being milked to the last; but no one who conducts a dairy on proper principles will be guilty of this inhumanity. The best plan is to allow the cow to go gradually dry, and not milk her at all for six or eight weeks before calving. This will keep her in a reasonably good condition, and save extra food, which it is not advantageous to give on a luxuriant scale, because high feeding at this period may induce inflammation and fever at calving.

Calving—Treatment of the Calf.

No animal is so liable to abortion as the cow: it takes place at uncertain periods during the pregnancy; sometimes it occurs from fright, teazing by other cattle in the field, or from over-high condition; but also not unfrequently from some bad habit acquired by the animal. It has been found that the habit is infectious; and when once it has got among a parcel of cows, it can be banished only with the greatest difficulty. In all cases the aborted fœtus should be buried deep and far from the cow pasture; the cow physicked, and its parts washed with chloride of lime; the cow-house thoroughly lime-washed and otherwise purified; and lastly, the cow fattened and sent to market.

If in a state of health, no difficulty will occur at the parturition; but should the case be otherwise, we prefer leaving the cow-keeper to ask assistance from a person of practical skill, or veterinary surgeon, than to offer any speculative advices on the subject. With respect to the treatment after calving, we beg to quote the following directions from the volume on Cattle, 'Library of Useful Knowledge:'—'Parturition having been accomplished, the cow should be left quietly with the calf; the licking and cleaning of which, and the eating of the placenta, if it is soon discharged, will employ and amuse her. It is a cruel thing to separate the mother from the young so soon; the cow will pine, and will be deprived of that medicine which nature designed for her in the moisture which hangs about the calf, and even in the placenta itself; and the calf will lose that gentle friction and motion which help to give it the immediate use of all its limbs, and which, in the language of Mr Berry, "increases the languid circulation of the blood, and produces a genial warmth in the half-exhausted and chilled little animal." A warm mash should be put before her, and warm gruel, or water from which some of the coldness has been taken off. Two or three hours afterwards, it will be prudent to give an aperient drink, consisting of a pound of Epsom salts and two drachms of ginger. This may tend to prevent milk fever and garget in the udder. Attention should likewise be paid to the state of the udder. If the teats are sore, and the bag generally hard and tender, she should be gently but carefully milked three or four times every day. The natural and the effectual preventive of this, however, is to let the calf suck her at least three times in the day if it is tied up in the cow-house, or to run with her in the pasture, and take the teat when it pleases. The tendency to inflammation of the udder is much diminished by the calf frequently sucking; or should the cow be feverish, nothing soothes or quiets her so much as the presence of the little one.' For instructions respecting the condition and diseases incidental to cows at and after the period of calving, we must refer to the valuable work now quoted.

If the calf be a male, and is to be pastured and fattened for market, or to be bred as a working ox, it should be cut between the first and third months; if deferred later, the operation is dangerous. Whether calves are kept for veal or for stock, they are begun to be fed in the same manner, by sucking milk from a dish. As they naturally seek for the teat when their nose is put to the dish, the fingers of the attendant may be put into their mouth when in the milk, and this will set them going in the art of artificial sucking. 'The milk,' says the author of Clerical Economics, 'should be given to them sparingly at first, to render their appetite more keen, and prevent them from loathing at their food. For the first two weeks they should be fed on the milk first drawn from the cow, locally termed the *forebroads*, which abounds with serum; and as they grow up, the quantity of milk is gradually increased to as much as the calves can be made to drink. After the first two or three weeks, by all means give them plenty of milk, warm from their mother; and let it be that which is last drawn from the cow, locally termed *afterings*, which are much richer. Keep abundance of dry litter under them. Have them in a place that is well aired, and of a uniform temperature, neither too hot nor too cold; let the apartment be quite dark, excepting when the door is opened to give them food. If they enjoy the light, they become too sportive, and will not fatten. Take care they are fastened to the wall, in such a way, by "swivels," that they cannot hang themselves. Never let them make their escape at the door, or, by their running and jumping, they will do more injury to themselves in three minutes than a week's feeding will make up. Don't keep them till they become too old, because, when they begin to grow to the bone, they require more milk than the manse can generally produce; and whenever they cease to advance in the fattening process, they begin to recede, and the milk for a week or two is lost. They should be kept from four to seven weeks, according as milk may be abundant and rich. If a calf be kept long, during the last two or three weeks it will require the richest part of the milk of at least two or three cows to bring it to the highest pitch of fatness. When the milk begins to fall short of the calf's appetite, some mix eggs, and others peas-meal, into their food; others try infusions of hay, oil-cake, and linseed; but none of these additions are approved of by those who feed calves to the greatest perfection. Meal is understood to darken the flesh, web, and lights of the animal; but sago has of late years been almost, from the first two or three weeks, boiled and mixed in its liquid state with the milk, and to great advantage. Begin with a saucerful of it or so, and gradually increase the quantity. Calves are very fond of chalk, and they also feel the want of salt. If a calf happens to be dropt about the middle of summer, when the processes of butter and cheese making wont admit of their being fattened to perfection, they are sometimes, even at the manse, brought sparingly forward for two or three months on whey and skimmed milk; and in November, when veal is very high priced, they are fattened at considerable cost, and sold so as to yield a great return, owing both to their weight and the high markets at that season of scarcity. A calf well managed in ordinary seasons and prices, should yield, when sold, six or seven shillings for every week it has been kept and fattened.'

Cow-house—Cleaning.

The cow-house should be airy and well ventilated, of moderate temperature, and kept very clean. The stalls for the cows should be paved with smooth stones, slope gently towards the foot, where there should be a clear run of a gutter to carry off the urine to a pit outside. (See No. 31.) The stalls must be daily scraped and swept, and all refuse carried out to the dung-heap. In general, far too little litter is allowed. The cow should have plenty of straw bedding, kept in a cleanly condition; and this, when soiled, is to be mixed with the dung for manure. The only fastening for the cow should be a chain to go round the neck, with the other end round an upright post, but easily movable up and down, and allowing room for the animal shifting its position. The feeding manger or stone trough is on the ground, and ought to be kept free of all impurities; for though the cow is not so nice as the horse, it has a disinclination for food not fresh and cleanly.

Except in dairies of a high order, it is customary to keep cows in a shamefully unclean condition. The floor of their habitation is filthy, the walls ragged and full of vermin, and the hides of the animals dusty or barkened with dirt. Persons who keep cows are not aware of the loss they incur from allowing them to live in this uncleanly state. Some people seem to think that they do quite enough for their cows if they give them food and shelter; but besides this, they require to be kept very cleanly, though seldom indulged in that luxury. The cow should be curried daily like the horse; its hide should be freed from all impurities, and relieved from everything that causes uneasiness. When you see a cow rubbing itself against a post, you may depend on it that the animal is ill kept, and requires a good scrubbing. Irritation of the skin from impurities also causes them to lick themselves, a habit which is injurious, for the hairs taken into the stomach form a compact round mass, which may destroy the animal. If well curried, any danger from this catastrophe is avoided, the health is generally improved, and this improves the quality of the milk, besides increasing the quantity. A cottager might easily make two or three shillings more of his cow weekly by attention to this point; and if he at the same time took pains to preserve all the liquid refuse of the cow-house, he might double that amount. How strange to reflect, that many decent and well-meaning, but ignorant and rather lazily-disposed people, are suffering a loss of four or five shillings weekly from no other cause than this! It is long, however, before old habits are eradicated, and new and better ones established.

Feeding—Modes of.

The cow requires to be supplied with an abundance of food, not to make her fat, which is not desirable, but to keep up a regular secretion of milk in the system. The feeding must be regular, from early morning to night, and pure water must also be offered at proper intervals, if the animal has not the liberty of going to the water herself.

Regarding the nature of the food of cows, although soiling, or artificial feeding in the house, is at all times economical, there can be no doubt that the best milk and butter are produced by cows fed on natural pasture; and although the quantity of milk is not so great, yet the butter has a sweet taste, never to be discovered in the produce of soiled cows. It was formerly the case in Scotland, and the practice is still continued in some parts, to put the cows out to grass in spring, in such an emaciated state, that a considerable part of the best season was gone before they yielded the quantity of milk they would otherwise have done. On well-enclosed farms, it is the custom of many to keep their cows out both night and day, from May till the end of October, so long as a full bite can be obtained; and some bring them into the house twice a day to be milked. In moorish and unenclosed districts, they are put under the charge of a herd through the day, and are brought into the byres during the night. In either case, exposure to wet and cold, or to extreme heats, should be guarded against.

Soiling, or feeding entirely in the house or court-yard, is seldom practised, except by some farmers in arable districts. Although complete soiling is only occasionally resorted to, yet a considerable quantity of rich green food is served out to the dairy stock in their stalls at night, and in the heat of the day, by such farmers as bring their cows into the house at these times. This mode of feeding is more especially followed when the pasture begins to fail; the second crops of clover and tares, cabbages, coleworts, and other garden produce, are all given to the cows in the house at this period. It is upon this system that the whole perfection of the Flemish husbandry is founded, and it could be put in practice, with the most beneficial results, in many other countries. (See No. 32, pp. 509–10.) In Holland, the cows, when fed in the house, have their drink of water invariably mixed with oil-cake, rye, or oatmeal. Dairy cows are allowed to be much injured by being denied a due supply of salt, which is said to improve the quality and increase the quantity of the milk. In the best-managed dairies in Scotland, when the cows are taken in for the winter, they are never put out to the fields until spring, when the grass has risen so much as to afford a full bite. In the moorish districts, however, they are put out to the fields for some hours every day when the weather will permit. In these districts, the winter food is turnips with marsh meadow hay, occasionally straw, boiled chaff, and other refuse from the barn.

In the richer districts, turnips and straw are given, and occasionally some clover hay in spring, or when the cows have calved. Upon this subject nothing need be added, but that the quantity and quality of the milk will be in proportion to the nourishment in the food. White turnips afford a good quantity of milk, but they impart a very disagreeable taste, which may be removed, however, by steaming or boiling the turnips, or by putting a small quantity of dissolved saltpetre into the milk when new drawn. The quality of the milk depends a great deal on the cow, influenced, however, by the food she eats. Linseed, peas, and oatmeal, produce rich milk; and a mixture of bran and grains has been recommended as food in winter. Brewers' grains are said to produce a large quantity of milk, but very thin, the quality being somewhat similar to that sold in large towns, yielding neither good cream nor butter. It has been found of some importance to feed cows frequently—three or four times a day in summer, and five or six in winter, and to give them no more at a time than they can eat cleanly.

What has been stated regarding the feeding of cows applies principally to those kept on dairy farms. In establishments for the supplying of large towns with milk, the method of feeding is somewhat different; there the practice is to feed them chiefly on distillers' wash, brewers' grains, and every sort of liquid stuff that will produce a large quantity of milk, without reference to its quality. The Edinburgh cow-keepers begin to feed with grain, dreg, and bran mixed together, at five o'clock in the morning; feed again at one o'clock afternoon; and a third time at seven or eight o'clock in the evening: grass in summer, and turnips and potatoes in winter, being given in the two intervals. The grass is laid upon the straw, in order to impart to it a certain flavour, and make it palatable; it is eaten after the grass: and in winter, straw or hay is given after the turnips. Part of the turnips and potatoes are boiled, particularly when there is a scarcity of grains. For the mode of feeding in the large London dairies, see the concluding pages of the present number.

The following is mentioned in the 'Farmer's Magazine' as an improved mode of feeding milch cows, near Farnham, in Surrey:—'Go to the cow-stall at six o'clock in the morning, winter and summer, give each cow half a bushel of the mangel-wurzel, carrots, turnips, or potatoes, cut; at seven o'clock, the hour the dairy-maid comes to milk them, give each some hay, and let them feed till they are *all* milked. If any cow refuses hay, give her something she will eat—such as grains, carrots, &c.—during the time she is milking, as it is *absolutely necessary* the cow should feed whilst milking. As soon as the woman has finished milking in the morning, turn the cows into the airing ground, and let there be plenty of *fresh water* in the troughs: at nine o'clock, give each cow three gallons of the mixture (as under—to eight gallons of grains add four gallons of bran or pollard); when they have eaten that, put some hay into the cribs: at twelve o'clock, give each three gallons of the mixture as before. If any cow looks for more, give her another gallon. On the contrary, if she will not eat what you give her, take it out of the manger, for never at one time let a cow have more than she will eat up *clean*. Mind and keep your mangers clean, that they do not get sour. At two o'clock, give each cow half a bushel of carrots, mangel-wurzel, or turnips; look the turnips, &c. over well, before you give them to the cows, as one rotten turnip, &c. will give a bad taste to the milk, and most likely spoil a whole dairy of butter. At four o'clock, put the cows into the stall to be milked; feed them on hay as you did at milking-time in the morning, keeping in mind that the cow, whilst milking, must feed on something. At six o'clock, give each cow three gallons of the mixture as before. Rack them up at eight o'clock. Twice in a week put into each cow's feed at noon a quart of malt-dust.' The writer of these directions adds, that the daily expense of subsisting each cow on the above feed would be about two shillings.

Milking.

Cows are milked twice or thrice a day, according to circumstances. If twice, morning and night: if thrice, morning, noon, and night. They should not go too long unmilked, for, independently of the uneasiness to the poor animal, it is severely injurious.

The act of milking is one which requires great caution; for if not carefully and properly done, the quantity of the milk will be diminished, and the quality inferior—the milk which comes last out of the udder being always the richest. It should therefore be thoroughly drawn from the cows until not a drop more can be obtained, both to insure a continuance of the usual supply of milk, and also to get the richest which the cows afford. Cows should be soothed by mild usage, especially when young; for to a person whom they dislike, they never give their milk freely. The teats should be always clean washed before milking, and when tender, they ought to be fomented with warm water. The milking and management of the cow should, in these circumstances, be intrusted only to servants of character, on whom the utmost reliance can be placed. In the southern and midland counties of England, it is a common practice to employ men to milk the cows, an operation which seems better fitted for females, who are likely to do the work in a more gentle and cleanly manner, which is of essential importance.

The writer in the magazine above quoted, gives the following explicit directions to the dairy-maid in regard to milking:—'Go to the cow-stall at seven o'clock; take with you *cold water* and a sponge, and wash each cow's udder clean before milking; douse the udder well with *cold* water, winter and summer, as it braces and repels heats. Keep your hands and arms clean. Milk each cow as dry as you can, morning and evening; and when you have milked each cow as you *suppose* dry, begin again with the cow you first milked, and drip them each; for the principal reason of cows failing in their milk is from negligence in not milking the cow dry, *particularly* at the time the calf is taken from the cow. Suffer no one to milk a cow but yourself, and have no gossipping in the stall. Every Saturday night give in an exact account of the quantity of milk each cow has given in the week.'

GENERAL TREATMENT OF CATTLE.

Cattle are subject to various diseases, the result of improper treatment, or of causes connected with climate, which it is difficult to avert. By attention to feeding, housing, and cleaning, as already noticed, much may be done to prevent some of the more fatal distempers. Cattle that have passed their lives, both day and night, in the open air, are generally so hardy, that they are not injured by a wetting of the skin, and are liable to few of the complaints of dairy or stall-fed animals. Cows, being compelled to lead an artificial mode of life, are the most delicate in every respect, and require the most careful treatment. They should not be left out all night; and when they return from the field wet, it is always a safe and humane plan to dry them with a wisp of straw. The diseases to which they are most liable are of an inflammatory kind, and for these the veterinary surgeon prescribes bleeding, and perhaps some medicines to be taken internally. Leaving cow-keepers to seek the advice of those professional men, or at least of persons possessing practical skill, we need here allude only to three common disorders for the sake of general information.

Diseases—The Hove.

The hove, or blown, in cattle is a swelling in the paunch, caused generally by eating wet grass or clover in warm weather. The substance ferments, and the membrane becomes distended by the creation of air or gas, which cannot find the means of escape; and if not taken off artificially, the animal will be suffocated. Mr Loudon, in his 'Encyclopædia of Agriculture,' mentions the following methods of relief from this fatal distension:—'There are three modes of relieving the complaint, which may be adverted to, according to the degree of distension and length of time it has existed. These are, internal medicines; the introduction of a *probang* of some kind into the paunch by the throat; and the puncturing it by the sides. 'Dr Whyatt, of Edinburgh, is said to have cured eighteen out of twenty hoved cows, by giving a pint of gin to each. Oil, by condensing the air, has been successfully tried. Any other substance, also, that has a strong power of absorbing air may be advantageously given. Common salt and water, made strongly saline, is a usual country remedy. New milk, with a proportion of tar equal to one-sixth of the milk, is highly spoken of. A strong solution of prepared ammonia in water often brings off a great quantity of air, and relieves the animal. Any of these internal remedies may be made use of when the disease has recently taken place, and is not in a violent degree; but when otherwise, the introduction of an instrument is now very generally resorted to.

The instrument principally in use is a species of probang, invented by Dr Munro of Edinburgh. Another, consisting of a cane of six feet in length, and of considerable diameter, having a bulbous knob of wood, has been invented by Eager, which is a more simple machine, but hardly so efficacious. It is probable that, in cases of emergency, even the larger end of a common cart-whip, dexterously used, might answer the end. But by far the best instrument for relieving hoven cattle, as well as for clystering them, is Read's enema apparatus, which is alike applicable to horses, cattle, and dogs. It consists of a syringe, to which tubes of different kinds are applied, according to the purpose and the kind of animal to be operated upon. There is a long flexible tube for giving an enema to horses and cattle, and a smaller one for dogs. To relieve hoven bullocks effectually, it is necessary not only to free the stomach from an accumulation of gas, but from the fermenting pultaceous mixture which generates it; for this purpose a tube is applied to the extremity of the syringe, and then passed into the animal's stomach through the mouth, and being put in action, the offending matter is discharged by a side opening. When the same operation is performed on sheep, a smaller tube is made use of. The characteristic excellency of Read's instrument is, that there is no limit to the quantity of fluid that may be injected or extracted. The same syringe is used for extracting poison from the stomach of man, for smoking insects, extinguishing fires, and syringing fruit-trees. The introduction of any of these instruments may be effected by the help of an assistant, who should hold the horn of the animal by one hand, and the dividing cartilage of the nose with the other; while the operator himself, taking the tongue in his left hand, employs his right in skilfully and carefully introducing the instrument; the assistant bringing the head and neck into such an attitude as to make the passage nearly straight, which will greatly facilitate the operation.

When no instruments can be procured, or as cases may occur when indeed it is not advisable to try them—as when the disease has existed a considerable time, or the animal has become outrageous, or the stomach so much distended with the air, that there is danger of immediate suffocation or bursting—in these instances the puncture of the maw must be instantly performed, which is called *paunching*. This may be done with the greatest ease, midway between the ilium or haunch-bone, and the last rib of the left side, to which the paunch inclines: a sharp penknife is frequently used; and persons in veterinary practice should always keep a long trocar, which will be found much the most efficacious, and by far the most safe, as it permits the air escaping certainly and quickly, at the same time that it prevents its entrance into the cavity of the abdomen, which would occasion an equal distension. As soon as the air is perfectly evacuated, and the paunch resumes its office, the trocar may be removed; and in whatever way it is done, the wound should be carefully closed with sticking-plaster or other adhesive matter. It is necessary to observe, that this operation is so simple and safe, that whenever a medical assistant cannot be obtained, no person should hesitate a moment about doing it himself.

After relief has been afforded by means of either the probang or the paunching, a stimulant drink may be very properly given: half a pint of common gin, or one ounce of spirit of hartshorn in a pint of ale, or two ounces of spirit of turpentine in ale, may any of them be used as an assistant stimulus. When, also, the cud is again chewed, still some relaxation of the digestive organs may remain; at first, therefore, feed sparingly, and give for a few mornings a tonic.' The apparatus mentioned above, with directions for use, may now be had from the principal makers of or dealers in agricultural implements. The cane tube, to employ in emergencies, no cow-keeper should be without.

Epidemic Murrain.

The malignant epidemic, generally called murrain, is a species of catarrh, affecting the respiratory organs, and is most frequent in damp climates or ill-drained parts of the country. The writer of the work on cattle, already quoted from ('Library of Useful Knowledge'), thus speaks of its nature and remedies:—'There are few diseases that assume, in its earlier or later stages, a greater variety of form; but, disarmed somewhat of its virulence in modern times, or at least not having appeared in all its terrors for some years past [written in 1830], it will generally be distinguished by some or the greater part of the following symptoms:—

There will be cough, frequent and painful, and in many cases for a week or more before there is any other marked symptom. The farmer may not always be aware of this, but he will find it out if he inquires about it; and he will be fully aware of the importance of the fact before we shall have done with this division of our subject.

After a few days, some heaving of the flanks will be added to the cough; the pulse will be small, hard, frequent, and sometimes irregular; the mouth hot; the root of the horn cold; the fæces sometimes hard and black, at others liquid and black, and then very fetid. Presently afterwards, that of which we have to speak again and again, is observed—extreme tenderness along the spine, and particularly over the loins.

The cough becomes more frequent and convulsive, and a brown or bloody matter runs from the nostrils and mouth; the eyes are swelled and weeping; the patient grinds his teeth; there is frequent spasmodic contraction about the nostrils; and the animal rarely lies down, or, if he does, rises again immediately.

The eyes soon afterwards become unusually dull; the pulse remains small, but it has become feeble; the respiration is quicker; the flanks are tucked up; the tenderness on the loins is removed; insensibility is stealing over the frame; and the fæces are more loaded with mucus, and more fetid. The patient moans and lows, and grinds his teeth almost incessantly; the head is agitated by a convulsive motion; blood begins to mingle with the fæces; the breath, and even the perspiration, become offensive; and the poor animal staggers as he walks.

Tumours and boils now, or often earlier, appear on various parts. If they are to come forward, the sooner they rise the better, for much depends on what becomes of them. If the animal has sufficient strength for them to go through the usual process of suppuration, although the sloughing and the stench may be greater than could be thought possible, the beast will have a chance to recover; but if there is not energy to bring these tumours forward—if they become stationary—and most assuredly, if they recede and disappear, the patient will die.

The treatment of this disease is most unsatisfactory. If the farmer could be brought to attend more to this cough in cattle, if here he had recognised the violent and increasing cough, and, although he had not dreamed of murrain, had bled and physicked the beast on account of the cough, the disease would probably have been arrested, or at least its virulence would have abated at that stage.

The early stage even of murrain is one of fever, and the treatment should correspond with this—bleeding. Physic should be cautiously, yet not timorously resorted to. For sedative medicines there will rarely be room, except the cough should continue. Small doses of purgative medicine, with more of the aromatic than we generally add, will be serviceable, effecting the present purpose, and not hastening or increasing the debility which generally is at hand; but if the bowels are sufficiently open, or diarrhœa should threaten, and yet symptoms of fever should be apparent, no purgative must be given, but the sedatives should be mingled with some vegetable tonic. The peculiar fetid diarrhœa must be met with astringents, mingled also with vegetable tonics. In combating the pustular and sloughing gangrenous stage, the chloride of lime will be the best external application; while a little of it administered with the other medicines inwardly, may possibly lessen the tendency to general decomposition. The external application of it should not be confined to the ulcerated parts alone, but it should be plentifully sprinkled over and about the beast; and the infected animal should be immediately removed from the sound ones.'

Red-Water.

This disease, indicated at first by the redness of the urine, is properly inflammation of the kidneys, and arises from an undue determination of blood to these parts of the animal. The cause of this local inflammation is generally connected with the nature of the food. In many instances, it is found to have arisen from the cattle eating plants of a noxious quality, and which, as it appears, are not confined to any particular species of soil. When in its aggravated form, the disease becomes what is called *Black-Water*. On the slightest indication of the early stages of the distemper, the cattle ought to be immediately shifted to different pasture, or housed and stall-fed for a short period; and if this simple precaution prove unavailing in restoring health, each animal affected should be copiously, and if necessary, frequently bled; and let that active treatment be followed up by purgatives, so as to clear out and restore a proper tone to the bowels. Should these means fail, let a skilled practitioner be consulted. On no account listen to the absurd advices of superstitious and ignorant people either on this or any other disease of cow or bullock. In every quarter of the country, there are persons who, from total ignorance of the physiology of cattle, and the natural causes and action of disease, ascribe calamities of this kind to witchcraft or other supernatural influences. Let all such quacks, and their irrational salves, be carefully shunned.

Fattening for Market.

The stall-feeding or soiling of cattle is considered to possess several advantages over feeding in the fields. In field-feeding, the animals waste a certain quantity of pasture by treading and lying upon it, and by dropping their dung, the grass which grows on the dung spots being ever after rejected; the animals also spend time in seeking for the herbage which suits their fancy, and much is allowed to go to seed untouched. In stall-feeding, the whole time is devoted to eating and ruminating, while no food is lost, and the animals are brought to a higher condition. Another important advantage of soiling is, that it uses up the waste straw of a farm as litter, and thus furnishes a plentiful supply of that indispensable article, manure, for the fields. Some feeders tie up their cattle to the stall while preparing for market; but others permit them to roam about on a thick bed of straw in an enclosure in the farm-yard, with a shed to retire to for shelter, the feeding in this case being from racks. Unless for a period during the final process of fattening, the straw-yard method is reckoned the best for keeping the cattle in a healthy state, and consequently for producing beef of the finest kind. The practice of feeding cattle for a considerable length of time, in darkened stalls, on oil-cake, turnips, mangel-wurzel, &c. produces, as is well known, a great deposition of fat, and swells the animals to a monstrous size. The beef, however, of such over-fed cattle is never fine. The fat with which it is loaded easily escapes in cooking, and leaves lean of an inferior quality. The best sign of good meat is its being *marbled*, or the fat and lean well mixed, when brought to the table, and this is not to be expected from beef fed in an unnatural condition.

Speaking on this subject, the writer of the article Agriculture, in the 'Encyclopædia Britannica,' observes—' The age at which cattle are fattened depends upon the manner in which they have been reared, upon the properties of the breed in regard to a propensity to fatten earlier or later in life, and on the circumstances of their being employed in breeding, in labour, for the dairy, or reared solely for the butcher. In the latter case, the most improved breeds are fit for the shambles when about three years old, and very few of any large breed are kept more than a year longer. As to cows and working oxen, the age of fattening must necessarily be more indefinite; in most instances, the latter are put up to feed after working three years, or in the seventh or eighth year of their age.'

Many of the cattle fed for the metropolitan markets, as formerly mentioned, have originally been brought from the Highlands and Isles of Scotland, also from Wales and Ireland. According to the General Report of Scotland, ' the Highland cattle often pass through three different hands or more before they come to the butcher. They are improved at every stage by a greater quantity and better quality of food, instead of being suddenly transported from poor to rich feeding; and while each successive owner applies his produce to the best advantage, and receives a suitable return according to its value from the advance of price, the consumer at last purchases his beef cheaper, and of a much superior quality, than if the cattle had been at once prepared for the shambles at any of the intermediate stages.

The West Highland cattle make this progress oftener than the larger cattle of the north-eastern counties. Many of them are brought to Dumbartonshire and other places at the age of two years and two years and a half, wintered on coarse pastures, with a small allowance of bog-hay or straw, and moved to lower grounds next summer. They are then driven further south, where they get turnips in straw-yards through the following winter, and in April are in high condition for early grass, upon which they make themselves fit for the shambles in the month of June.

The larger varieties of the north-eastern counties do not leave the breeder at so early an age. They are seldom brought to market till they are three or three years and a half old, and then frequently in good condition for being fattened either on grass or turnips. A great many of the Aberdeenshire cattle are bought for the straw-yards of the southern counties, get a few turnips through winter and spring, and are either driven to England in April, or fattened at home in the course of the ensuing summer. The Fife cattle, like the other breeds of the Lowlands, are generally sold to the graziers at three years old, having got a liberal allowance of turnips during the preceding winter.'

Rules for Selecting Cattle.

In selecting cattle for feeding, their qualities may be in some measure known by examining the hide, horns, &c. ' It is well known that the grazier and the butcher judge of the aptitude that any animal has to fatten from the touch of the skin. When the hide feels soft and silky, it strongly indicates a tendency in the animal to take on meat; and it is evident that a fine and soft skin must be more pliable, and more easily stretched out to receive any extraordinary quantity of flesh, than a thick or tough one. At the same time, thick sound hides are of great importance in various manufactures. Indeed they are necessary in cold countries, where cattle are much exposed to the inclemency of the seasons; and in the best breeds of Highland cattle, the skin is thick in proportion to their size, without being so tough as to be prejudicial to their capacity of fattening. It appears, from Columella's description of the best kind of ox, that the advantage of a soft skin is not a new discovery, but was perfectly well known to the husbandmen of ancient Italy.' These are the observations of Sir John Sinclair, who adds the following as a summary of good points to be attended to in choosing cattle:—' They should be—1. Of a moderate size, unless where the food is of a nature peculiarly forcing; 2. Of a shape the most likely to yield profit to the farmer; 3. Of a docile disposition, without being deficient in spirit; 4. Hardy, and not liable to disease; 5. Easily maintained, and on food not of a costly nature; 6. Arriving soon at maturity; 7. Producing considerable quantities of milk; 8. Having flesh of an excellent quality; 9. Having a tendency to take on fat; 10. Having a valuable hide; and lastly, Calculated (should it be judged necessary) for working.' It is thought best to begin to break in draught oxen at three years old, and to give them full work at four.

With respect to judging of cattle by their horns and teeth, we offer the following observations from the 'Cyclopædia of Practical Husbandry, by Martin Doyle:' —' The ordinary guide for ascertaining the precise age of cattle is the horn, which is also indicative of the breed: at three years old (this is laid down as a rule) the horns are perfectly smooth, after this a ring appears near the root, and annually afterwards a new circle; so that, by adding two years to the first ring, the age is calculated; but the contributors to the volume so frequently quoted, have clearly shown that this is a very uncertain mode of judging; "that the rings are only distinct in the cow;" and that "if a heifer goes to the bull when she is two years old, or a little before or after that time, there is an immediate change in the horn, and the first ring appears; so that a real three-year old would carry the mark of a four-year old." "In the bull they are either not seen until five, or they cannot be traced at all;" nor in the ox do they "appear until he is five years old, and they are often confused;" besides, "there is also an instrument called a rasp, which has been said to make many an arm ache a little before a large fair." Without any delusive intentions, however, an ugly set in the horns of young cattle is often remedied by filing a little off the sides of the tips opposite to the direction which it is desired that the horns should take.

Some breeders have an antipathy to horns altogether, and would even carry their dislike so far as to extirpate them from the brows of all their cattle: they can indulge their taste by paring off the tops of the horns when they first break through the skin. Perhaps it is not generally known that the larger and more massive the horn, the thinner the skull.

The age is indicated with unerring certainty by the teeth, to those who have judgment and experience, until the animal reaches the age of six or seven: until two years old, no teeth are cast; at that age two new teeth are cut; at three, two more are cut; and in the two succeeding years, two in each year; at five, the mouth is said to be full, though not completely so until six, because until that period the two corner teeth (the last in renewal) are not perfectly up. The front or incisor teeth are those considered, for a full-grown beast has altogether thirty-two teeth.'

Method of ascertaining the Weight of Live Cattle.

This is of the utmost utility for those who are not experienced judges by the eye; and by the following directions—given in the 'Cattle-Keeper's Guide'—the weight can be ascertained within a mere trifle:—' Take a string, put it round the beast, standing square, just behind the shoulder-blade; measure on a foot-rule the feet and inches the animal is in circumference; this is called the girth; then, with the string, measure from the bone of the tail which plumbs the line with the hinder part of the buttock; direct the line along the back to the fore part of the shoulder-blade; take the dimensions on the foot-rule as before, which is the length, and work the figures in the following manner:—Girth of the bullock, 6 feet 4 inches; length, 5 feet 3 inches; which, multiplied together, make 31 square superficial feet; that again multiplied by 23 (the number of pounds allowed to each superficial foot of cattle measuring less than 7 and more than 5 in girth,) makes 713 pounds; and, allowing 14 pounds to the stone, is 50 stones 13 pounds. Where the animal measures less than 9 and more than 7 feet in girth, 31 is the number of pounds to each superficial foot. Again, suppose a pig or any small beast should measure 2 feet in girth, and 2 feet along the back, which, multiplied together, make 4 square feet; that multiplied by 11, the number of pounds allowed for each square foot of cattle measuring less than 3 feet in girth, makes 44 pounds; which, divided by 14, to bring it to stones, is 3 stones 2 pounds. Again, suppose a calf, a sheep, &c. should measure 4 feet 6 inches in girth, and 3 feet 9 inches in length, which, multiplied together, make 16½ square feet; that multiplied by 16, the number of pounds allowed to all cattle measuring less than 5 feet, and more than 3 in girth, makes 264 pounds; which, divided by 14, to bring it into stones, is 18 stones 12 pounds. The dimensions of the girth and length of black cattle, sheep, calves, or hogs, may be as exactly taken this way as is at all necessary for any computation or valuation of stock, and will answer exactly to the four quarters, sinking the offal, and which every man, who can get even a bit of chalk, can easily perform. A deduction must be made for a half-fatted beast of 1 stone in 20, from that of a fat one; and for a cow that has had calves, 1 stone must be allowed, and another for not being properly fat.'

THE DAIRY.

The dairy should be cool, airy, dry, and free from vermin of all kinds. To prevent the intrusion of flies, the windows or ventilators ought to be covered with a fine wire gauze. The floor should be laid with smooth glazed tiles, and also the lower part of the walls; the benches on which the milk-pans are to be placed are best when made of stone or slate, and about 30 inches broad. The ceiling should be at least 8 feet from the floor, and finished in every respect like that of an ordinary dwelling-house. A slate roof is preferable to one of tile, as it tends to keep the temperature more equable. Cleanliness is of the most essential consequence in dairy management, and, if not strictly looked after, may cause considerable loss. It is this which has raised the produce of the dairies of Holland so much in public estimation. Every article in which milk is placed, more especially when made of wood, ought to be washed in boiling water, with a little soda or lime dissolved in it. If milk should happen to sour in any dish, the acid thus generated will injure any which may be afterwards put into it; but if washed with water in which an alkali has been dissolved, the acid will be neutralised or destroyed.

The utensils of a dairy are very numerous. The principal are milk-pails, shallow coolers for holding the milk, sieves for straining it through after it is taken from the cow, dishes for skimming the cream, churns for making the butter, scales, weights, &c. For making cheese, there are likewise ladders, vats, tubs, curd-breakers, and presses; and various other articles will be required, which it is almost impossible to enumerate. In form, these vessels, with a few exceptions, are alike throughout Great Britain; and even in other countries there is little variation. The majority of them are made of wood; but in some of the best dairies in England and Scotland, it is now the practice to have the coolers made of cast-iron, wood lined with tin in the inside, or glazed earthenware. Maple is the wood generally used in England for the manufacture of these dishes; both from its lightness, and being easily cut, it can be finished in a neater style. In Holland, the milk dishes are very commonly made of brass; and certainly brass or iron is to be preferred to wood, because the dishes make from either of these materials are more durable, and can be easier cleaned. It has been objected to earthenware vessels that, being glazed with lead, the acid of the milk acting upon the glaze forms a very noxious poison. This, however, is scarcely correct; it would require a much stronger acid than that of milk to decompose the glaze; and in some parts of England lead has been long used, and never objected to. Zinc pans, which have been recommended for their cheapness as well as for their cool and cleanly qualities, are also pretty generally used; and latterly, since the abolition of the duty on glass, this material is spoken of as likely to supersede all others. Though somewhat objectionable on the score of brittleness, glass is undoubtedly to be preferred to wood in point of cleanliness, and to any metallic substance, like zinc or lead, which might be acted upon by the lactic acid, and so produce compounds of a deleterious nature. It may be added, however, that in all cases of ordinary management, neither zinc nor lead vessels can ever be so extensively acted upon by the acid of the milk as to produce any lactate capable of affecting the human system.

Cheese-presses are usually made of stone of various weights, according to the size of the cheese. Granite is preferred for this purpose, on account of its great weight. A lever was a method long practised, one end of which being placed in a hole in the wall, the sinker acted as a fulcrum, and one or two unhewn stones, hung on the end of the pole, produced the pressure. Another kind of press consisted of a stone weight placed upon the sinker, which was raised and depressed either by a block and tackle or a screw. The kind most commonly used at present is a lever with a double wheel, which occupies little space, is easily worked, and allows of the weight being better regulated than by a stone placed upon the sinker.

Churning is now, in all large dairy establishments, performed by machinery, worked either by horse or water power, or attached to a thrashing-machine, if there is one in the dairy. Churns vary in size from ten to fifty, and even one hundred gallons, according to the size of the establishment. The plunge-churn, which has the appearance of a barrel placed on its end, is that most commonly used—the plunge being worked by a lever connected with a shaft and crank, moved by a wheel outside. The common hand-churns are of various forms, either upright with a plunge, or horizontal with horns inside, which are turned by an iron handle. A churn formed like a cradle is much used in Canada, and has been strongly recommended for adoption in this country. It is rocked regularly by a child sitting astride, who may thus be usefully employed while amusing himself. Great care should be taken to wash churns thoroughly with boiling water, both immediately after they have been used, and before they are again to be put in operation; and those churns which admit of being easily cleaned are always to be recommended, even although they should not be so elegant in construction.

Milk.

Milk consists of three materials blended together, called in science the butteraceous, lactic, and serous kinds of matter, which can be separated by artificial means, so as to form *butter*, the milk called *buttermilk*, and serum or whey. The whey is little else than water, slightly saline, and is generally the chief ingredient in the milk. When taken from the cow, milk should be removed to the dairy or milk-house, and after being sieved, placed in shallow pans, to throw up the butteraceous matter termed cream, which, like all fatty substances, being lightest, floats on the top.

The following observations on milk and its management, made by Dr Anderson, in his 'Recreations,' are worthy of the consideration of cow-keepers :—

'Of the milk drawn from any cow at one time, that part which comes off at the first is always thinner, and of a much worse quality for making butter, than that afterwards obtained; and this richness continues to increase progressively to the very last drop that can be obtained from the udder.

If milk be put into a dish, and allowed to stand till it throws up cream, the portion of cream rising first to the surface is richer in quality and greater in quantity than that which rises in a second equal space of time; and the cream which rises in the second interval of time is greater in quantity and richer in quality than that which rises in a third equal space of time; that of the third is greater than that of the fourth; and so of the rest: the cream that rises continuing progressively to decrease in quantity and decline in quality so long as any rises to the surface.

Thick milk always throws up a much smaller proportion of the cream which it actually contains than milk that is thinner; but the cream is of a richer quality; and if water be added to that thick milk, it will afford a considerably greater quantity of cream, and consequently more butter, than it would have done if allowed to remain pure; but its quality is at the same time greatly deteriorated.

Milk which is put into a bucket or other proper vessel, and carried in it to a considerable distance, so as to be much agitated, and in part cooled, before it be put into the milk-pans to settle for cream, never throws up so much or so rich cream as if the same milk had been put into the milk-pans, without agitation, directly after it was milked.

From these fundamental facts, the reflecting dairyist will derive many important practical rules. Some of these we shall enumerate, and leave the rest to be discovered. Cows should be milked as near the dairy as possible, in order to prevent the necessity of carrying and cooling the milk before it is put into the creaming dishes. Every cow's milk should be kept separate, till the peculiar properties of each are so well known as to admit of their being classed, when those that are most nearly allied may be mixed together. When it is intended to make butter of a very fine quality, reject entirely the milk of all those cows which yields cream of a bad quality, and also keep the milk that is first drawn from the cow at each milking entirely separate from that which is last obtained, as the quality of the butter must otherwise be greatly debased, without materially augmenting its quantity. For the same purpose, take only the cream that is first separated from the first drawn milk. Butter of the very best quality can only be economically made in those dairies where cheese is also made; because in them the best part of each cow's milk can be set apart for throwing up cream, the best part of this cream can be taken in order to be made into butter, and the remainder, or all the rest of the milk and cream of the dairy, can be turned into cheese. The spontaneous separation of cream, and the production of butter, are never effected but in consequence of the production of acid in the milk. Hence it is, that where the whole milk is set apart for the separation of cream, and the whole of the cream is separated, the milk must necessarily have turned sour before it is made into cheese; and no very excellent cheese can be made from milk which has once attained that state.'

We now pass on to a consideration of the most valuable ingredient in dairy produce; namely—

Butter,

which is made of cream, freed from its milky and serous properties. This is effected by churning. Some imagine that no butter can be good except such as is made from fresh cream; but this is a mistake, as cream requires to have a little acidity before the butter will form. The length of time which the cream should stand before churning has never been clearly ascertained; from three to seven days, however, may be considered as the proper period. A more important matter than the length of time which cream requires to stand is the degree of temperature at which the cream will turn into butter. This has been ascertained from experiment to be from 45 to 75 degrees of Fahrenheit. In Holland, when the cream is too cold, hot water is put into the churn to raise the temperature to 70 or 75 degrees. The best quality of butter is obtained at a temperature of 51 degrees, according to experiments performed by Mr Pooler; and the greatest quantity at a temperature of 56 degrees. During the process of churning, the agitation will increase the heat to about five degrees more than it was when the cream was put into the churn. Mr Pooler is of opinion that the greater quantity of butter is obtained by the increased heat causing more milk to remain amongst the butter; and this of course must decrease its quality.

In some of the dairies in the neighbourhood of Edinburgh, and in all those near Glasgow, the butter is made by churning the cream and the milk together. This is done in order to obtain the buttermilk, the demand for which is always great in large cities. When the milk and cream are to be churned together, the milk is kept in the coolers for from twelve to twenty-four hours, and then poured into a milk-tub. It remains here until required for churning; and will, during this time, have coagulated. If a certain quantity of milk is put into the milk-tub, and has coagulated before any more has creamed, the coagulated milk must in no way be disturbed, or if the two quantities are mixed together, too much fermentation may be the consequence. The milk is not churned till it has become acid; and when once coagulation has taken place, it should be churned as early as convenient. If the milk has not fermented before churning, the buttermilk will keep for a much longer time, will have an agreeable taste, and will bear to be mixed with a little water. When the milk has fermented before being churned, the buttermilk will never be so good, nor will it keep for such a length of time as in the former case.

The operation of churning, whether it be of cream alone, or cream and milk, is performed in the same manner. The milk requires more time than cream to complete the process, from two to three hours being considered necessary, while cream alone may be effectually churned in an hour and a half. It is necessary that the operation should be slow in warm weather; for if done too hastily, the butter will be soft and white. If the cream is at too high a temperature, the churn should be cooled with cold spring water, to reduce it to the proper degree of heat. In winter, again, the operation of churning should be done as quickly as possible, the action being regular; and the churn should be warmed, to raise the temperature of the milk or cream. The air which is generated in the churn should be allowed to escape, or it will impede the process by the froth which it creates.

After the churning is performed, the butter should be washed in cold spring water, with a little salt in it, two or three times, to extract all the milk which may be lodging about the mass. It is said by some that the butter retains its sweetness much longer when no water is used; and others affirm that the washing improves the flavour. The extraction of the milk from butter will reduce its weight; but it appears from the experiments of Mr Pooler upon the temperature of the cream, that the less milk which is in the butter its quality is proportionably improved. Kneading and beating the butter too much render it tough and gluey. After the milk has been carefully extracted, if the butter is to be salted, it should be mixed with the finest salt, in the proportion of ten ounces to the stone of fourteen pounds, more or less, according to the time the butter is to be preserved. The butter and salt should be well mixed together with the hand; and in Ireland it is customary to add a little saltpetre. A compound of one part sugar, one part nitre, and two parts of the best Spanish salt, finely powdered together, has been highly recommended for preserving butter. It is used in the proportion of one ounce to the pound: and it is said to give a flavour to the butter which no other known ingredients can impart.

For making butter casks or kegs, the wood of the lime-tree is highly recommended, as containing no acid; and after it the white oak and the ash. When wood contains acid, it acts powerfully upon the salt in the butter, converting it into brine. Fir has also been recommended for making casks; and indeed any wood will answer if boiled for a few hours, for by this process the pyroligneous acid will be entirely taken out.

In salting, the butter should never be put into the firkins in layers; but the surface should be left every day rough and broken, so as to unite better with that of the succeeding churning. The quality may likewise be better preserved by covering it from the air with a clean linen cloth dipped in pickle, and finally placing it in a cool situation.

Buttermilk.

This is the liquid which remains in the churn after removing the butter. If milk has been employed for churning, the buttermilk is thin, poor, and easily sours; but if from the churning of cream, the buttermilk is more thick and rich, and is considered by many a delicious beverage. Good buttermilk is at all events exceedingly wholesome and nutritious. In Ireland, it is largely used at meals with potatoes; in Scotland, it is more frequently employed as a relish with oatmeal porridge; and for this purpose large quantities are brought to Edinburgh, Glasgow, and other towns, from the adjoining rural districts. In England, the buttermilk of farmers is usually employed in feeding pigs. Latterly it has been used in conjunction with carbonate of soda in the preparation of a light and wholesome household bread.

Clouted Cream.

This is a preparation of the rich milk of Devonshire, and may be said to be a kind of half-formed butter, such is the solidness of its consistency. In Vancouver's 'Survey of Devonshire,' the following is described as the mode of preparing this delicious article:—'The milk is put into tin or earthen pans, holding about ten or twelve quarts each. The evening's meal is placed the following morning, and the morning's milk is placed in the afternoon, upon a broad iron plate heated by a small furnace, or otherwise over stoves, where, exposed to a gentle fire, they remain until after the whole body of cream is supposed to have formed upon the surface; which being gently removed by the edge of a spoon or ladle, small air-bubbles will begin to rise, that denote the approach of a boiling heat, when the pans must be removed from off the heated plate or stoves. The cream remains upon the milk in this state until quite cold, when it may be removed into a churn, or, as is more frequently the case, into an open vessel, and then moved by the hand with a stick about a foot long, at the end of which is fixed a sort of peel from four to six inches in diameter, and with which about twelve pounds of butter may be separated from the buttermilk at a time—the butter in both cases being found to separate much more freely, and sooner to coagulate into a mass, than in the ordinary way, when churned from raw cream that may have been several days in gathering; and at the same time will answer a more valuable purpose in preserving, which should be first salted in the usual way, then placed in convenient-sized egg-shaped earthen crocks, and always kept covered with a pickle, made strong enough to float and buoy up about half out of the brine a new-laid egg. This cream, before churning, is the celebrated clouted cream of Devon.'

Cheese.

Cheese may be made from cream alone, or from the whole milk; the object in either case being in the first place to separate the serum from the other materials.

This is effected by curdling the cream or milk by the infusion of an acid, the refuse being the serum or whey, which is of scarcely any value. No acidulous substance is found so suitable for curdling milk as *rennet*, which is formed of the gastric juice of a calf that has been fed on milk. Some persons preserve the maws or stomach-bags of calves with the curd contained in them; others employ the stomach-bags alone, putting a few handfuls of salt into and around them. They are then rolled up, and hung in a warm place to dry, and are kept for some time before they are used. The stomach is never made use of in Gloucestershire until it is a twelvemonth old; for, if used before this, it is said to swell the cheese, making it full of *eyes* or holes. The usual way of preparing the rennet in England is to add to every six skins or stomachs two gallons of brine, and two lemons, which take away any unpleasant taste, and give the rennet an agreeable flavour. A large quantity is made at a time; and it is never used until it has stood at least two months. The method of preparing a good-flavoured rennet, recommended by the late Mr Marshall, is as follows:—

'Take the maw of a newly-killed calf, and clean it of its contents, salt the bag, and put it into an earthen jar for three or four days, till it forms a pickle; then take it from the jar, and hang it up to dry: after which it is to be replaced in the jar, the covering of which should be pierced with a few holes to admit the air, and allowed to remain in the jar for twelve months. When wanted for use, a handful each of leaves of sweet-brier, dog-rose, and bramble, with three or four handfuls of salt, are to be boiled together for a quarter of an hour, when the liquid is to be strained off, and allowed to cool. The maw is then to be put into the liquid, together with a lemon stuck round with cloves; and the longer it remains in the liquid, the stronger and better will the rennet be. Half a pint of the liquid is sufficient to turn fifty gallons of milk.'

As almost every dairy county in England has its own particular method of steeping and salting the maws and preparing the rennet, we shall only give that pursued in Ayrshire, the most important dairy district in Scotland. The stomach of the calf is examined, and all impurities, such as straw, removed from the curdled milk. Two handfuls of salt are then put into and around the bag, which is hung in a warm place to dry thoroughly. It is seldom used before it is a year old, and even a longer period is thought to improve it. When wanted to prepare rennet, the bag is cut into small pieces, and put into a jar, with a handful or two of salt and a quantity of boiled soft water, cooled down to about sixty-five degrees, or new whey taken off the curd is put into the jar. The quantity of water or whey will vary according to the quality of the yirning; and if it is that of a new-dropped calf, three English pints will be enough; but if fed for four or five weeks, two quarts will be about the quantity required. This is allowed to stand in the jar for two or three days, and is then strained off, and another pint of water placed upon the maw, which, after standing three days, is added to the first infusion. If any impurities appear in the liquid, it should be carefully strained through a sieve, and the whole can be bottled and used as wanted. A glassful of whisky is sometimes put into each bottle; but this is not common. The liquid thus prepared may be used either immediately, or kept months if required, and a table-spoonful will coagulate thirty gallons of milk in the course of ten minutes; whereas the English rennet requires nearly three hours to effect the same purpose.

Dunlop cheese has of late come into very general repute; and although nowhere so well made as in the parish in Ayrshire from which it derives its name, it is now manufactured in Galloway, in the counties of Renfrew, Lanark, and Ayr, and is extending to others. The cheeses are made of various sizes, from a quarter to half a hundredweight; and the process of making them is as follows:—Sweet milk for Dunlop cheese is composed of all the milk as it is yielded by the cows, without having the cream separated from it. When so many cows are kept upon a farm that a cheese can be made every time they are milked, the milk is passed through a sieve into the vat, and formed into a curd by the rennet. But when the cows are not so numerous as to afford milk sufficient to form a cheese at each milking, it is put into the coolers about six or eight inches deep. At the next milking, the cream is skimmed off, and without being heated, the milk is put into the curd-vat along with that just drawn from the cows. The milk is then raised to a temperature about blood heat, or in summer to 90 degrees, and in winter 95 degrees. If coagulated much warmer, the curd becomes too adhesive; some of the butteraceous matter is lost in the whey, and the cheese will be found dry, tough, and tasteless. If too cold, on the other hand, the curd, which is then soft, does not part readily with the serum, and the cheese is so wanting in firmness that it is difficult to get it to keep together. Even after the utmost care has been taken to extract the whey and give solidity to the cheese, holes, which in provincial language are termed *eyes*, whey-drops, and springs, frequently break out, and render the cheese either rancid or insipid.

It is not enough that the milk is brought to a right temperature when the rennet is applied, but the milk must be kept neither too hot nor too cold from the time it is taken from the cow. The temperature of the milk-house ought to be kept as equal as possible, never rising above 55 nor sinking below 50 degrees. In operations so critical as those of the dairy, where any material alteration in the temperature will affect the quality of the cheese, this ought at all times to be ascertained. Instead of this, the general practice is for the dairymaid merely to pass her fingers through the milk, than which nothing can be more uncertain. A thermometer ought not only to be in every milk-house, but also in every byre, as extremes of heat or cold, or sudden changes in the temperature, have a great effect upon the secretion of milk.

About a table-spoonful of the liquid rennet is considered sufficient for 100 quarts of milk, and the curd is formed by it in twelve or fifteen minutes; but in some dairies, the curd does not appear in less than forty-five or sixty minutes, although double the quantity of rennet is used. This must be owing either to a want of strength in the rennet, or from some peculiarity in the herbage upon which the cows have been fed. The curd, when formed, should be broken with the skimming-dish or the hand as soon as possible, but without pressing, as the least violence has been found to make it come off white, and thus weaken the quality of the cheese. The whey may be run off by lifting the tub gently on its edge, and allowing it to flow into a vessel placed beside the tub. The curd should then be allowed to stand until the whey has gathered in another part, and this is also poured off.

When quite freed from the whey, and the curd has acquired a little consistence, it is cut with the cheese-knife, gently at first, and more minutely as it hardens, after which it is put into the drainer, a square vessel with small holes in the bottom, and a cover to fit inside. The lid is placed upon the curd, with a cloth thrown over it, and pressure is applied according to the quantity of curd; and in this state it is allowed to stand for about half an hour. It is then cut into pieces about two inches square; the whey is again discharged, and double the former weight is placed upon it. This process of cutting is smaller every half hour, and increasing the weight until the pressure is 100 pounds, is continued for three or four hours. It is then cut very small, and thoroughly salted; thirteen ounces of salt to twenty-four pounds English of the curd being sufficient.

A clean cheese-cloth, rinsed in warm water and wrung out, being then placed in the chessel, the curd is put in, and half a hundredweight laid on it for an hour. It is then put under a press of two hundredweight, where it remains during an hour and a half, after which it is taken out, and a fresh cloth placed in the chessel, The cheese is then placed upside down, and laid, with increased weight, under the press, letting it remain three or four hours in the press at a time, and at each shifting getting a clean dry cloth. Some have shortened the process of pressing by placing the cheese, when it comes from the press for the first time, into water heated to about 95 or 100 degrees, where it remains till the water becomes milk-warm. The cheese is then dried well, and again placed under the press.

When ultimately taken from the press, the cheeses are generally exposed for about a week to a considerable degree of drought, turned over every twenty-four hours, and rubbed with a dry cloth. They are then removed to the store-room, which should be in a cool exposure, between damp and dry, without the sun being allowed to shine on them, or a great current of air admitted—this gradual mode of ripening being found essential to prevent the fermenting and swelling of the cheese and cracking of the rind. The mode of sweating cheeses, after they come from the press, and before they are laid up to dry, although common in England, is not approved of nor practised in Ayrshire. Yet Dunlop cheeses do not crack in the skin, except when the milk has begun to acidify before being coagulated, or when they are exposed to too much drought at first. Whey springs, or eyes, are seldom seen in the cheeses of Ayrshire. Cheese, like butter, is sometimes coloured with an infusion of annato, but the practice is far from being common. The Dunlop or Ayrshire cheeses have not so high a flavour and spicy taste as some of the English, owing perhaps to the inferiority of the pasture, and to the greater pains taken in the English dairies to give the cheese an acrid taste.

Cheshire Cheese.—It has been remarked, that although good imitations of the cheese made in the English counties have been produced elsewhere, yet in no trial has a cheese possessing the true Cheshire flavour been made. This is attributed to the abundance of the saline particles in the earth, resulting from the numerous salt springs in that county. Cheshire is almost entirely a dairy county. It is said to possess 32,000 milch cows; the quantity of cheese made annually is estimated at 11,500 tons; and the average quantity afforded by each animal at 300 pounds. In making the cheese, the practice followed is to set the evening's milk apart till the following morning, when the cream is skimmed off, and two or three gallons put into a brass pan, which is immediately placed in hot water, and rendered scalding hot. Half of the milk thus heated is poured upon the night's milk, and the other half mixed with the cream, which is rendered thinner by the mixture. This is done by the dairywoman while the other servants are milking the cows; and the morning's milk being immediately added to that of the previous evening, the whole mass is set together for cheese. The rennet and colouring being then put into the tub, the whole is well stirred, and a wooden cover put over the tub, with a linen cloth thrown over it. It in general requires an hour and a half before the milk curdles; and if the cream should rise to the surface in this time, the whole must be again well stirred, which is done every time the cream rises, until coagulation takes place.

When the curd is formed, if it be firm, it is cut with the cheese-knife, and then cut across, making the incisions about an inch distant from each other. The curd is then broken by the dairywoman, until every part of it is made as small as possible, about forty minutes being generally spent in this process, when the curd is left about half an hour to subside, covered over with a cloth. After this, the curd is put in a favourable position in the tub to drain, and a weight of about sixty pounds put upon it, in order to press out the whey, which is drained to the lower side of the tub and ladled out. When well drained, the curd is turned upside down, and pressed as before. It is cut into pieces of about nine inches square, which are piled one above another, and pressed both with the hand and the weight, so long as the whey continues to flow.

These pieces are then cut into three parts of about the same size, which are broken very small, and salted at the rate of three handfuls to each. They are then put into a cheese-vat, furnished with a coarse cheese-cloth. The curd is heaped in the vat in a conical shape, the cone being covered with a cloth, to prevent any curd from falling off. As soon as the curd adheres together, a weight of about sixty pounds is put upon it, and several iron skewers are stuck through it by holes in the sides of the vat. These holes are made in order to allow any whey remaining in the curd to escape. The weight and skewers are then removed, and the curd is broken as small as possible half way down the vat. The pressing and skewering are again repeated, and a clean cloth is put over the upper part of the curd, which is then taken out of the vat, and put into it again upside down, and broken half way down as before. When no more whey can be extracted, the curd is turned in the vat, and rinsed in warm whey. The curd is still kept above the edge of the vat, being bound round with strong tape to keep it in a proper shape. The cheese is next put into the press, which has generally the power of fourteen or sixteen hundredweight, and is then well skewered with strong wires, eighteen or twenty inches long, and sharp at the points. The vat is furnished with holes on the sides to receive the skewers; and after being about half an hour in the press, the cheese is again turned, and supplied with a clean cloth. It is turned again and again several times for forty-eight hours, each time supplied with a clean cloth, and is then put mid-deep into salt, its top covered with salt, where it remains for three days, its position being reversed each day. When taken out of the vat, it is put into a wooden hoop or girth of the same breadth as the thickness of the cheese, and is placed on the salting-bench, where it stands about eight days, being well salted during that time. The cheese is then washed in lukewarm water, and after being wiped, is placed on the drying-bench, where it remains about seven days; it is then again washed and dried as before, and rubbed all over with sweet butter. After this, it is placed in the warmest part of the cheese-room, and rubbed each day with sweet butter for the first seven days.

These cheeses vary in size, being in some dairies nearly 140 pounds in weight. The quantity of salt made use of during the process is uncertain; three pounds to a cheese of sixty pounds is thought to be about the amount; but much of this is lost in the salting-house. Whether the cheese acquires much saltness during the steeping and rubbing, is uncertain, though much salt is expended in these operations.

The double Gloucester cheese, which is held in such high repute, is almost wholly made in the vale of Berkley in Gloucestershire. Its excellence is said to depend much upon the quality of the land, and the great attention which is paid to the management of the dairies. The quantity of cheese made in this vale annually is about 1200 tons, and each cow is estimated to yield 350 pounds. It is usually made in the months of May, June, and July, and the process of manufacturing is as follows:—

When the curd—which is seldom prepared from artificially-heated milk, but, if possible, from the milk as it is drawn from the cow, and when it has fallen to about 85 degrees—is considered firm enough for breaking, it is cut gently and slowly into squares of about an inch; and after standing, to allow the whey to gather, it is again cut at this time into larger pieces than before, and slowly at first. This cutting is gradually quickened, the incisions being made nearer to each other. The lumps of curd are lifted with the skimming spoon in one hand, and cut with a knife in the other hand, while suspended. The curd is now allowed to settle about a quarter of an hour, when the whey is taken from it by being poured through a fine hair sieve, the dairymaid at the same time cutting the curd, so that all the whey may escape. The curd is then pressed down with the hand into vats, covered with large cheese-cloths of fine canvas, and placed in the press for half an hour. It is then put into a mill, which crumbles it to small pieces, thus saving the labour of squeezing and rubbing with the hands—an operation which is thought to be a great improvement in the manufacture of cheese.

The whey is next completely extracted, and the curd put as compactly as possible into the vat, heaped above the vat just so far that it can be pressed down to a level with the edge. A cheese-cloth is then spread over the vat, and a little hot water thrown over the cloth, which has a tendency to harden the outside of the cheese, and prevent it from cracking. The curd is next turned out of the vat into the cloth, and the inside of the vat being washed in whey, the inverted curd with the cloth is returned to the vat. The cloth is then folded over, and the vat put into the press for two hours, when it is taken out, and dry cloths applied through the course of the day. It is then replaced in the press until salted, which is generally performed about twenty-four hours after it is made. In salting, the cheese is rubbed with finely-powdered salt; and this is thought to make the cheese smoother and more solid than when the salting process is performed upon the curd. The cheese is after this returned to the vat, and put under the press, in which more than one are placed, the newest one at the bottom, and the oldest on the top. The salting is repeated three times, twenty-four hours being allowed to intervene between each; and the cheese is finally taken from the press to the cheese-room in the course of five days. In the cheese-room it is turned over every day for a month, when it is cleaned of all scurf, and rubbed over with a woollen cloth, dipped in a paint made of Indian red or Spanish brown and small beer. As soon as the paint is dry, the cheese is rubbed once a week with a cloth. The quantity of salt employed is about three and a half pounds; and one pound of annato is sufficient to colour half a ton of cheese.

'There is nothing very peculiar in all this process,' says a standard authority, 'except the more than usually slight agitation of the milk before it is set with the rennet, and the great care with regard to the degree of temperature. Something perhaps may be attributed to a less degree of squeezing with the hand in bruising the curd, when a great deal of the fatty matter of the cheese may be pressed out, the knife being more used than the hand in dividing it. The principal characteristics of the Gloucester cheese are its richness, and its smooth and oily texture, instead of breaking when cut, and its retaining fatty matter so perfectly in the operation of toasting.

The "single Gloucester" is the skim-milk cheese; the "double Gloucester," or "best making" cheese, is manufactured from the pure or unskimmed milk; although it is not unusual in a large dairy to set aside sufficient milk to afford cream and butter enough for the family, and afterwards to add it to the next day's milking. These are sometimes called "coward" cheeses; they are either thin, weighing about 16 lbs. per cheese, or thick, averaging from 30 lbs. to 40 lbs. The best "single Gloucester" is either the "two-meal cheese," made of equal portions of unskimmed and skimmed milk, or sometimes two portions of skimmed milk and one part of pure or "coward" milk. The inferior cheese, acknowledged to be the skim-cheese, is what its name imports it to be; and the dairymaid usually skims it often enough before she is allowed to convert it into curd.'

Stilton cheese is made by putting the night's cream, without any portion of skimmed milk, into the next morning's milk; but those who wish to make it very fine, add still more cream; and thus its richness depends upon the quantity of cream made use of. Butter is also said sometimes to be used in its manufacture. The rennet is then added without any colouring; and when the curd has formed, it is taken out without being broken, and put whole into a sieve or drainer. In the drainer it is pressed with weights until all the whey is extracted, and when dry, put into a hooped chessel. The outer coat being salted, it is then put into the press, and when sufficiently firm, it is taken out of the chessel, and bound tightly in a cloth. This cloth is changed every day until the cheese is quite dry, when it is removed; and the cheese requires no further care except occasional brushing and turning. The Stilton cheeses, although small—not weighing more than twelve pounds—require two years to bring them to full maturity.

Parmesan cheese is manufactured in that part of Italy which lies between Cremona and Lodi, comprising the richest portion of the Milanese territory. The cows are kept in the house nearly all the year round, and fed in summer with cut grass from the rich irrigated meadows of the country. Some of the cheeses are so large as to contain nearly 180 pounds; and the milk of 100 cows is required to produce one of this size. This cheese is made from the milk of the evening, which is skimmed in the morning and at noon, and the milk of the morning, which is also skimmed at noon. These two milks are put together into a large copper caldron, which is hung on the arm of a lever, and can be taken off and put on the fire at pleasure. The milk is heated in this vessel to about 120 degrees, and then removed from the fire, and kept quiet until the internal motion has ceased.

The rennet is then added, and in an hour the curd will have formed, when it is again put on the fire and heated to a temperature of 145 degrees. While heating, the mass is briskly stirred, till the curd separates in small pieces, when part of the whey is run off, and a little saffron added to colour the cheese. When the curd is sufficiently broken, nearly the whole of the whey is taken out, and two pailfuls of cold water are thrown in. The temperature is thus reduced so far as to allow the dairymen to collect the curd, by passing a cloth under it and gathering up the corners. It is now pressed into a frame of wood, placed on a solid platform, with a heavy weight on the top. In the course of the night the curd cools, parts with the whey, and assumes a firm consistence. The next day one side is rubbed with salt, and the succeeding day the cheese is turned, and the other side rubbed in the same manner, this alternate salting being continued for forty days. After this, the outer surface of the cheese is pared off, the fresh surface rubbed with linseed oil, the convex side is coloured red, and the cheese is fit for sale.

It appears that this highly-esteemed cheese is altogether made from skimmed milk, and yet all the pores are filled with an oily substance. This seems too rich to be imparted by the butteraceous matter of milk which has been deprived of its cream, and it is generally supposed that some portion of oil is mixed with the curd. This, however, has not been ascertained to be the case.*

Swiss Cheese.—The finest cheese made in Switzerland is that of Gruyere, in the canton of Friburg. It is rich in quality, and generally flavoured with a powdered dry herb, the *Melilotus officinalis*. The cheeses weigh from forty to sixty pounds each, and are exported in large quantities. Mr Laing, in his work, 'Notes of a Traveller,' thus alludes to the primitive dairy operations of the small pastoral farmers in Switzerland:—'Each parish has its *alp*—that is, its common pasture for the cows of the parish—and each inhabitant is entitled to a cow's grazing, from June to October, on this common pasture. Few, however, have cows in sufficient number to repay the labour of attending them at the summer grazing in the alps. The properties are too small, in general, to keep more than five or six cows all winter; and few can keep more than three. Yet these small proprietors contrive to send cheeses to market as large as our Cheshire dairy farmers with their dairy stocks of forty or fifty cows; and, as the price of Gruyere cheeses shows, incomparably better in quality.

Each parish in Switzerland hires a man, generally

* For our information upon the manufacture of cheese in the English counties, we have been indebted to the British Husbandry and the different county reports; and for the account of the Parmesan cheese, principally to the Journal de Physique.

from the district of Gruyere, in the canton of Friburg, to take care of the herd, and make the cheese; and if this important functionary should really come from Gruyere, all that he makes is called Gruyere cheese, although made far enough from Gruyere. One cheese-man, one pressman or assistant, and one cow-herd, are considered necessary for every forty cows. The owners of the cows get credit, each of them, in a book daily, for the quantity of milk given by each cow. The cheeseman and his assistants milk the cows, put the milk together, and make cheese of it; and at the end of the season each owner receives the weight of cheese proportionable to the quantity of milk his cows have delivered. By this co-operative plan, instead of the small-sized, unmarketable cheeses only, which each could produce out of his three or four cows' milk, he has the same weight in large marketable cheese superior in quality, because made by people who attend to no other business. The cheeseman and his assistants are paid so much per head of the cows, in money or in cheese, or sometimes they hire the cows, and pay the owners in money or cheese.

In October, the cows are brought home, and the home grass-lands having been mown for hay twice during the summer, the winter food is provided; and a very small area of land keeps a cow, when the home grass has not been burdened with the summer grazing. The pasture in these alps, or summer grazings, is abundant and rich. In some of the upper valleys, inhabited winter as well as summer, but in which the corn crops are secondary, and dairy produce the main object—as, for instance, Grindewalde—a man with a house suitably situated is permanently established for receiving the milk of the neighbourhood. Each family takes care of and milks its own cow or cows, keeps the milk wanted for family use, and sends the rest of it daily to the cheeseman, who gives each family credit for the milk delivered each day; and the cheese made during the season is divided, or very usually the cheese is marketed, and the money divided; and in this way cheeses of great weight are manufactured, although no one cow-owner possesses milk sufficient to make one of marketable size.

I went one warm forenoon, while ascending the Rhigi, into one of these conjoint dairy houses. From the want of dairymaids or females about the place, and the appearance of the cow-man and his boys, I thought it prudent to sit down on the bench outside of the smoky dwelling-room, and to ask for a bowl of milk there. It was brought me in a remarkably clean wooden bowl, and I had some curiosity, when, clean or dirty, my milk was swallowed, to see where it came from. The man took me to a separate wooden building; and instead of the disgusting dirt and sluttishness I had expected, I found the most unpretending cleanliness in this rough milk-room; nothing was in it but the wooden vessels belonging to the dairy, but these were of unexceptionable nicety; and all those holding the milk were standing in a broad rill of water led from the neighbouring burn, and rippling through the centre of the room, and prevented, by a little sluice, from running too full, and mingling with the milk. This burn running through gave a freshness and cleanliness to every article; although the whole was of rude construction, and evidently for use, not show. The cows were stabled, I found, at some distance from the milk-house, that the effluvia of their breath and dung might not taint the milk. Cheese is almost the only agricultural product of Switzerland that is exported; and it is manufactured by these small farmers certainly as well, and with as much intelligence, cleanliness, and advantage, as by large farmers.'

Whey.

Whey, or the thin watery serum of milk, is of a pale-greenish hue, and saline in taste, and forms an agreeable beverage when cool. Some dairy farmers in England are in the habit of extracting a little butter from it; but with careful management, this practice would be quite unnecessary, as it is only when the milk has been coagulated too hot that any quantity of butter will remain in this liquid. In Scotland, the whey is used as food by the farmers and their families in making oatmeal porridge; and a saving of nearly one-third of meal is effected when the porridge is made of whey instead of water. By boiling, what is called float-whey is obtained, which, when mixed with a little sweet milk, is thought little inferior to curd. Whey is also very valuable in feeding swine; and it is estimated that the whey of three or four cows will, in the course of one season, with little additional solid food, fatten a pig to the weight of twelve or fourteen stones.

LONDON DAIRY MANAGEMENT.

The quantity of fresh milk annually consumed in the British metropolis was lately calculated to be 39,420,000 quarts, costing £985,500, and being the produce of 12,000 cows, kept principally in large dairy establishments in all parts of the environs. The milk is generally of the best kind when drawn from the animals; but, between the dairy and the consumer, it passes through several hands, each of whom takes a profit upon it, and increases the quantity of saleable liquid by large infusions of water, chalk, &c. In the condition it usually reaches the public, it is shamefully adulterated—a fraud which could be readily checked, were the police empowered to employ Donné's or some other kind of *lactometer*, and to seize every quart found beneath the standard indication. The charge of deteriorating the quality of the article is seldom made, however, upon the cow-keepers, whose establishments are, for the most part, models of good management. As it may be interesting to our readers to have some account of these large dairies, we present the following particulars:—

The two largest dairy establishments are those of Mr Flight (known as Layrock's dairy) and of the representatives of the late Mr Rhodes. Flight's is one of the curiosities of London; it covers fourteen acres of ground, surrounded by a high wall, and including buildings for the different purposes required. In the cow-house there are upwards of 400 cows, the whole of which are fed in stalls. The food is very properly varied: at one time they have mangel-wurzel; then they have turnips, carrots, cabbages, and clover; and when fattening for market, they are fed on oil-cake and other articles. All are curried daily. Adjoining the cow-house is an hospital for unwell cows, or cows which are calving. The milk-house is kept beautifully clean, being scoured daily with hot water.

With respect to Rhodes' dairy, which is situated at Islington, Mr Loudon, in his 'Encyclopædia of Agriculture,' has condensed the following description of its extent and mode of management from various sources:—'The number of cows kept exceeds, on an average of the year, 400: at one time these individuals are said to have had upwards of 1000 cows in their different establishments. The surface on which the buildings are placed is a slope of two or three acres, facing the east; and its inclination is about one inch in six feet. The sheds run in the direction of the slope; as well for the natural drainage of the gutters, and the more easily scraping, sweeping, and wheeling out of the manure, as for supplying water for drinking to small cast-iron troughs, which are fixed in the walls, at the heads of the cattle, in such a manner as that the one trough may be supplied from the other throughout the whole length of the shed. The sheds are twenty-four feet wide; the side walls about eight feet high; the roof of tiles, with rising shutters for ventilation, and with panes of glass, glazed into cast-iron skeleton tiles, for light. The floor is nearly flat, with a gutter along the centre; and a row of stalls, each seven and a half feet wide, and adapted for two cows, runs along the sides. The cows are fastened by chains and rings, which rings run on upright iron rods, in the corners of the stalls; the common mode being departed from only in having iron rods instead of wooden posts. A trough or manger, formed of stone, slate, or cement, of the ordinary size of those used for horses, and with its upper surface about eighteen inches from the ground, is fixed at the head of each stall. Four sheds are placed parallel and close to each other, and in the party walls are openings, about a foot in breadth and four feet high, opposite each cow. The bottom of these openings is about nine inches higher than the upper surface of the troughs, and is formed by the upper surface of the one-foot-square cast-iron cisterns, which contain the water for drinking. Each cistern serves two cows, which of course are in different sheds, but adjoining and opposite each other. All these troughs are supplied from one large cistern by pipes, in a manner which can be so readily conceived that we shall not stop to offer a description. Each of these troughs has a wooden cover, which is put on during the time the cows are eating their grains, to prevent their drinking at the same time, and also from dropping grains in the water.

At the upper end, and at one corner of this quadruple range of sheds, is the dairy, which consists of three rooms, of about twelve feet square: the outer or measuring-room; the middle or scalding-room, with a fireplace and a boiler; and the inner or milk-and-butter-room, separated by a passage from the last. At the lower end of the range is a square yard, surrounded by sheds; one for fattening the cows when they have ceased to give milk, and the others for store and breeding pigs. The pigs are kept for the purpose of consuming the casual stock of skim milk which occasionally remains on hand, owing to the fluctuations in the demand. This milk is kept in a well, walled with brick laid in cement, about six feet in diameter, and twelve feet deep. The milk becomes sour there in a very short time; and, as is well known, is found most nourishing to the pigs when given in that state. Breeding swine are found most profitable, the sucking pigs being sold for roasting. Beyond this yard is a deep and wide pit or pond, into which the dung is emptied from a platform of boards projecting into it. The only remaining building wanted to complete the dairy establishment is a house or pit for containing the exhausted malt (grains), on which the cows are chiefly fed. Messrs Rhodes have a building or pit of this description at some distance, where they have a smaller establishment. There are a stackyard, sheds, and pits for roots, straw, and hay; a place for cutting hay into chaff; cart-sheds, stables, a counting-house, and other buildings and places common to all such establishments, which it is not necessary to describe.

The dairy cows are purchased newly calved in the market held in Islington every Monday. They are kept as long as they continue to give not less than two gallons of milk a day, and are then fattened on oil-cake, grains, and cut clover hay, for the butcher. The short-horned breed is preferred, partly for the usual reason of being more abundant milkers than the long-horns, partly because the shortness of their horns allows them to be placed closer together, and partly because this breed is more frequently brought to market than any other. The Ayrshire breed has been tried to the number of 150 at a time, and highly approved of, as affording a very rich cream, as fattening in a very short time when they have left off giving milk, and as producing a beef which sold much higher than that of the short-horns. The difficulty, however, in procuring this breed was found so great, that Mr Rhodes was obliged to leave it off. The length of time during which a cow, treated as in this establishment, continues to give milk, varies from six months to the almost incredible period of two years. We were assured of there being at this moment several cows among the 330 which we saw, that had stood in their places even more than two years, and continued to give upwards of one gallon of milk daily.

The treatment of the animals differs from that in most other establishments. The cows are never untied during the whole period that they remain in the house. In most other establishments, if not in all, stall-fed cows or cattle are let out at least once a day to drink; but these animals have clear water continually before them. They are kept very clean, and the sheds are so remarkably well ventilated, by means of the openings in the roofs, that the air seemed to us purer than that of any cow-house we had ever before examined; probably from its direct perpendicular entrance through the roof, this, in moderate weather, being certainly far preferable to its horizontal entrance through the side walls.

The principal food of the cows in Rhodes' dairy, as in all the other London establishments, consists of grains; that is, malt after it has been used by the brewer or the distiller. As the brewing seasons are chiefly autumn and spring, a stock of grains is laid in at these seasons sufficient for the rest of the year. The grains are generally laid in pits bottomed and lined with brickwork set in cement, from ten to twenty feet deep, about twelve or sixteen feet wide, and of any convenient length. The grains are firmly trodden down by men, the heaps being finished like hay-ricks, or ridges in which potatoes are laid up for the winter, and covered with from six to nine inches of moist earth or mud, to keep out the rain and frost in winter and the heat in summer. As a cow consumes about a bushel of grains a day, it is easy to calculate the quantity required to be laid in. The grains are warm, smoking, and in a state of fermentation when put in, and they continue fit for use for several years; becoming somewhat sour, but they are, it is said, as much relished by the cows as when fresh. It is common to keep grains two or three years; but in this establishment they have been kept nine years, and found perfectly good. The exclusion of the air almost prevents the increase of the fermentation and consequent decomposition. What is called distiller's wash—which is the remainder after distillation of a decoction of ground malt and meal—is also given to cows, but more frequently to such as are fattening than to those in milk. Salt is given at the rate of two ounces each cow a day. It is mixed with the grains, which are supplied before milking, about three o'clock in the morning; and in the afternoon, about two o'clock, just before milking. Of green food or roots, portions are supplied alternately with the grains; and in winter, when tares or green grass cannot be procured, after the turnips, potatoes, or mangel-wurzel have been eaten, a portion of dry hay is always given.

The produce of this dairy is almost entirely milk and cream, for private families and for public hospitals and other institutions. A number of the public establishments are supplied directly from the dairy by contract; but private families are principally supplied by milk-dealers: these have what are called milk-walks—that is, a certain number of customers, whom they call upon with supplies twice a day; and they are thus enabled to ascertain the average of what their customers consume, and to contract with Messrs Rhodes for this average. The latter calculate the number of cows sufficient to give the dealer the supply wanted, and this number the dealer undertakes to milk twice a day—namely, at three o'clock in the morning, and at three in the afternoon. The milk is measured to the dealer, and should he have milked more than his quantity, it remains with the dairyman; but should the cows have been deficient in the quantity, it is made good from the milk of other cows, milked on account of the contracts of the establishment. As the supply of the cows and the demand of the dealers are continually varying, it often happens that considerable quantities of milk remain on the dairyman's hands, frequently, we are told, as much as sixty or seventy gallons a day. This quantity is placed in shallow earthen vessels, to throw up the cream in the usual manner: this cream is churned, and the butter sold. The skimmed milk, as well as the buttermilk, are, as is usual in English dairies, given to the pigs.

THE SHEEP—GOAT—ALPACA.

In the *Ruminant* order of the Mammalia, a distinguished place is given to the sheep, the flesh and wool of which have been recognised as alike of the greatest use to man from the earliest ages. In our own country, within the last half century, the different breeds have been improved by the growing intelligence, skill, and industry of the farmers; and their management has, under high patronage, been brought to a degree of perfection perhaps nowhere else attained. It may be added that, as the sciences of anatomy, physiology, botany, and chemistry are every year throwing new light on those laws of nature which regulate the structure, health, nutrition, and reproduction of the Animal Kingdom, we may entertain the hope of still further improvement in this department of rural economy.

BREEDS OR VARIETIES OF THE SHEEP.

The numerous varieties of sheep that now exist in different parts of the globe, have all been reduced by Cuvier into four distinct species:—1. (*Ovis Ammon*)—the Argali; this species is remarkable for its soft reddish hair, a short tail, and a mane under its neck. It inhabits the rocky districts of Barbary and the more elevated parts of Egypt. 2. (*Ovis tragelaphus*)—the bearded sheep of Africa. 3. (*Ovis musmon*)—the Musmon of Southern Europe. 4. (*Ovis montana*)—the Mouflon of America; but this species, which inhabits the Rocky Mountains of North America, is now believed to be identical with the Argali, which frequents the mountains of Central Asia, and the higher plains of Siberia northwards to Kamtchatka. This leaves only three distinct species of wild sheep as yet discovered.

It is still a point in dispute from which of these races our domestic sheep have been derived; nor is the question of great practical importance, though its solution is very desirable in a physiological point of view. Whether the wild races may be regarded as of one species, as some naturalists contend, or of different species, according to others, the best judges are next to unanimous that the domestic races of this country are of one species; and what are called different breeds are nothing more than varieties, the result of different culture, food, and climate. The influence of these conditions, in diversifying the character and condition of sheep, will be adverted to under their proper heads. The following may be regarded as the principal breeds reared in this country:—

1. *The Shetland sheep*, inhabiting those islands from which they derive their name, and extending to the Faroe Islands and the Hebrides. In general, they have no horns. The finest fabrics are made of their wool, which resembles a fine fur. This wool is mixed with a species of coarse hair, which forms a covering for the animal when the fleece proper falls off. A similar variety is known to inhabit the most northerly parts of Europe, from which it is supposed the fine-wooled sheep of our northern islands and Highlands have been derived. They are hardy in constitution, and well adapted to the soil and scanty pastures on which they are reared, but would ill repay their cultivation in Lowland districts.

2. *The Dun-wooled breed*, the colour of which is not confined to the wool, but extends to the face and legs. They seem at one time to have been cultivated very extensively, and remnants of them still exist in Scotland, Wales, and the Isle of Man.

3. *The Black-faced heath breed*, which, being the most hardy and active of all our sheep, are the proper inhabitants of every country abounding in elevated heathy mountains. They have spiral horns, their legs and faces are black, with a short, firm, and compact body; their wool is coarse, weighing from 3 to 4 lbs. per fleece; they fatten readily on good pastures, and yield the most delicious mutton, weighing from 10 to 16 lbs. per quarter. They still exist in considerable numbers in the more elevated mountains of Yorkshire, Cumberland, Westmoreland, Argyleshire, and the central Highlands of Scotland.

4. *The Moorland sheep of Devonshire*—sometimes termed the Exmoor and Dartmoor, from the different districts of Devonshire in which they are reared—have horns, with legs and faces white, wool long, with a hardy constitution, and are said to be well adapted to the wet lands which they occupy. Their wool weighs about 4 lbs. the fleece; but they are rather small, and in some respects ill-formed.

5. *The Cheviot breed*, deriving their name from the Cheviot mountains, in which they are said to be indigenous, are longer and heavier than the black-faced. Their wool is fine; a medium fleece weighs about 3 lbs.; a carcase, when fat, weighs from 12 to 18 lbs. per quarter. Their faces are white; their legs are long, clean, and small boned, and clad with wool to the hough. Their only defect of form is a want of depth in the chest; yet, with this exception, their size, general shape, hardy constitution, and fine wool, are a combination of qualities in which, as a breed for mountain pasturage, they are yet unrivalled in this country.

6. *The Horned varieties of fine-wooled sheep of Norfolk, Wiltshire, and Dorset.*—The members of this breed have short wool, in which they differ from the black-faced sheep and moorland sheep of Devonshire, and from the Cheviot, in having large spiral horns. They are not much lighter than the Cheviots, but they are ill formed, and thin, flat in the ribs, and slow feeders; a medium fleece weighs about 2 lbs. It is believed that the South-down will eventually displace them. The Wiltshire sheep are still heavier than those of Norfolk, being the largest of our fine-wooled sheep; they are said to thrive well in the downs of Wiltshire, but are also giving ground to the South-downs. The Dorset sheep have horns, white faces and legs; their three-year-old wethers weigh from 16 to 20 lbs. per quarter; their wool is less fine, but heavier than that of Wiltshire, weighing from 3 to 4 lbs. the fleece. One of the peculiar advantages of this breed is, the ewes admit the ram at so early a period that they generally have lambs in the months of September and October—a stock which finds a ready market in large towns for winter consumption.

7. *The Ryeland breed*, deriving their name from a southern district in Hertfordshire, which at one time was regarded as incapable of growing anything but rye. The members of this variety are white-faced, and without horns; their general form is tolerable; they fall short of the improved breeds, in being more flat in the ribs, and less level in the back; their wool is fine, weighing from 1½ to 2 lbs.; their mutton is delicate; they arrive soon at maturity, and fatten easily, and weigh from 12 to 16 lbs. per quarter: this breed has been crossed by the Spanish Merino. The offspring of this cross were at one time in high fame in England, under the name of the Anglo-Merino; and though their wool is said to have been of a fine quality, the breed has for long declined in popular favour.

8. *The South-down breed.*—The members of this section have no horns; their legs and faces gray. They have fine wool, which is from two to three inches in length, and weighs from 2½ to 3 lbs. per fleece; they are slightly deficient in depth and breadth of the chest, but their mutton is excellent, and highly flavoured; they are kindly feeders, and when fat, their average weight may be stated at from 15 to 18 lbs. per quarter. They have, from time immemorial, been reared upon

the chalky soils of Sussex, but are now widely extended, and thrive excellently not only on the chalk downs and light soils of England, but on the sheltered lawns of Scotland. In a note to the author from Lord Pitmilly, near St Andrews, are the following facts:—'I generally keep about a score of South-down ewes for early lambs; they pasture in the lawn with the black-faced wethers kept for family use. The lambs dropped early in winter 1839–40 not being wanted, were sent to Edinburgh; ten of the ewes lambed again in September 1840, and again in March 1841. Some of them had twin lambs; all did well. The September lambs I sold in August 1841, when eleven months old, at 30s. a-piece. I ascribe the fact of the ewes thriving so well to the dry ground, and to their being put every night, summer and winter, into a shed, and well bedded; they have no extra food, except at lambing time, when they get a little oil-cake or sliced turnip.' The above facts are highly deserving the attention of breeders of this variety of sheep, testifying as they do to the greatest degree of fecundity of which we have yet any authentic account.

9. *The Merino breed*, which is supposed to have been originally from Africa. Marcus Columella saw a variety from that country at some of the games exhibited at Rome. He procured some of them for his own farm, crossed them with the breeds of Tarentum, and sent the offspring of this cross to Spain. In Spain they soon rose to such perfection and celebrity, that they attracted the attention of breeders of stock in other nations, and this breed may now be found in every part of the globe. They were imported into England for the first time in 1788. The Ryeland and other fine-wooled breeds of England were crossed by Merino rams in 1792. The Merino breed of rams were cultivated with great care by George III. The sales of his majesty's stock, which commenced in the year 1804, attracted such general attention in England that a society was formed for promoting the breed in 1811; but the high expectations which were formed of the result of this cross with native sheep were far from being realised. The quality of the wool of the native sheep was improved, but the increased value of the fleece was an inadequate compensation for defects in the character of the animals themselves, which proved less hardy than the parent stock, were slow feeders, and very defective in form.

The Merinos that have been naturalised in this country retain their natural character, except that they become larger in the carcass, and the wool longer and heavier, than in Spain; but the Merino, as a feeding animal, is too small and ill-formed, and the mutton deficient both in quantity and quality. These points have given rise to some controversy; but in the forcible language of Professor Lowe—'It is vain that some breeders still contend for the superiority of the pure Merino; the general judgment of farmers is against them, and with perfect reason.'

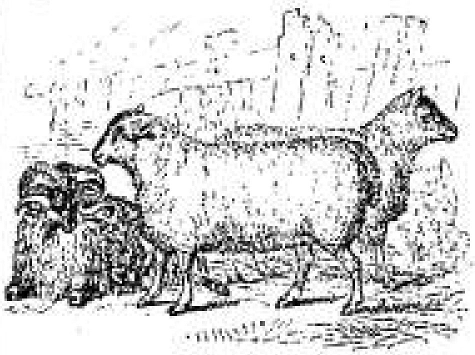
The Merino sheep are cultivated in Spain and Germany with a greater regard to the wool than to the weight and value of the animal; but the farmers in England think it more profitable to raise the weight and value of the mutton, and it is believed, by those well qualified to judge, that the best Merinos under the more rigorous climate of Britain would never yield mutton equal in quality to that of Spain. The wool of this breed is finer than that of any other sheep. In Spain, the fleece of the ram weighs 8 lbs., and that of the ewe 5 lbs.; but this wool having such a large quantity of yolk, which absorbs every kind of impurity with which it comes in contact, it loses three-fifths of its weight by being properly washed. In Australia, whither Merinos have been imported, the breed has not only improved in size and weight, but the wool produced is quite equal to the finest sorts of Europe—the result of a mild and equable climate, and not ungenerous pasture.

10. *The Devonshire Notts, Romney Marsh, Old Lincolnshire, Teeswater, and Old Leicester sheep.*—The Devonshire Notts consist of two varieties: the one is called the Dun-faced Notts, from the colour of the face; this is a coarse animal, with flat ribs and crooked back, but it yields a fleece weighing 10 lbs., and when fat, weighs 22 lbs. per quarter when only thirty months old. The second variety is called the Bampton Notts; it resembles the former in many respects, but is easier fed, yields less wool, and has a white face and legs.

The Romney Marsh breeds are very large animals, with white faces and legs, and yield a heavy fleece, the quality good of its kind. Their general structure is defective, the chest being narrow, and the extremities coarse. The result of their being crossed by the New Leicester is still a point in dispute—one party alleging, that though the quantity of wool has been lessened, and the size of the animal diminished by the cross, yet the tendency to fatten and their general form have been much improved. On the other hand, some well-informed breeders contend, that besides the loss of the quantity and quality of the wool, the constitution of the animal is rendered less fitted to the cold and marshy pastures on which it feeds.

The Old Lincolnshire breed are large, coarse, ill-shaped, slow feeders, and yield indifferent mutton, but a fleece of very heavy long wool. The Teeswater breed were originally derived from the preceding, and pastured on the rich lands in the valley of the Tees, from which they derive their name; but Professor Low remarks, that 'it is entirely changed by crossing with the Dishly breed, and that the old unimproved race of the Tees is now scarcely to be found.' They are very large, and attain a greater weight than almost any other breed—the two-year-old wethers weighing from 25 to 30 lbs. per quarter, and yielding a long and heavy fleece.

The Old Leicester is a variety of the coarse long-wooled breeds. On rich pastures they feed to a great weight; but being regarded as slow feeders, their general character has either been changed by crossing, or altogether abandoned for more improved varieties.



Black-faced—Leicester—South-down.

11. *The New Leicester and Improved Teeswater breeds.*—Mr Bakewell of Dishly, in the county of Leicester, has the honour of forming this most important breed of sheep. He turned his attention to improving the form of feeding animals about the year 1755. The exact method he followed in forming his breed of sheep is not accurately known, as he is said to have observed a prudent reserve on the subject. But we now know that there is but one way of correcting the defective form of an animal—namely, by breeding for a course of years from animals of the most perfect form, till the defects are removed, and the properties sought for obtained. The great properties of the New Leicester for the farmer, are their early maturity and disposition to fatten, in which they excel all other breeds. They are less in size than several other breeds, and their wool is deemed inferior to the Cheviot; but they are now reared with great success in almost every part of England and in the colonies of Australia, whither they and the South-downs were early imported.

That class of sheep now known by the name of the

Improved Teeswater, is derived from the old breed. Its improvement has been chiefly effected by crossing with the New Leicester. They are not so large as the older race, but are still the largest of our improved breeds; productive in lambs, and yield a good fleece; yet their form renders them less fitted for general cultivation than the New Leicester.

CHOICE OF BREEDS.

If the farmer has rendered himself master of the constitution and character of the different breeds of domestic sheep, already given, and with the general and peculiar character of the climate, soil, and pasturage of the locality on which he is to settle, the selection of the breed that will, upon the whole, yield him the highest profit, will not be a matter of very difficult calculation. But should an error be committed on this head in the first trial, very slight experience would enable a practical farmer to correct it, unless he belong to that class of persons—unfortunately too numerous—to whom the lessons of history and experience convey neither knowledge nor correction.

The breeds best adapted to the soil and climate of the different districts of Great Britain, are arranged by Professor Low in the following manner:—1st. The sheep of the mountains, lower moors, and downs; and 2d. The sheep of the plains. The sheep of the first class have sometimes horns, and sometimes want them. The finest of them have no horns—namely, the Cheviot and South-down. One of them, the black-faced heath breed, has coarse wool; another of them, the Moorland sheep of Devonshire, has long but not coarse wool; and all the others have short and fine wool.

Of the moorland and down breeds, as they may be called, the hardiest is the black-faced heath breed; and this property points it out as the most suitable for a high and rugged country, where artificial food cannot be procured. The breed next to this in hardy properties, but surpassing it in the weight of the individuals, is the Cheviot. Where the pasture contains a sufficiency of grasses, this breed deserves the preference over any other known to us for a mountainous country. The next breed deserving of cultivation is the South-down. This breed is suited to the chalky and sandy downs of the south of England. It is in this respect a very valuable breed, but it is unsuited to the more rough and elevated pastures to which the black-faced and Cheviot are naturally adapted.

The moorland and down breeds appear to be the most deserving of cultivation in this country. Of the larger breeds of the plains, the New Leicester is the best adapted to general cultivation, and wherever an improved system of tillage is established, this admirable breed may be introduced. The Leicester, the Cheviot, and the black-faced, have for long been regarded as the breeds best adapted for the different districts of Scotland. That these three breeds have nearly stood in the same numerical ratio to one another for some years, is a good proof that each has been placed in that locality best fitted by nature for promoting its health and productiveness. The Leicester is admirably adapted to the rich alluvial soils of our cultivated plains; the Cheviot breed is peculiarly fitted for the grassy mountains chiefly formed of the transition series of rocks; then our most elevated mountain ranges are formed mainly of primitive rocks, and covered with coarse herbage and heath, on which none but the black-faced, the most active and hardy of our breeds, could survive.

The above arrangements have generally been acquiesced in as the best possible by the farmers of Scotland. But the claims of South-downs for the middle range of the Highland pastures in Scotland have been urged, in the following terms, by an agriculturist of long experience and high standing in his profession—namely, Mr Watson of Keillor:—"Having, during the last twenty-five years, been in the management or possession of a considerable breeding flock of South-down ewes, varying at different times from 500 to 1000 in number, and during that period having had good opportunities of drawing close comparisons betwixt that and the other breeds of mountain sheep—namely, the Cheviot and black-faced—I have come to the conclusion (and am acting upon it in my own practice), that from a pasture ranging from 500 to 1200 feet above the level of the sea, having a moderate portion of green sward, the rest whin and heather, there can be no more profitable stock of sheep kept than a flock of South-downs of the best sort. My chief reasons for having preferred this breed are, that the South-down sheep, although naturally spirited and active, are easily controlled by a good shepherd; can go over more ground for their food than any other kind of sheep, without stopping their growth; and when tried by severe storms in winter, will brave it better than even the black-faced Highland sheep; and although reduced very low in spring, sooner pick up condition than the other short-wooled sheep. As a proof of the South-downs' tendency to fatten, when put to good keep, I may mention a fact, that while I have seldom been able to produce a fat Cheviot ewe the same season that she has reared a lamb, I never fail to make good fat of the cast South-downs off grass. Their wool is so closely matted on their backs, and about the head and neck, as to be almost impervious to rain or snow; hence so soon as the storm ceases, they appear dry and comfortable, their coat not the least disordered, and altogether free from that *droukit* (Anglice, drenched) appearance which longer-wooled sheep exhibit even for days after a winter storm.

In all my experience, the South-down sheep have kept remarkably healthy. I have never seen an instance of rot in my flock; while, during the last twenty years, I have been forced to clear off a lot of Cheviot and also of black-faced ewes from that incurable disease. This, however, may have been owing more to the unsoundness of the pasture from which I got them, than from any peculiarity of the animals themselves. My average loss in the South-down lot has invariably been much under that of any other sheep I have bred. They are hardy, and easily managed at lambing-time; affectionate mothers, and, on moderate keep, give a great quantity of milk; and if there is any inducement for early lambs, they will go with the ram almost as soon as the lamb is weaned. When crossed with a well-bred Leicester ram, and brought into good keep, they produce perhaps the most profitable lamb that is bred, taking wool and carcass into account. I have for the last ten years put all the ewes I could spare from pure breeding to this sort of crossing, lambing the ewes on turnips in spring, then turning them, as soon as the season would permit, to the hill pasture (the Sidlaws) till weaning-time, when the lambs are brought to the in-field pastures, and put to turnips for the winter, on which food they are kept for about 2d. per week each, and kept on the earliest grass in spring; so that in a month or six weeks after they are clipped, they are fit for the butcher, who values this cross almost as high as the pure-bred South-down. The wool is of the finest quality for combing, and fetches the highest price of any British-grown wool—generally from 2s. to 2s. 2d. per lb.; and the clip in a good season will average about 6 lbs. At sixteen months old, I have never realised less than 40s. each, wool and mutton. In Smithfield this cross is much sought after.

On lands where folding is found necessary, the South-down submits to this treatment better than any other breed of sheep; such, indeed, in all cases where I have put them to the test, is their spirit and hardiness, that nothing short of ill-treatment seems to injure them. Combining these facts, I can have no hesitation in recommending a South-down flock of sheep in preference to every other, on such situations as I have now described—namely, too high to be occupied during the whole season by a flock of Leicesters, and under that level above which only the native black-faced breed can be expected to thrive.

So far as I know, it is not yet sufficiently ascertained by experience how far a cross betwixt the South-down and Leicester may be carried, so as to keep up the activity of the former with the well-known fattening qualities of the latter. Another train of breeding through the black-faced and South-down sheep, whose habits seem so much akin, seems likely to succeed. By this cross, improvement in quality of wool would be gained, while that of the mutton would not be deteriorated.' On the other side, Professor Low remarks—'The South-down breed is best suited to the chalky and sandy downs of the south of England. It is in this respect a very valuable breed; but it is unsuited to the more rough and elevated pastures to which the black-faced and Cheviot are adapted.'

In Ireland, the breed of sheep has been much improved since the beginning of the present century. About that time, Mr Cully attended the celebrated fair at Ballinasloe, and thus describes the Irish sheep of that period:—'I am sorry to say I never saw such ugly sheep as I saw there. The worst breeds we have in Great Britain are much superior. One would almost imagine that the sheep breeders in Ireland have taken as much pains to breed awkward sheep, as many of the people in England have taken to breed handsome ones. I know nothing to recommend them except their size, which might please some old-fashioned breeders, who can get no kind of stock large enough. But I will endeavour to describe them, and leave my readers to judge for themselves. These sheep are supported by very long, thick, crooked gray legs; their heads long and ugly, with large flagging ears; gray faces, and eyes sunk; necks long, and set on behind the shoulders; breast narrow and short; hollow both before and behind the shoulders; flat-sided, with high narrow herring backs; hind-quarters drooping, and tail set low. In short, they are almost in every respect contrary to what a well-formed sheep should be.' But an immense improvement was soon effected by Mr St George, and Mr Astley of Odston, who imported a valuable selection from the flocks of the best breeders of the new Leicesters; and by carefully breeding from these, their sheep soon obtained a degree of perfection little inferior to those of England. They soon began to let their tups at very high prices. They let thirty rams in 1800 at £1744. One of them was to have been 150 guineas. Mr Cassan, near Tipperary, was the person who had hired this famous animal, and had the misfortune of having him murdered the night after he had arrived at his farm, by some malignant opposer of the new breed.

The Irish sheep, since the introduction of the improved breeds, are now able to compete in the markets with the English breeders. There is no entry in the books of the Custom-house of sheep exported from Ireland farther back than the year 1797, and in that year there is an entry of 1875. The number had increased in 1811 to 26,029; and the sheep exported from Ireland to Liverpool in 1831 was 134,762; and in 1832 amounted to 44,260; and, in addition to this immense number of sheep, 20,000 lambs, in good market condition, annually cross the Irish Channel. And at the Fair of Ballinasloe, the number of sheep exhibited range from 80,000 to nearly 100,000. The most valuable sheep husbandry in Ireland exists at present in Roscommon, Galway, Clare, Limerick, and Tipperary. But with all this advance, there is much still to be done in the management of sheep in Ireland. The soil and climate are in many places peculiarly adapted for sheep husbandry. And from the progress Ireland has made within the last forty years, there need be no misgivings regarding her future eminence in sheep husbandry. Could the native talents and energies of Ireland be directed to the cultivation of the soil, arts, and commerce, instead of being perverted and enfeebled by fierce and feverish political agitation, from the genius of her people, the richness of the soil, the mildness of the climate, her geographical position, the number of her ports and harbours, the facilities for inland navigation, she might soon rival in wealth and civilisation the most favoured nation of Europe.

IMPROVEMENT OF BREEDS.

The first point of essential importance to be attended to by the sheep farmer is the selection of a breed whose size and constitutional qualities best accord with the climate and the pastures on which they are to feed. An error of any magnitude in these respects would be attended with fatal effects both on the health and productiveness of the flock, and thus ruin the finances of the farmer.

It is true that sheep can exist in almost every country, and may be said to reach nearly from the equator to the poles. They are found approaching the eternal snows and icy barriers of the arctic regions; they are found at great elevations in the Cordilleras of South America, and in the still more elevated Himalaya Mountains of Asia. Yet though sheep can be reared within an immense range of latitude and temperature, it is equally true that the climate and soil fix the limits within which our domestic breeds can be cultivated with advantage. Climatic influences wear down the rocks, and thus forms the soil; hence the natural pastures of all countries.

The climate, and the condition of existence which it induces, affect, with irresistible force, the structure, health, and reproductiveness of men and animals from the equator to the poles. The laws of nature cannot be transgressed with impunity. But this condition being accurately adjusted, the next objects which the sheep farmer ought to keep steadily in view are the quantity and quality of the mutton and the wool. Nature has perhaps forbidden that the same sheep should, in any circumstances, yield the greatest weight of the best mutton, and a fleece of the greatest value. The farmer will be able easily to determine, from the country, climate, and various other considerations, to which of these he should direct his chief attention. In England, for example, the farmer finds it more profitable to promote the weight and quality of the mutton than the wool; while the farmer in Spain, Germany, and Australia, finds it his interest to attend more to the wool than the mutton.

The properties most desirable in the sheep are—1. Size; 2. Form; 3. Early maturity; 4. Constitutional hardiness; 5. Productiveness; 6. Disposition to fatten; and 7. Lightness of offal.

1. The size of the sheep must be regulated by the climate, the pasture, and the steepness or levelness of the lands on which it is to feed. One rule never to be violated is, that the size of the sheep should bear some reference to the nature of the pasture: and very heavy sheep are unsuited to very elevated and precipitous mountain ranges. On this subject, a practical question of very considerable importance is still undetermined, and that is, what is the ratio of food consumed by a large animal and one of moderate size. The result of an experiment is given by Dr Parry, where it is stated, that by breeding small sheep instead of large ones, the numbers were increased from 660 to 890 ewes and lambs, and the profit from £450 to above £724. But this experiment, and all others that have been tried, have never, in our opinion, contained all the elements necessary to determine the question with anything like philosophical accuracy.

2. The *form* of the sheep should consist of that happy combination of anatomical structure on which the health and productiveness of the animal depend; and the points of practical men must be tested by this internal anatomical structure. That eminent surgeon, Mr Cline, in his Communications to the Board of Agriculture, states—'That the lungs of an animal are the first objects to be attended to, for on their size and soundness the health and strength of an animal principally depend; that the external indications of the size of the lungs are the form and size of the chest, and its breadth in particular; that the head should be small, as by this the birth is facilitated, and affords other advantages in feeding, and as it generally indicates that the animal is of a good breed; that the

length of the neck should be in proportion to the size of the animal, that it may collect its food with ease; and that the muscles and tendons should be large, by which the animal is enabled to travel with greater facility; and the bones should be small and clean.'

We may here add a description of the best proportions of a Cheviot ram, by the late Mr Culley of Northumberland:—'His head should be fine and small; his nostrils wide and expanded; his eyes prominent, and rather bold and daring; ears thin; his collar full from the breast and shoulders, but tapering gradually all the way to where the neck and head join, which should be very fine and graceful, being perfectly free from any coarse leather hanging down; the shoulders broad and full, which must at the same time join so easy to the collar forward, and chine backward, as to leave not the least hollow in either place; the mutton upon his arm or fore-thigh must come quite to the knee; his legs upright, with a clean fine bone, being equally clear from superfluous skin and coarse hairy wool, from the knee and hough downwards; the breast broad and well forward, which will keep his fore-legs at a proper wideness; his girth or chest full and deep, and instead of a hollow behind the shoulders, that part, by some called the fore-flank, should be quite full; the back and loins broad, flat, and straight, from which the ribs must rise with a fine circular arch; his belly straight, the quarters long and full, with the mutton quite down to the hough, which should neither stand in nor out; his twist or junction of the inside of the thighs deep, wide, and full, which, with the broad breast, will keep his four legs open and upright; the whole body covered with a thin pelt, and that with fine bright soft wool. The nearer any breed of sheep comes up to the above description, the nearer they approach towards excellence of form; and there is little doubt but if the same attention and pains were taken to improve any particular breed that has been taken with a certain variety of the Lincolnshire, the same advantages would be obtained.'

3. *Early maturity* is a property of great importance to the farmer who breeds and feeds all his own sheep for the shambles; they not only make a quicker return for their food, but yield a higher profit to the breeder than slow-feeding animals. This valuable property of early maturity can be induced by breeding, food, and treatment. The new Leicester variety possesses this property in a higher degree than any other of our domestic breeds, and they also yield a greater quantity of mutton on the same quantity of food.

4. *Constitutional hardiness*, in a rigorous climate, and in bleak and elevated mountains, in which artificial food cannot be obtained, is an indispensable quality. But a farmer will seldom make a wrong selection in circumstances so obvious.

5. *Productiveness* is a property which characterises some varieties of sheep and other animals; it may be extended by careful selection in breeding, and from food and treatment. Pets have almost invariably twin lambs. The draft ewes from the mountains of Scotland have generally twins when taken to a milder climate, and kept on superior food.

6. *Disposition to fatten* is a property of very great importance to feeders, as his sheep can be made fit for the market both in a shorter period and with a less quantity of food. None of our domestic breeds possess this quality in greater perfection than the New Leicester; this quality also may be ascertained by examining the depth and breadth of the chest, according to Sir John S. Sebright. And the great physiologist John Hunter found that easy corpulence was concomitant with small bones; it is also accompanied with a pliable, soft, and mellow skin.

7. *Lightness of offal.*—It is obvious that to whatever extent the weight of the offal, or uneatable portion of the carcass, can be diminished, the value of the animal is increased. The perfection of an animal is, when the dead weight of all the eatable parts approaches the nearest to the weight of the animal when alive.

Principles of Breeding.

The fundamental and essential principles of improving any of our domestic animals by breeding, consist in a skilful selection of those males and females, the union of whose qualities will remove the defects and induce the properties desired. The sheep farmer can neither raise nor keep his flock in the highest perfection of which the climate and pasture admit, without a rigid adherence to this primary principle. It was upon this principle that Bakewell formed his celebrated breed of sheep, and it is the only principle upon which any breed can be raised to the highest perfection of which it admits. *Breeding in and in*, as it is called, has given rise to a long controversy, which our increasing knowledge of the physiology of the animal economy, and a wider induction of facts, carefully observed and accurately recorded, will speedily bring to a final close. The facts now collected from a wide surface, and attested by men skilled in the sciences of physiology and anatomy, as well as by practical breeders of live-stock, establish the important fact, that breeding by too near affinities, the offspring degenerates. It is a law of nature, and applies to men and animals, and even plants. The accurate experiments of Mr Knight establish the fact, that in the vegetable as well as in the animal kingdom, the offspring of male and female plants, when not related, possess always more strength and vigour than those of near affinities. Sir John S. Sebright tried many experiments by breeding in and in with dogs, fowls, and pigeons, and found that the offspring uniformly degenerated. Sir John Sinclair relates an experiment with pigs, which he carried so far that the females almost ceased to breed; and if they did breed, the offspring was so small and delicate, that they died as soon as they were born. To breed, therefore, from the same race, but of different families, is now established as the only system that will secure the highest results in the different breeds.

Crossing is a means of improving a breed that requires many concurring circumstances to insure success. The climate and the food must accord with the size and constitution of the animal to be produced. To increase the size of sheep, without augmenting or improving their food, would be a ruinous enterprise, and in the face of all principle. The attempt to increase size by crossing with heavier rams from another country, requires also great care that the food and climate be adapted to the condition and character of the expected race; for it is in proportion as size is gained by crossing, that delicacy of constitution and liability to disease are increased. The constitutional qualities of a race of sheep will not accommodate themselves to the soil or climate of a country differing much in pasturage and temperature from that on which it has been long a native, without time, great care, skill, and attention. Were we to cross our mountain Cheviot ewes with Leicester rams, the offspring would labour under two fatal disadvantages—a constitution too delicate for the climate, and a size above the pasture. An attempt was made in Scotland some years ago to raise the quality of the wool of our mountain sheep by crossing them with Cheviot rams, and the result, so far as then developed, was a complete failure.

It is now generally admitted that the male has a higher influence on the character of the offspring than the female. This law is in beautiful accordance with that beneficent design so visible in the arrangements of nature, as it enables man to bring the domestic animals to their most profitable condition in a far shorter period than if the law had been reversed. There is another fact apparently well established, that the male, by one connection, has a higher influence on the second generation than the actual father. This shows that no important change in the character of any breed can be effected, unless the crossing is continued until the fourth or fifth generation.

Age of the Parents; its Effects on the Sex of the Offspring.—Some very interesting experiments were begun some years ago, the result of which, so far as they go, tend to establish, as a general law of nature, that the offspring of a young ram and ewe, of from four to five years old, will in general be feminine, while that of an old ram and young ewe will in general be masculine. Could such a law be practically acted upon, it would be of immense advantage to breeders of stock in every country, but particularly to breeders of stock in such a country as Australia, in which the rapid increase of the number of stock is an object of such importance. There is an able paper on this curious subject in the first number of the 'Quarterly Journal of Agriculture,' containing the results of the experiments made in France, from which the following facts and views are extracted:—'M. Charles Giron de Buzareingues proposed, at a meeting of the Agricultural Society of Severac, on the 3d of July 1826, to divide a flock of sheep into two equal parts, so that a greater number of males or females, at the choice of the proprietor, should be produced from each of them. Two of the members of the society offered their flocks to become subjects of his experiments; and the results have now been communicated, which are in accordance with the author's expectations. The first experiment was conducted in the following manner:—He recommended very young rams to be put to the flock of ewes from which the proprietor wished the greater number of females in their offspring, and also, that during the season when the rams were with the ewes, they should have more abundant pasture than the others; while to the flock from which the proprietor wished to obtain male lambs chiefly, he recommended him to put strong and vigorous rams four or five years old. The following tabular view contains the result of these experiments, which are strongly in favour of the views of M. Giron:—

FLOCK FOR FEMALE LAMBS.			FLOCK FOR MALE LAMBS.		
Age of the Mothers.	Sex of the Lambs.		Age of the Mothers.	Sex of the Lambs.	
	Males.	Fem.		Males.	Fem.
Two years old,	14	26	Two years old, .	7	3
Three years, .	16	29	Three years, .	13	14
Four years, .	5	21	Four years, .	23	14
Total, .	35	76	Total, .	43	31
Five years and older, . .	18	8	Five years and older, . .	25	24
Total, .	53	84	Total, .	68	55
N.B.—Three twin births in this flock. Two rams served it, one fifteen months, the other nearly two years old.			N.B.—No twin births in this flock. Two strong rams, one four, the other five years old, served it.		

The general law, as far as we are able to detect it, seems to be, that when animals are in good condition, plentifully supplied with food, and kept from breeding as fast as they might do, they are most likely to produce females; or, in other words, when a race of animals is in circumstances favourable for its increase, nature produces the greatest number of that sex which, in animals that do not pair, is most efficient for increasing the number of the race. But if they are in a bad climate, or on stinted pasture, or if they have already given birth to a numerous offspring, then nature, setting limits to the increase of the race, produces more males than females. Yet, perhaps, it may be premature to attempt to deduce any law from experiments which have not yet been sufficiently extended. M. Giron is disposed to ascribe much of the effect to the age of the ram, independent of the condition of the ewe.' The author of this treatise has uniformly observed, that in every favourable season, when his stock was in high condition, he had a much larger number of female lambs than of males; and in one of the most favourable seasons that has occurred during his own personal experience, the female lambs exceeded the males to the number of ninety, in a flock of 600 ewes. The ewes had no artificial food at any season of the year; they lived entirely on the natural grasses of our mountain pastures. They got bog and lea hay in snow storms, but nothing else.

GENERAL MANAGEMENT.

The management of sheep must be varied according to the nature and character of the breed, the soil and climate, character of the pastures, natural or artificial, the position of the farm in reference to markets, and whether all the sheep upon the farm can be prepared for the butcher, or must all be sold lean, as is the case with those farmers whose flocks subsist entirely on the natural grasses of our mountain pastures; and whether early lambs would be profitable or otherwise. These and many other circumstances must regulate the proper time for admitting the rams to the ewes; hence the lambing season, the proper time for washing, shearing, dipping, smearing, &c. Different names are applied to sheep at different periods of their age. A young sheep remains a *lamb* from birth till the first smearing time. From this till the first clipping it is called a *hog*. From the first to the second clipping it is termed a *gimmer*. It is now called a *young ewe*, till it bears its first lamb. When male sheep are cut, they are denominated *wedders*; and, according to their age, are called wedder hogs, &c. At three years old, the wedder is in its prime for mutton.

Lambing.

The period at which sheep begin to breed is in the autumn of the second year after birth, when both rams and ewes are at their maturity. In the British islands, the company of the ram is permitted at the beginning of October. The ewe goes with young about 152 days, or between twenty-one and twenty-two weeks, and consequently the lambing season is at the beginning of March. It is of high importance that sheep, during gestation, should be managed with peculiar gentleness and care, the rash use of the dog being attended with the most pernicious consequences. The ewes should be well but not overfed, as the ewes being in too high condition greatly increases the risk in lambing. Though parturition, being a natural process, cannot be regarded as a disease, still, in the sheep, as well as in many of our domestic animals, it is attended with some risk; and in certain states of the atmosphere, and ewes in too high condition, the loss is often very considerable from inflammation.

'As the period of parturition approaches,' observes an intelligent writer in the 'Penny Cyclopædia,' 'the attention of the shepherd should increase. There should be no *dogging* then, but the ewes should be driven to some sheltered enclosure, and there left as much as possible undisturbed. Should abortion take place with regard to any of them, although it does not spread through the flock as in cattle (see No. 38, p. 596), yet the ewe should be immediately removed to another enclosure, and small doses of Epsom salts, with gentian and ginger, administered to her, no great quantity of nutritive food being allowed.

The ewes should now be moved as near home as convenience will permit, in order that they may be under the immediate observation of the lamber. The operation of *clatting*, or the removal of the hair from under the tail and around the udder, should be effected on every long-wooled ewe, otherwise the lamb may be prevented from sucking by means of the dirt which often accumulates there, and the lamber may not be able at all times to ascertain what ewes have actually lambed. The clatting before the approach of winter is both a useless, cruel, and dangerous operation.

The period of lambing having actually commenced, the shepherd must be on the alert, yet not unnecessarily worrying or disturbing the ewes. The process of nature should be permitted quietly to take its course, unless the sufferings of the mother are unusually great, or the progress of the labour has been arrested during several hours, or eighteen or twenty hours or more have passed since the labour commenced. His own experience, or the tuition of his elders, will teach him the course which he must pursue.

If any of the newly-dropped lambs are weak, or scarcely able to stand, he must give them a little of the milk which at these times he should always carry about him, or he must place them in some sheltered warm place; in the course of a little while, the young one will probably be able to join its dam. The lambing field often presents at this period a strange spectacle. 'Some of the younger ewes, in the pain and confusion and fright of their first parturition, abandon their lambs. Many of them, when the udder begins to fill, will search out their offspring with unerring precision; others will search in vain for it in every part of the field with incessant and piteous bleating; others, again, will hang over their dead offspring, from which nothing can separate them; while a few, strangely forgetting that they are mothers, will graze unconcernedly with the rest of the flock.

The shepherd will often have not a little to do in order to reconcile some of the mothers to their twin offspring. The ewe will occasionally refuse to acknowledge one of the lambs. The shepherd will have to reconcile the little one to its unnatural parent, or to find a better mother for it. If the mothers obstinately refuse to do their duty, they must be folded by themselves until they are better disposed; and, on the other hand, if the little one is weak and perverse, it must be repeatedly forced to swallow a portion of her milk, until it acknowledges the food which nature designed for its sustenance.'

Male lambs are cut nine or ten days after birth. Weaning, or removal from the mother, takes place from three to four months after birth, according to circumstances. In weaning, the ewes and lambs must be separated so far that they will not hear the bleatings of each other. The lambs are at first put on the tenderest herbage that can be selected. Some ewes may have so much milk, that the udders will swell when deprived of the lambs, and this requires to be attended to by the shepherd at this trying season of his labours.

Food—Tending—Shelter.

The best kind of food for sheep is nutritious grassy pasture, growing on a dry and firm soil. The sheep is most assiduous in picking up food, and will range over a great space in quest of the herbage which it is fond of. In the Highlands of Scotland, and in Australia, where the herbage is scanty, the sheep-farm requires to be very large: twelve miles in length and breadth is no unusual size of a Highland sheep-farm. In countries liable to be covered with snow in winter, grass, hay, or some other vegetable material must be preserved for the subsistence of the flocks when their ordinary walks are under a snowy mantle. Natural meadow hay and turnips are used in Scotland for winter keep when ordinary resources fail; and the employment of these, in the case of heavy drifts, sometimes saves large numbers of sheep. If the flock can be conveniently driven to a cleared hay-field, such is done in preference to carrying food to the animals: there should be one field for the rams and another for the lambs, or for sheep in a weakly condition. A general rule for sheep intended for the butcher is, that they should never be allowed to turn lean, but be kept in a constant state of improvement; and that kind of food should be selected that will bring the animals to the highest profit in the shortest time and at the least expense. In well-managed store farms, sheep are now allowed many kinds of food little thought of in former times, as sliced turnips, oil-cake, &c.; and are, besides, provided with troughs of pure water, and a trough of salt, that they may lick when their taste leads them to that indulgence. In all artificial feeding, the food should be free of dirt or any insect spawn.

Heedless farmers are sometimes apt to purchase and keep more sheep than they can conveniently feed on their grounds, which causes a serious evil. To overstock a farm, where artificial food cannot be obtained, is one of the most fatal errors a farmer can commit. It does not merely diminish the quantity, but also fouls and deteriorates the quality of the food. A farm may be overstocked for a few years, but death will by and by not only lessen the numbers, but diminish to a great extent the health and productiveness of those that survive. Avarice and ignorance have tempted not a few farmers to carry on this unequal struggle against the laws of nature and humanity for years, but it has always ended, as it ever must, either in the farmer's ruin, or reformation of his plan.

The tendency which most sheep have to ramble, renders it necessary for them to be attended by a shepherd and his dog. The duties of a shepherd are very irksome, and require to be performed by a man of firm resolution, good temper, and discretion. To keep the flock within bounds may be troublesome, but much may be done in the way of preventive; and at all events, the sheep must not be harassed and chased as if they were so many wild beasts. Being naturally of a timid and gentle nature, the sheep ought to be treated with a degree of gentleness, and taught rather to look up to their shepherd as a friendly protector than a tyrant. Lazy shepherds, who do not exercise a judicious foresight in keeping the flock to its ground, try to remedy the evil by hounding the dog after the stragglers, besides giving no small toil to their own limbs in running. We are desirous to lay it down as a rule, well known to all good shepherds, that there should be *only a rare and cautious use of the dog*. Much also depends on the dog being of the proper breed (see No. 42), and well trained to his duty. A good dog gives little tongue; he is seldom heard to bark: his great knack consists in getting speedily and quietly round the further extremity of the flock, and then driving them slowly before him in the direction which his master has pointed out. A wave of the hand in a certain direction, and the word *There*, are usually enough as a sign. Under-bred dogs bark at and fly upon the poor animals, chasing them hither and thither without any rational purpose. All such dogs should be destroyed, as unfit for the important duties which they are intended to perform. A first-rate shepherd's dog is invaluable to the store farmer, and no reasonable price should be grudged to obtain one.

In those districts which are exposed to storms, it is important to afford shelter to the flocks. Where there are jutting or overhanging rocks or bushes, the sheep will crowd under their lee, and so far protect themselves from harm; but where the country is bare, it will be necessary to erect artificial walls or enclosures of turf and stone, to which they can be led in cases of emergency. On the exposed hill-sides of Scotland it is usual to build circular folds, locally termed *stells*, of sufficient size for a *cut*, or parcel of sheep. The stell is a rude enclosure, formed of a stone and turf wall about four feet in height, and is placed on a piece of ground known to be seldom drifted. Besides these, there should be on every sheep farm ample and conveniently-situated folds for the various sortings of sheep, such as for weaning lambs, shearing, and drafting or drawing out any animals required. Such folds are ordinarily constructed of *flakes*, or movable wooden palings, and occasionally of rope netting.

Shearing—Wool.

The winter coat of the sheep begins to be ragged in spring or early in summer, while the lambs are in course of being suckled; and towards June, the wool is seen to be falling off in lumps, or caught in every bramble. To save the wool in time, and relieve the animal, it is the practice to shear them about the middle of June, when the lambs have been weaned, and the weather is genial. In any case, however, it should not be done till the new wool is observed to be pushing off the old. Previous to shearing, all the sheep should be collected, and washed in a running brook or pool, to rid the fleece of impurities. Some shepherds employ a little soap in this operation. On being washed, the animals should be put into a clean field or fold to dry. Fine weather should be selected for washing. The shearing is performed a day or two after, by means of large shears made for the purpose. In shearing, care should be taken not to break or tumble the wool, but to take off the fleece neatly, and without injuring the skin of the animal.

Mr Walter Buchanan has written directions to the wool-growers of Australia respecting the management of wool, many of which are of general application:—

It is of great importance that the fleece should be well washed, that the wool may be brought to market with as bright a colour as possible. Every convenience, and a very plentiful supply of pure water, should therefore be provided, a running stream being most desirable. The preferable mode of washing is that which is performed before shearing, according to the German manner. Some growers have tried the plan of washing after the fleeces have been shorn and sorted, and, as is supposed, to have used tepid water, following the French and Spanish method; but this has not been approved of by the buyers generally, and particularly by those who buy for combing purposes.

The breaking of the fleece and washing after shearing give the wool more the appearance of Spanish than of German wool, and it is consequently reduced to a lower standard of comparison. It is well known that the sheep of those German flocks that are best washed are, after that operation, driven into some shed strewed with clean litter, or penned up with hurdles on clean grass; that the utmost care is taken to prevent their exposure to dirt, or whatever else might tend to sully their whiteness; and that they are not shorn until a sufficient degree of moisture is deposited in the fleece, by perspiration, to impart a soft handle to the wool. It may here be added, that it is very important, if possible, to prevent the sheep from filling their fleeces with grass seeds, broken leaves, and other extraneous substances, which cannot be removed in the operation of washing, and which are productive of labour and expense in every process of manufacturing; in some cases, indeed, rendering wool almost unsaleable. It may be here observed, that so conscious are the Spaniards of the superiority of the German mode of washing and assorting, that they are now making every effort to introduce it.

In order to assimilate the Australian wool as much as possible with the German, in preparing it for market, the fleeces should not be broken, but merely divested of the breech and stained locks, and so assorted or arranged, that each package may contain fleeces of the same character as to colour, length of staple, fineness of hair, and general quality.

If the washing has been performed at the same time and place, and with an equal degree of care, the colour is likely to be uniform, and it will then only be necessary to attend to the separation of the fleeces as to length, fineness, and general quality: but if a larger grower has flocks of different breeds, and fed on different soils, care should be taken that the fleeces be separated, first as to colour, and then again as to length of staple, fineness, &c.

The fleeces being assorted as already suggested, should be spread one upon another, the neck of the second fleece being laid upon the tail of the first, and so on alternately, to the extent of eight or ten fleeces, according to their size and weight. When so spread, the two sides should be folded towards the middle, then rolled together, beginning at each end, and meeting in the centre, and the roll or bundle so formed held together by a slight packthread. The bagging should be of a close, firm, and tough nature. The material hitherto most generally used has been sail canvass, which very ill resists bad weather on a long voyage; and when received here, even in favourable condition, is so dry and crisp, that it will tear like paper: a thicker, twilled, more flexible, and tough material, would be preferable. The size and form of the package may be in length about nine feet, and width four feet, sewed up on the two long sides and at one end, the other end being left open, and the sheet so formed being suspended, with the open end upwards, to receive the bundles, made up as before directed, which are to be put in one at a time, one of the flat sides of the roll or bundle being put downwards, and so on in succession, being well trod down, until sufficiently filled for the mouth to be closed. This is the German mode of packing; but it is doubtful whether smaller packages, of the dimensions that have been hitherto sent from the two colonies, may not be more convenient for so long a voyage. The operation of screwing should be discontinued where it has been practised, as the screw pressure, and remaining compressed during the voyage, occasion the wool to be caked and matted together in a manner that is highly prejudicial to its appearance on arrival. The practice also of winding up each fleece separately, and twisting a portion into a band, is productive, in a minor degree, of the same prejudicial effect; and it is to avoid this that the making German bundles of eight or ten fleeces is suggested.'

Qualities of Wool.—Improving the quality of the wool, or at least of not allowing it to deteriorate, is now an object of as great importance to the British store farmer as in raising the weight of the carcass. The finest wools are those purchased for making broad cloths, merino, and mousseline-de-laine fabrics (*laine* is the French word for wool). 'The wool of which good broad cloth is made,' observes Dr Ure in his Dictionary of Arts, 'should be not only shorter, but, generally speaking, finer and softer than the worsted wools, in order to fit them for the fulling process;' and to judge of this degree of fineness, great nicety of discernment is required. 'There are four distinct qualities of wool upon every sheep: the finest being upon the spine, from the neck to within six inches of the tail, including one-third of the breadth of the back; the second covers the flanks between the thighs and the shoulders; the third clothes the neck and the rump; and the fourth extends upon the lower part of the neck and breast down to the feet, as also upon a part of the shoulders and thighs to the bottom of the hind-quarter. These should be torn asunder and sorted immediately after the shearing, or at all events before being prepared for the roving or spinning-frame.

The harshness of wools is dependent not solely upon the breed of the animal, or the climate, but is owing to certain peculiarities in the pasture, derived from the soil. It is known that in sheep fed upon chalky districts, wool is apt to get coarse; but in those upon a rich loamy soil, it becomes soft and silky. The ardent sun of Spain renders the fleece of the Merino breed harsher than it is in the milder climate of Saxony.

All wool, in its natural state, contains a quantity of a peculiar potash soap, secreted by the animal, called in this country the *yolk*, which may be washed out by water alone, with which it forms a sort of lather. It constitutes from 25 to 50 per cent. of the wool, being most abundant in the Merino breed of sheep; and however favourable to the growth of the wool on the living animal, should be taken out soon after it is shorn, lest it injure the fibres by fermentation, and cause them to become hard and brittle. After being washed in water somewhat more than lukewarm, the wool should be well pressed, and carefully dried.'

The quantity of wool imported annually into the United Kingdom, a large portion (21,000,000 lbs.) of which is now from Australia, has latterly been about 65,000,000 lbs.—a quantity not nearly equal to that produced from native flocks. As the imported wools are chiefly of a finer quality than those of native growth, so far is the large importation from injuring the British wool-growers, that it is the means of giving them higher prices for their commodity. It has been satisfactorily shown by clothmakers before a parliamentary committee, that unless they imported foreign wool to mix with that of Britain, they could not produce the finer class of goods, and consequently that British wool would be much less in demand.

Smearing.

Smearing is a process of anointing the skins of sheep with certain ingredients, principally for the purpose of rendering the animal less liable to injury from winter cold (the unguent being a slight counter-irritant), and of destroying the vermin which lodge among the roots of the wool. Smearing with a mixture of tar and butter was general in Scotland in former times. The proportions varied in different districts; but in general six pounds of butter to a gallon of tar were deemed sufficient for twenty sheep. The time for laying on this salve was in the end of October and beginning of November, before the rams are admitted to the ewes, which, in the mountain farms of Scotland, is in general about the 23d of November. The smearing with butter and tar has very much declined of late years, and various other preparations—such as butter and oil, turpentine, arsenic with a solution of soft soap, and various other baths—are used instead of butter and tar. Which of the various baths now in use are the best, it would be difficult to determine, as each has its advocates. On this, as on other subjects, the store farmer, without running rashly into experiments, ought to have his mind open to well-considered improvements, and adopt such measures as are supported by respectable authorities placed in similar conditions of climate, food, nature of stock, and demand.

DISEASES OF SHEEP.

The sheep, in a state of domestication, is subject to a great variety of diseases; but the most formidable, and by far the most destructive, is

The Rot.

It is unfortunate that in the early stages of rot the disease gives no external intimation of having commenced its destined fatal career; for it is at the beginning of most diseases that human skill is most efficacious in arresting their progress. But sheep in the early stages of the rot, instead of showing symptoms of disease and decay, acquire a great tendency to fatten, which has been turned to advantage by Mr Bakewell and others. But after the disease has undermined the general health, the animal becomes listless, and unwilling to move, leaves its companions, and sinks rapidly in flesh; its eye becomes sunk, dull, and glassy; the wool comes easily from the skin; the breath becomes fetid; the bowels variable, at one time loose, with a black purging, and at another costive; the skin becomes yellow, and sometimes spotted with black; emaciation now becomes more rapid; general fever is induced, and death ensues. There are various methods by which practical men endeavour to ascertain the incipient symptoms of the disease, but the two following are the most general:—

The first is, by handling the sheep on the small of the back, and if the flesh feel firm and solid, the animal is judged sound, but if the flesh feel flabby and soft, and give a crackling sound when rubbed against the ribs, the animal is unsound. The other method is by examining the small veins at the corners of the eyes, and if filled with yellow serum instead of blood, the animal is pronounced unsound; but the greatest practical tact and talent will not always insure success in discovering the early stages of this insidious disease.

Appearances on Dissection.—The whole cellular tissue is filled with a yellow serous fluid; the muscles are pale, and appear as having been macerated, being soft and flabby; the kidneys are infiltrated, pale, and flaccid; the mesenteric glands distended with a yellow serous fluid; the lungs filled with tubercles; the heart enlarged and softened; the peritoneum thickened; the bowels are often distended with water, and sometimes grown together. But the liver is the primary seat of the disease; its whole structure is in different states of disease; one part is scirrhous and indurated, and another soft and ulcerated; and the biliary ducts are filled with flukes. This appears to be the origin of the disease which has involved so many organs, and effected such a vast derangement of the whole animal frame.

Causes.—In endeavouring to ascertain the cause of this disease, it seems natural to begin by inquiring whether those parasites which are found in such numbers in the biliary ducts of the liver are the cause or effect of the disease. The parasites named the liver-fluke (the *fasciola* of Linnæus, the *Distoma hepaticum* of Rudolphi, the *planaria* of Goese) are not peculiar to the sheep, but have been found in the biliary ducts of the goat, deer, ox, horse, ass, hog, dog, rabbit, guinea-pig, and various other animals, and even in the human being. The parasite is of a brownish-yellow colour, and resembles a small sole divested of its fins; in size it may be seen from that of a pinhead to an inch and a quarter in length, and half an inch in breadth. It is supposed to be a hermaphrodite, as no distinction of sex has yet been made out: in scientific language, it increases, like many of the lowly-organised animalcules, by self-division and gemmation. The spawn or eggs of this parasite are found in great numbers in the biliary ducts of the liver; those eggs are also found in every part of the intestinal canal, and very often seen in the dung of a sound sheep, though always numerous in that of a diseased one. This animalcule, and many other of the *entozoa*, have never been found out of the intestines; but this is not positive proof that they cannot or do not exist out of the body. Mr Blacklock, in his very valuable treatise on sheep, after laying flat all his opponents, comes to the following conclusion:—'From all this data, the conclusion must at once be drawn, that as living flukes cannot reach the liver from without, they must of necessity be produced only in particular states of the animal they inhabit: how they originate we cannot of course determine, and this is not the place to hazard a physiological conjecture; but it will be found that their appearance in the bile is always preceded by tuberculous deposits on the lungs and liver.'

That Frommen found the fluke-worm in the fœtus of the sheep, is a strong fact, but not decisive; for Mr Blacklock must know that although he is anatomically correct when he states that there is no direct vascular communication between the fœtal and maternal side, yet the indirect communication may be sufficient. And besides this, Mr Blacklock's own views on this point are extremely unphilosophical, as when he says—'That living flukes cannot reach the liver from without, they (the flukes) must of necessity be produced only in particular states of the animal they (the flukes) inhabit.' This is just saying that the flukes inhabit the animal before its particular states produce them. This must mean that the eggs of the fluke exist in the liver of the sheep, ready to be hatched by the peculiar states of the animal; and as these eggs could not, according to Mr Blacklock, reach the liver from without, the only other alternative is, that the liver lays the eggs when in a healthy state, and hatches them when diseased. This wont do: equivocal generation is absurd. But the limits prescribed forbid the author pursuing this interesting inquiry further: he must simply state his belief that the ova of the fluke are not generated by the liver of the sheep, but find their way to that organ by means not yet ascertained; but these ova are not vivified in the liver except under certain states of that viscus. The ease with which Mr Bakewell could induce rot in his sheep, by putting them on ground which he had previously flooded for that purpose, shows that other circumstances must concur to produce the disease. It is not caused by scanty food, as has often been alleged, for sheep may be starved to death without producing rot: the fact that the sheep has an extraordinary tendency to acquire fat in the early stages of the disease, shows that the causes act as a stimulant at first, and originate a slight degree of inflammation in the liver, as the first step in the progress of this fatal disease. But the numerous and well-attested facts now obtained from various climes and countries, lead to the conclusion that the nature of the soil and pastures, and the character of the seasons, are the chief agents in causing rot. This view is confirmed by the fact, that rot is most prevalent in wet seasons, and is nearly confined to lands subject to be occasionally flooded with water at certain seasons of the year, and to soils naturally moist and marshy. Moist and level lands of retentive soil, from which water is slowly evaporated by the sun, and a temperature favourable to the decomposition of vegetable matter—on such lands, when not thoroughly drained, rot may be said to be indigenous, while on lands that are dry and hanging the disease is unknown. The nature of the plants which the soil produces is not so important as the plants being kept in a morbid state by that degree of moisture and heat favourable to their decomposition. These views will be amply verified by any one who will take an accurate survey of the midland, eastern, and southern counties of England, in which the disease is most destructive. Besides supporting the views here advocated, the following passage from the pen of M. Hammond, the founder of the veterinary school in Egypt, is highly interesting to every sheep farmer:—'It appears every year in Egypt after the falling of the Nile, and it follows and keeps pace with the subsidence of the waters; desolation and death accompany it wherever it passes, and it annually destroys at least 160,000 sheep. As soon as the waters of the Nile subside, the pastures which were submerged are speedily covered by a tender rushy grass; the sheep are exceedingly fond of it, and they are permitted to feed on it all day long; in the course of a very little time they begin to get fat, when, if possible, they are sold; their flesh is then exceedingly delicate, but soon after this the disease begins to appear, and the mortality commences. The disease is more frequent and fatal when the sheep are first turned on the newly-recovered pasture, than when the ground becomes dried and the rushy grass harder. But if the sheep pasture in the midst of mud, or on the borders of the marshes and canals, rot attends every step; the rot does not occur in elevated countries, where the sheep feed on dry aromatic herbage. The Bedouin Arabs sell all the sheep which they can before they quit the Nile, for then they are in high and prime condition, after which they lose not a moment in reassembling their flocks and driving them back to the desert.'

Prevention and Treatment.—If the true causes of rot have been accurately given, every farmer has in his own hands the most efficient means for its prevention; on all lands that can be defended from being flooded with water, and on all lands whose levels admit of thorough drainage, the manner and amount of drainage must be determined by the position of the land, whether level or hanging, and by the character of the soil, and the quantity of the moisture to be removed; and on all these points each farmer must decide for himself, or be guided by the advice of a competent judge. The only indispensable rule is, that the drainage must be thorough, in order to be effectual; and if the drainage is carried to this point, the farmer will have the pleasure to see the rot, that dreadful scourge of his flock, disappear. This important point is established by practical men whose testimony cannot be impeached, that there would be no rotten sheep found, even upon the most spongy lands in the country. The treatment of rot is confined to narrow limits, from the curious fact that sheep, in the early stages of rot, acquire fat with singular rapidity; and the best thing the farmer can do, as soon as he finds his flock tainted, is to sell them to the butcher for what they will bring in the market. From the condition of the sheep, this forced sale may be attended with considerable loss, but it will be a loss inferior to that sustained in the fruitless attempt to effect a general cure.

Tainted flocks have recovered, it has been alleged, by being sent to pasture on salt marshes; but though the efficiency of such pasture were admitted, it is a remedy which only a few farmers could obtain. To change the flock to a more dry and elevated part of the farm, when this is practicable, has been attended with favourable results. The free use of salt is universally admitted to be the best medicine within the reach of the farmer for checking the progress of this deadly disease. That many cures have been effected by the proper use of salt, is attested by persons of the highest character and intelligence. Sir John Sinclair states that at Mr Mosselman's farm at Chenoi, beyond the Wavre, he found that salt was used for sheep, and that by allowing them to lick it, the rot was completely cured. And as the only explanation of sheep taking on fat rapidly, in the early stage of the disease, is, that the digestive organs are stimulated for a time by inflammation of the liver, perhaps the disease might be checked *in limine* by copious bleeding; but the disease can scarcely ever be detected at that period in which bleeding would be proper, and bleeding late in this, as in almost all diseases, is fatal. But in this disease the sheep farmer must direct his energies and care to the prevention rather than the cure, though some of the remedies just mentioned may be of service at the beginning: yet from the insidious nature of the disease, it can undermine the constitution, before it is perceived, to that extent which no known remedies can restore, so that every sheep farmer must rest his hopes of safety not in curatives, but in the vigorous use of the means of prevention.

Braxy.

Braxy, or sickness, is an inflammatory disease, whose ravages are chiefly confined to hogs, and those in the highest condition are most liable to be attacked. This disease is not nearly so destructive as it was formerly, when hogs were hirsled. This has been accounted for by alleging the inexperience of hogs in selecting their food, and their tendency to feed too much on the succulent parts of their pasture. Braxy, being entirely an inflammatory affection, may be excited by a variety of causes, such as drinking cold water in a heated state; any great or sudden change of temperature; by hail, snow, or rain; feeding on soft rank grasses, which are apt to excite fermentation, and by extrication of gas, distending the stomach, thus originating inflammation, and sometimes producing sudden death by pressure on the diaphragm. One very frequent cause of braxy is that kind of frosty mornings which load the pastures with hoar-frost. The hogs, from feeding chiefly on dry and binding pastures at that season of the year (from November till March), eat the succulent spots of grass laden with hoar-frost very greedily; and thus the temperature of the stomach is so suddenly lowered to icy coldness, that violent inflammation is immediately produced, and death often ensues in a few hours. In the list of the causes of braxy, the improper use of the dog must not be omitted. It is as clear as a sunbeam that nothing is more calculated to produce inflammation than violent heating a sheep by incessant use of the dog at seasons of the year so liable to sudden and great falls of temperature.

Symptoms.—The animal appears uneasy, often lying down and rising up, standing with its head down and back raised, taking no food, but often drinking water; fever then ensues, when the pulse becomes strong and quick, respiration laborious and rapid, the skin hot, and the fleece clapped; the eyes are languid, watery, and half-closed; by and by it ceases to follow the flock, and soon dies.

Appearances on Dissection.—On opening the body, the appearances vary, according to the parts affected. Sometimes only the reed is affected, and all the rest of the viscera appear perfectly healthy, and the flesh not at all affected. In other cases, the effects of violent inflammation are visible through the whole of the viscera, and the entire flesh of the animal is in a state of rapid putrefaction.

Treatment.—From the nature of the disease, it is obvious that the first and most effective remedy is prompt and copious bleeding from the jugular veins; this being effected, the constipation of the bowels must be removed. The best purgative for this purpose is Epsom salts, two ounces for a dose, dissolved in warm water, and followed by thin warm gruels; these remedies would generally prove effectual if applied at an early stage of the disease; but in a large flock of mountain sheep the disease is frequently not observed by the shepherd till too late for any remedy. The best preventive of the disease in mountain sheep is skilful and attentive herding, by preventing the young sheep from fastening too much on marshy succulent spots, and by seeing they graze regularly over every part of the pasture, and be allowed perfect repose for rumination, undisturbed by the dog.

Sturdy.

The proximate cause of this formidable disease is hydatids formed in the brain, or by an accumulation of water or serum in the ventricles of the same organ. Many ingenious writers both in France and in our own country have favoured the public with a few facts and much speculation to account for the manner in which hydatids reach the brain, and the causes of the accumulation of water in the ventricles; but none of these speculations are in the least degree satisfactory, and many of them can be shown to be absurd, from the known anatomy and physiology of the brain of the sheep. Many plans have been adopted to extract the hydatids from the brain. Hogg, the Ettrick Shepherd, was successful by the use of the wire. He says, 'When I was a youth, I was engaged for many years in herding a large parcel of lambs, whose bleating brought all the sturdies in the neighbourhood to them, and with whom I was exceedingly plagued; but as I was frequently knitting stockings, I fell upon the following plan:—I caught every sturdied sheep that I could lay my hands upon, and probed them up the nostrils to the very brain with one of my wires, and I beheld with no small degree of pleasure, that by this simple operation I cured many sheep to different owners; but I kept all my projects to myself, for I had no authority to try my skill on any of them;' and he adds, 'that several years passed before I failed in this operation in any one instance. Nothing approaching this success, however, has ever attended the operation in the hands of any of Mr Hogg's disciples; though, when the hydatid is situated in the ventricles, or in the upper portion of the brain, some farmers and shepherds have acquired such tact in the use of the wire as to cure considerable numbers.

The operation performed with the trocar, and various other instruments that have been used, is liable to many inconveniences and great danger. If the hydatid is situated in the base of the brain, it cannot be reached by the nostril; then there is great danger of rupturing some of the numerous blood-vessels of the brain, and thus producing inflammation—a disease as fatal as the one attempted to be cured. The use of the trephane is also attended with difficulty and danger. It lays open at once an immense vacuum in the brain to the action of the atmosphere, and its consequent irritation, and hence the risk of inflammation. When the situation of the hydatid can be ascertained by the softening of a portion of the skull, to destroy the vitality of the hydatid by perforating it with the trocar or other sharp instruments, is perhaps the method attended with the least danger of exciting inflammation, and hence the most likely to succeed. But the extent to which the disease must have injured the brain, before the softening of the bone to reveal the position of the hydatid, is an insuperable evil, diminishing the chances of success in any mode of conducting the operation that can be devised. There is no medicine that can justly be regarded as of any avail. But carefully-observed and accurately-recorded facts may yet throw some light on the remote causes of this formidable disease, under that higher anatomical and physiological knowledge which has within these few years been brought to bear on the diseases of our domestic animals.

Pining.

This disease, it is said, was unknown in this country before the sheep-walks were thoroughly drained and the moles exterminated. If this statement is correct, the cause of the malady must obviously be too dry and binding pasture; and in accordance with this view, constipation of the bowels is always present in this disease. To open the bowels freely, and change to a more nutritive pasture, are the obvious remedies; and when both can be readily applied, they seldom fail of complete success.

Dysentery.

This disease begins with violent discharges from the bowels of a green slimy mixture, which in progress of time becomes mixed with blood. It has often been confounded with diarrhœa, from which it differs in many particulars. Diarrhœa attacks young sheep, particularly hogs, occasioned by a sudden rush of grass in the spring, or from too sudden a change from a scanty to an over-rich pasture; when such are the causes of diarrhœa, the mere change to a drier pasture will effect a cure. But dysentery attacks old sheep, and generally does not commence till June or July. Many writers allege that this disease is highly contagious, but the best established facts do not sustain the allegation. The disease prevails in fouled pastures, and in seasons characterised by a peculiar state of the atmosphere with regard to heat and moisture, a certain combination of which renders the malady so fatal to our army, especially in tropical climates. In the treatment of this disease, bleeding is a proper remedy in an early stage; but if late, gentle purgatives alone must be used: Epsom salts or castor oil, with twenty-five to thirty drops of laudanum, are the best purgatives. Mr Stevenson also used an infusion of logwood, and doses of ipecacuanha, in numerous cases with great effect.

Trembling.

Trembling, or Louping Ill, in mountain flocks, is a disease caused by cold east winds, which are prevalent in April and May, and at which season this disease, after a bad winter, is often very destructive. The animal sometimes leaps from the ground and falls down dead; but more generally it is seized with trembling, loses the power of its legs, and lies on its side, grinding its teeth, and moving its limbs with great violence. The appearances on dissection are very uniform; great congestion of blood in the liver and lungs, and particularly the heart, which is invariably gorged with dark blood; and the brain is also sometimes congested; the whole flesh of the body is as white as if the animal had been killed by the usual process of bleeding.

These appearances, and various experiments, led the writer of this paper to view the disease as the effect of a lost balance in the circulation; the cold east wind acting on the surface of the animal when she is just beginning to return from the lowest point by the coming grass, drives the blood from the surface, congests the lungs and liver, and overpowers the action of the heart with a rush of dark vinous blood. The numbness of the limbs, caused by the heart being unable to send the circulation to the extremities, has led some writers to regard the disease as a kind of palsy.

Treatment.—Copious bleeding in the first stage of the attack will often restore the balance of the circulation; but if the animal has been affected some time, it is often difficult to obtain a sufficient quantity of blood, which has been thrown from the surface upon the heart and other internal organs. In this state the animal must be put into a tub of hot water at 98 degrees, which will cause the blood to flow, and thus restore the action of the heart, and tend to restore the balance of the circulation. After a sufficient quantity of blood has been drawn, doses of Epsom salts, dissolved in warm water, and followed with thin warm gruels, must be given till the bowels are freely opened. The prompt application of these remedies on the first attack of the disease would in general be successful; but like many other diseases of sheep, it is not observed till the action of the heart has become too feeble for any remedies to restore the lost balance of the circulation. The same views of the nature, causes, and treatment of this destructive disease are supported by numerous facts and experiments brought forward by Mr Tod, in his prize essay, published in the 'Transactions of the Highland Society of Scotland.'

Foot-Rot.

This is a disease most prevalent in luxuriant meadows, and in all soft grassy lands saturated with moisture. The opinions entertained regarding the causes of this disease are discordant in the extreme. Some writers contend that it is comparatively a modern disease, and was first mentioned by two French physicians, M. Etienne and M. Leibault, who published some cases of the disease in 'La Maison Rustique' in the year 1520. Lulin says that it was brought from Piedmont to Geneva in the year 1766, and that the foot-rot did not exist among Swiss sheep before that period; and in a report of the management of Flemish sheep in 1763, published by authority, foot-rot is not once mentioned. In our own country, it is mentioned by Sir Anthony Fitzherbert in the year 1523. But whatever may have been its history and progress in other countries, it was very prevalent in Great Britain in 1749. Ellis, who wrote in that year, says 'that it raged particularly in the counties around the metropolis. The ewes were seized with foot-rot, which was communicated to other sound ewes and to the lambs which they suckled; and most of the meadows are so much infected with this sheep malady, that few of the suckling ewes are ever clear of it in a greater or less degree, and the pain and anguish thereof keeps them poor in flesh, and lessens their milk; so that two or three ewes thus affected give no more milk than one full milch ewe that is in perfect health.'

It will aid the reader to follow with greater clearness the following discussions regarding the nature and causes of foot-rot, to have first a correct view of the healthy anatomical structure of the foot of the sheep, at least in so far as this very formidable disease is concerned. 'There are some points of importance,' says that eminent veterinary surgeon Mr Dick, 'to be kept in view, in order to understand properly either the functions of the foot of the sheep, or the nature of the diseases to which it is liable. The foot presents a structure and arrangement of parts well adapted to the natural habits of the animal. It is divided into two digits or toes, which are shod with a hoof composed of different parts, similar in many respects to the hoof of the horse. Each hoof is principally composed of the crust or wall, and the sole. The crust, extending along the outside of the foot round the toe, and turning inwards, is continued about half way back between each toe on the inside. The sole fills the space on the inferior surface of the hoof between these parts of the crust, and being continued backwards, becomes softer as it proceeds, assuming somewhat the structure of the substance of the frog in the foot of a horse, and performing at the same time analogous functions. The whole hoof, too, is secreted from the vascular tissue underneath. There are, besides, two supplementary digits at the fetlock. Now this diversity of structure is for particular purposes. The crust, like that in the foot of the horse, being harder and tougher than the sole, keeps up a sharp edge on the outer margin, and is mainly intended to resist the wear and tear to which the foot of the animal is exposed.'

This structure of the foot of the sheep is extremely well adapted to Alpine ranges, which are the native abodes of the sheep in their natural state. 'Dwelling by preference,' in the language of Mr Wilson, 'among the steepest and most inaccessible summits of lofty mountains, among its native fastnesses, it is seen to bound from rock to rock with inconceivable swiftness and agility.'

From these facts, it is easy to perceive how our domestic sheep are subject to foot-rot, when confined to a limited range on soft and rich pastures, and in wet and grassy lands. In these situations, the growth of the crust of the hoof exceeds the wear and tear, and soon overlaps the sole, and in this situation is either rent or broken off, when sand or dirt reach the vascular parts of the foot, and hence inflammation is produced. The animal then becomes lame, suppuration takes place, and ulcers discharge fetid matter; and if these ulcers go on unchecked, they throw out fungous granulations; and if these be allowed to go on, the hoof falls off. When the disease reaches to this extent, the constitutional disturbance is very great from high inflammatory fever, and the animal rapidly loses flesh, and if unrelieved, dies of fever and starvation.

Such being the nature and causes of the disease, the author of this paper thinks the views of Mr Dick rest upon a more secure and philosophical foundation than any other writer that has come under his observation. And if these views are admitted, the treatment and means of prevention are very obvious. To pare away all the detached hoof, and dress the diseased part with some caustic, perhaps the muriate of antimony, has the greatest weight of authority. But as prevention is in all cases to be preferred to cure, the shepherd should keep a vigilant eye upon the flock, and pare regularly on lands that require it. By the simple means here recommended, the writer has prevented the disease from injuring his flock of sheep for more than twelve years, though the lands were subject to the disease. But if foot-rot be as virulently infectious as it is affirmed to be by a whole host of writers, many of whom are men of high character and attainments, very different means both of prevention and treatment must be adopted. As the decision of the question, whether foot-rot be infectious or non-infectious, is of great practical importance to every sheep-farmer, the evidence on both sides of the question would require to be stated with perfect candour, in order to arrive at the truth. In so far as evidence has been produced, the argument inclines to the side of those who contend for the non-contagiousness of the disease. Mr Dick very reasonably asks, 'Has any one ever attempted to produce the disease by inoculation? If it is highly infectious, surely it will at once be produced by inoculation. But this is not such an easy matter as one would expect, from a disease which is supposed to infect a whole field, and that, too, even if it be of five hundred acres in extent. Gohier, a French veterinarian, first applied a piece of horn from a diseased foot, covered with the matter, to the sole of a sound foot, without effect; secondly, he rubbed a diseased foot against a sound one, without effect; thirdly, he pared the sound foot, and having applied a piece of diseased hoof, the disease afterwards appeared; but in this case the foot afterwards got well of itself, and there seems to have been a doubt in the mind of Gohier as to whether it was truly foot-rot or not. Other French veterinarians have tried similar experiments, and particularly Vielhan of Tulle, and Favre of Geneva; and although I have not seen an account of their experiments, it is said they succeeded in producing the disease by inoculation. Now, it will be asked, Is not this a sufficient proof of its infectious nature? I answer that it is not. It appears to me that this is a strong proof against it. If it is produced with so much difficulty by the direct application of matter, is it not absurd to suppose that a few sheep with diseased feet should infect a whole field. I have not seen an account of the manner in which the experiments of the French veterinarians have been performed; I know not what quantity of matter was employed, neither have we any account of counter-experiments, nor whether any were tried to prove if a similar effect would not have been produced by the application of any other morbid matter; for example, whether the matter of grease from the heels of horses, or from thrushes, would not have produced similar effects. I have little doubt of such being the case; that suppuration might be produced by inoculating with that, or almost any other matter, if, in the operation, the wound was made sufficiently deep; nor would I doubt that disease would be produced if matter was spread over the foot in sufficient quantity, and applied for a sufficient time.' The same writer continues—'I repeat, that it is absurd to suppose that; if applied to the hoof, it would produce the disease. The hoof is not governed by the laws of living matter; it is totally insensible, and it has not a circulation, neither has it nerves; it absorbs moisture only like a piece of inert matter, and it is not acted upon as a living part. Matter from the foot of a diseased sheep might as well produce the disease in a tree; nay, even more likely, because it is a living body, which the hoof is not. Why, then, are we to suppose the hoof to be acted upon by matter from diseased feet, and that, too, after the matter has been exposed to the influence of the atmosphere? But rain and sun, we must suppose, have no influence upon it. Arsenic may be diluted with water to such an extent as to be swallowed with impunity, but water seems to increase the virulence of the matter of foot-rot. It is true that heat and moisture will reduce, after sufficient exposure, animal matter to a putrid mass of the same consistence and properties, but the influence of these agents is lost upon the matter of foot-rot. The plague is now known not to be so infectious as it was once thought to be, but the foot-rot will still infect the most extensive domains. The upas-tree may annihilate the existence of all that comes within its pestiferous shade, but what is that to the infection of the foot-rot, when a single sheep will contaminate a mountain! Nay, it will act even upon parts totally devoid of vitality; and such, too, is the eccentricity of its action, that it will allow its neighbouring toe to escape, and still infect the whole ground. But I need not discuss this point farther at present, as I trust I have already shown that all ideas of its infectious nature are merely chimerical.'

In support of these views, Mr Black, farm overseer to his Grace the Duke of Buccleuch, states that he had thirteen score of black-faced sheep, the greater part of which was affected with foot-rot, and many of them crawling about upon their knees. He turned them into a drier pasture, on which were seven score of Leicester and Cheviot sheep. All of the diseased sheep except four speedily recovered, and not one of the Leicesters or Cheviots was infected. This is a very strong fact, from the pressure of which the contagionists cannot easily escape.

The Scab.

This frequent and very mischievous disease has annoyed the cultivators of sheep in different parts of the world from time immemorial. It is mentioned by Ovid, Livy, and in the 'Georgics' it is very graphically described by Virgil. In our own country it is mentioned by our earliest writers; and in Italy, France, and Germany, there is scarcely a writer on sheep who does not describe this prevalent and ruinous disease.

Symptoms.—The sheep becomes restless, scratching itself, tearing off the wool with its teeth, and rubbing violently against any post, stone, or gate. When the skin is carefully examined, there are seen numerous pustules, which, having broken and run together, form large patches of scab. The back and shoulders are generally first affected. The general health of the animal sinks in proportion to the extent of the eruption and the virulence of the disease, and if allowed to proceed unchecked, it brings on general inflammation, and the animal dies in a most miserable condition.

It is now ascertained that this disease in sheep is caused by minute insects of the class *acari*. M. Walz, a German veterinarian, has given a very curious and interesting account of the operations of these acari, which are said to burrow in the skin of the sheep, and reappear again about the sixteenth day with a numerous brood. These young insects commence operations at once, and propagate in the same manner, till the poor sheep sinks under myriads of his destroyers. The work of M. Walz contains drawings of these insects, highly magnified. The subject deserves farther investigation, being of great importance to the sheep farmer.

The treatment of scab is thus rendered very simple—the destruction of the insect which caused it. Infusions of tobacco, hellebore, or arsenic, have all been employed with success. In bad cases, the mercurial ointment has been applied with the happiest effect. A very good receipt is a decoction of tobacco and spirit of turpentine, with a little soft soap and sulphur vivum.

The only caution necessary to be given in the use of any of these remedies is, to take care that they be brought thoroughly in contact with every part of the skin of the affected animal, lest any of the burrowed acari escape. And all folds or sheds in which infected sheep have been confined, and all gates, posts, and other rubbing places, must undergo thorough purification. Besides the acari, sheep are liable to be attacked by various other insects, such as the flesh-fly, and a species of aphis called the sheep-louse. The maggot only prevails in the moist and warm summer months, but increases in numbers with amazing rapidity, and requires great watchfulness on the part of the shepherd, as they soon destroy a large portion of the skin and flesh of the sheep if unchecked. The aphis also creates great irritation; but both species are easily destroyed by any of the preparations already detailed. The tick (*Acarus reduvius*) is also a very formidable insect to sheep. It almost buries itself in the skin, and adheres so firmly by six legs, very muscular and powerful, and so armed with serrated claws, that it can scarcely be disengaged from its hold, but will yield, like most of the parasites which infest the sheep, to the application of a mercurial preparation.

THE GOAT.

Goats form one of the families of the *ruminant* order of mammalia. The common domesticated goat is usually about the size of the sheep, though less round in form, and is marked by keen eyes, long hair, and generally bent horns. The males, called familiarly in England *billies*, have a long beard; but the females, or nannies, are seldom provided with that appendage. Whether in a state of nature or tamed, the goat is remarkably swift and agile, and will browse fearlessly on the most rugged precipices. We find, from ancient writers, that goats have long formed part of the stock of mountain-herdsmen, and were tended with even greater care in former than in present days. In many respects, indeed, the animal is valuable. Its skin is convertible to several useful purposes, and the flesh of the full-grown goat is good, though scarcely equal in quality to that of the sheep. But it is for the milk chiefly that the goat is prized; the qualities of that secretion being not only very nutritious, but even medicinal. Where cottagers have not the means of keeping a cow, a goat will be found a very useful animal, being easily fed, and contented with grasses which are rejected by the cow and the sheep. To those peasants who live in the neighbourhood of mountainous countries, the trouble and expense of keeping a couple of goats will be nothing, as they will find sufficient nourishment in the most heathy, rough, or barren grounds. Heaths also which are unfit for any kind of pasture, will afford this animal an ample supply of food; and it requires no care or attention, easily providing for itself proper and sufficient food. In some countries, goats render considerable service to mankind, the flesh of the old ones being salted as winter provision, and the milk is used in many places for the making of cheese. The flesh of the kid is highly palatable, being equal, if not superior in flavour, to the most delicate lamb.

In Britain, the goat produces generally two young at a time, sometimes three, rarely four. In warmer climates it is more prolific, and produces four or five at once, though the breed is found to degenerate. The time of gestation is five months. The male is capable of propagating at one year old, and the female at seven months, but the fruits of a generation so premature are generally weak and defective: their best time is at the age of two years, or eighteen months at earliest. A goat is accounted old at six years, although its life sometimes extends to fifteen.

If goats are properly trained, they will return to their owners twice a day to be milked, and prefer sleeping under a roof when accustomed to it. The milk of the goat is sweet, and not so apt to curdle upon the stomach as that of the cow; it is therefore preferable for those whose digestion is but weak. The peculiarity of this animal's food gives the milk a flavour different from that of either the cow or the sheep; for, as it generally feeds upon shrubby pastures and heathy mountains, there is a savoury mildness in the taste, very pleasing to such as are fond of that aliment. The quantity of milk produced daily by a goat is from three half pints to a quart, which yields rich and excellent cream. If properly attended to, a goat will yield milk for eleven months in the year. In several parts of Switzerland, Wales, and the Highlands of Scotland, the goat is the chief possession of the inhabitants. On those mountains where no other useful animal could find subsistence, the goat contrives to glean sufficient living, and supplies the hardy natives with what they consider a varied luxury. They lie upon beds made of their skins, which are soft, clean, and wholesome; they live upon their milk, with oat-bread; they convert a part of it into butter, and some into cheese; and the flesh furnishes an excellent food, if killed in the proper season, and salted. They are fattened in the same manner as sheep; but taking every precaution, their flesh is never so good or so sweet in our climate as that of mutton. It is otherwise between the tropics. The sheep there becomes flabby and lean, while the flesh of the goat rather seems to improve, and in some places is cultivated in preference to that of the sheep. The cream of goat's milk coagulates as easily as that of cow's, and yields a larger proportion of curd. The cheese is of an excellent quality, and high flavoured; and although to appearance it looks poor, it has a very delicate relish, and strongly resembles Parmesan cheese. Some farmers have been in the practice of adding a little goat's milk to that of cows, which materially improves the flavour. In winter, when native food becomes scarce, the goat will feed upon turnip-peelings, potato-peelings, cabbage-leaves, and other refuse of a house. In addition to the other products yielded by the goat, its tallow, we should mention, is also an article of some importance. It is much purer and finer than that of sheep, and brings a high price, being calculated to make candles of a very superior quality.

Cobbett advocates the keeping of a goat by cottagers. 'There is one great inconvenience belonging to goats—that is, they bark all young trees that they come near; so that if they get into a garden, they destroy everything. But there are seldom trees on commons except such as are too large to be injured by goats; and I can see no reason against keeping a goat where a cow cannot be kept. Nothing is so hardy; nothing is so little nice as to its food. Goats will pick peelings out of the kennel and eat them. They will eat mouldy bread or biscuit, fusty hay, and almost rotten straw, furze bushes, heath thistles; and indeed what will they not eat, when they will make a hearty meal on paper, brown or white, printed on or not printed on, and give milk all the while! They will lie in any dog-hole. They do very well clogged, or stumped out. And then they are very healthy things into the bargain, however closely they may be confined. When sea-voyages are so boisterous as to kill geese, ducks, fowls, and almost pigs, the goats are well and lively; and when no dog of any kind can keep the deck for a minute, a goat will skip about upon it as bold as brass.'

In Britain, no attempts have been made, at least successfully, to introduce foreign breeds of goats, although in France this has been done to a considerable extent. The Cashmere goat, famous for its long silky hair or wool, has been brought to the country mentioned, and there bred with the Thibet goat, a hardier species, but almost equally esteemed for its wool. The manufactures producible from this material, as the Cashmere shawls have long testified, are scarcely to be surpassed for fineness, and yield immense prices. It is probable that, in our warmest districts, a cross of these foreign goats with the common breed might be successfully and advantageously effected.

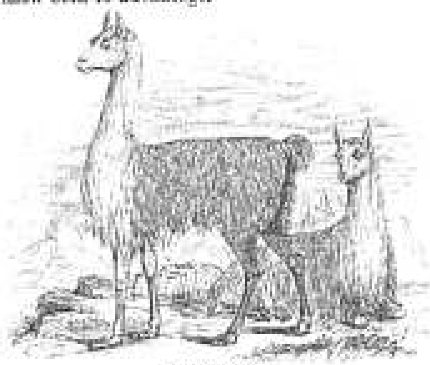
THE ALPACA.

Attempts are now making, under the most respectable auspices, to introduce the alpaca, or Peruvian sheep, as it is popularly termed, into the number of our domestic animals. As the subject is one of very considerable importance, in a national as well as individual point of view, we propose offering a few explanatory observations.

Nature, as is well known, furnishes animals expressly suited to the climate, vegetable productions, and other circumstances connected with the locality which they are destined to inhabit. The Andes, and other high mountain ranges and slopes of South America, are accordingly provided with several species of sheep, adapted, by their habits, to these lofty regions of scanty vegetation, and which so materially differ from the sheep of this and other European countries as to seem a perfectly distinct tribe of animals. The two most common of these South American sheep are the llama and alpaca, and they abound most extensively in Peru. The llama is somewhat taller than the alpaca, and though in some respects a remarkable animal, its peculiarities are not such as to render it so especially interesting as the alpaca, for purposes of practical utility, out of its native regions. The alpaca, which it is proposed to domesticate in Britain, is an animal combining the appearance of the common European sheep with that of the goat, and partly of the deer and camel. Like the sheep, the alpaca is lanigerous or wool-coated; in its general structure it is light, and possesses limbs adapted for springing and leaping like the goat; it resembles the deer in skin, flesh, and general appearance; and though without the camel's deformities, it is gifted, like him, with patience and docility, being often used as a beast of burden by the natives of South America (See No. 26, p. 402). The height of the alpaca is from three to four feet, when measured from the ground to the top of the back; the eyes are large, black, soft, and expressive; the animal has no horns; the neck is long, slender, curved backwards, and finely set; the head handsome, and the muzzle and ears lengthened; the hoof is horny, and divided; the tail short, and resembling what is called a switch-tail; the body has a tapering towards the loins, resembling that of the greyhound; and, as regards other points, the alpaca has partly the characters of the sheep (its incisors on the lower jaw, for example, and six molar teeth on each side), and partly those of the camel (the most remarkable being a similar reservoir in the stomach for fluids, suiting the creature to an arid climate). To common observers, the alpaca might seem to be a fine tall goat, with a small head and no horns, but of more gentle and fleecy appearance than that animal.

The wool of the alpaca forms, of course, a point of peculiar importance, taking into view the proposal for introducing the animal into Great Britain. The colour of the wool varies considerably, the majority of the tribe being of a tint intermediate between black and brown, while others are of a pure white. The texture is admitted on all hands to be peculiarly fine. In a memoir on this subject, written by Mr W. Walton (author of a small volume entitled 'The Alpaca,' and published by Blackwood, Edinburgh), the wool is thus described:—

'With the polite assistance of the secretary of the Polytechnic Institution, I was enabled to examine the anatomical structure of three samples of alpaca wool through a lens magnifying one million times. The colours of those subjected to the power of the microscope were white, black, and gray. When thrown upon the disk, each filament appeared equal in thickness to a man-of-war's topsail hallyard; perfectly distinct, and the fibrous structure more evident than in the wool of common sheep. White was the first sample tried, and it produced an effect at the same time singular and pleasing. The surface appeared polished and distinguished by a glittering brightness, almost, I could say, refulgence, which is wanting in sheep's wool. The general results produced by afterwards showing the black sample were the same, excepting that the shade on the disk was more opaque, and the brilliancy of each filament somewhat diminished. The gray exhibited a medium between these contrasts, and helped to show both to advantage.



The Alpaca.

There are instances of alpaca wool measuring thirty inches long; frequently it is seen twenty inches, and it averages from eight to twelve. In the samples, there appeared to be no under wool—no closer and immediate covering. No shorter hair or wool could, in fact, be perceived; the very reverse of what is observed when a morsel of an elk's or camel's coat is examined. Alpaca wool is also straighter than that of sheep, never appearing in those spiral curls which distinguish our piles, more particularly when the bearer of the fleece has been smeared. The smallness of the fibre, its softness and pliability, coupled with its elasticity, equally add to its value. There is, in the mass, what is technically called a *trueness* that is, an equal growth and an exemption from shaggy portions, accompanied by a soundness, by which is meant the general strength of the fibre—properties certainly of the first import to the manufacturer. In consequence of this characteristic disposition, alpaca wool breaks less in the act of combing, is freer from shreds, spins easily, and not being so harsh or so stubborn, does not injure the machinery so much. The thread spun with it is also finer and truer. In the manufacture of fine goods, it is agreed that the pile cannot be too soft or too silky, provided the strength of the fibre is not impaired. As well as I could, I have compared the strength of a filament of alpaca with those of other wools, and found it the strongest; and as it is devoid of that irregularity of surface—the knots and joints which some persons liken to those of a bamboo cane—the cloth made from it must consequently be less harsh to the touch.'

But the qualities of the alpaca wool for manufacturing purposes do not rest upon mere conjecture. 'The merits of alpaca wool have for some time past attracted the notice of manufacturers, and consequently of merchants; and through the advice of Mr Danson, and other enterprising individuals, the importations of it have within the last eight years considerably increased. Intelligent merchants on the spot, and engaged in the trade, assert that the total amount imported during the seven years ending December 1843 exceeded twelve millions of lbs. During his tour in Scotland, Mr Danson urged the expediency of introducing the alpaca into the Highlands, and pointed out the benefits which would accrue from this measure. In illustration of his views, he exhibited samples of the wool, and specimens of articles manufactured in England from it, imitating silk, some as black as jet, although of the natural colour, and without the aid of dye. He very ably contended that this wool would not enter into competition with that of our ordinary sheep, and, from the fineness and transparency of the filament, was peculiarly well adapted for the fine shawl trade of Paisley and Glasgow.' Even these trials have been made under disadvantages, for the alpaca wool has only reached this country in a dirty, and also in a mixed state, the wool of inferior breeds forming almost always a large proportion of the bales containing it. Another advantage consists in the greater weight of the fleece; for according to the authority now quoted, 'it ranges from 10 to 12 lbs.; whereas that of our full-grown sheep seldom exceeds 8 lbs., and in the small breeds from 4 lbs. downwards. From the larger size of the animal, and the increased surface consequently covered, the alpaca necessarily yields most wool; and it has already been ascertained that on British pastures the weight improves. At the Royal English Agricultural show held at Liverpool in July 1844, a sample of black wool was exhibited, taken from an alpaca belonging to the Earl of Derby's flock, the staple of which appeared to be about a foot long; when his lordship's farm-agent expressed his conviction that the same animal had then 17 lbs. upon its back.'

The value of the wool being once determined, the next question is, Have we space and food for the alpaca in Britain? On this point, after some arguments in proof of his views, Mr Walton reaches the following conclusions, which appear to be essentially correct:—'We therefore have, and must continue to have, large tracts, neither cropped with grain nor depastured by cattle, consisting of chains of barren hills, running in various directions through the United Kingdom, moors, heath, moss lands, &c. wholly unproductive, the amount of which may be set down at from twelve to fourteen millions of acres. And would it not be highly expedient to stock these lands with another domestic animal, yielding a commodity of such a nature as to reward the farmer for his care, and besides triple in value by the beneficial application of labour—an animal requiring no additional subsistence for its support, and consequently not likely to interfere with any cattle already on our farms?' Besides, if an improved race of domestic animals could be put even into our occupied lands, would it not be advisable to do so, even at the cost of diminishing the existing breeds?

Another material question is, Could the alpaca *live* in this country? 'Although delicate in appearance, the alpaca is perhaps one of the hardiest animals of the creation. His abstinence has already been noticed. Nature has provided him with a thick skin and a warm fleece, and as he never perspires, like the ordinary sheep, he is not so susceptible of cold. There is therefore no necessity to smear his coat with tar and butter, as the farmers are obliged to do with their flocks in Scotland—a process which, besides being troublesome and expensive, injures the wool, as it is no longer fit to make into white goods, nor will it take light and bright colours. "The Highland hills," says the Ettrick Shepherd, "are for the most part of a pyramidal form, very high, and commonly so steep and rugged, that to the eye of the traveller they have an appearance perfectly tremendous. The sides and banks of the glens and rivulets are commonly covered or mixed with a rich short grass, intermingled with numberless aromatic herbs and flowers. The extensive flats and sloping declivities around the bottom and lower parts are covered with a coarse mossy turf, interspersed with thin sapless heather, which has stood in the same squalid form since the time that it first made its appearance on the retreat of the universal deluge, mixed with some of the moss-stalks called ling and deer-hair." This is the description which so experienced a man as the Ettrick Shepherd gives of "that vast range of stupendous mountains, deep glens, and trackless forests which," he says, "at the first view every unprejudiced man must acknowledge nature never intended for the rearing of cattle; and where no one," adds he, "will hesitate whether sheep or goats are the most feasible stock." What pen could have sketched a more faithful picture of the Andes mountains—those high and secluded regions, inaccessible to other animals, where the alpaca lives "an inmate of the cloud and storm," gathering subsistence from edible plants which otherwise would be left to wither on the land!' We are aware of only one doubtful circumstance as to the successful domestication of the alpaca in any of the British islands, particularly in the Highlands—this is the *humidity of our climate*. If the alpaca can resist damp as well as our South-downs, we shall have nothing to fear on the score of hardiness in other respects.

Mr Walton alludes to the strong enamel on the alpaca's teeth, as fitting the creature peculiarly for rocky and mountainous pasturage. In the case of snow-storms, too, on our elevated ranges, by which so many of our common sheep are apt to be smothered every severe winter, the remarkable docility of the alpaca renders him almost secure, with little comparative toil to the herdsman. 'Peruvian sheep have, in fact, an unerring foresight of the coming danger, long before their tender (if they happen to have one) sees above him a threatening cloud, or dreams of a drift. Instinctively they know the safest side of a crag, as if they saw the point of the compass from which the storm was approaching; and thus admonished, collect their young, and fly to the *stell* which nature provided for them, even before the conflict of the elements and the raving of the wind shall have commenced. If within reach, the alpaca asks protection at the cottage door where at other moments he had been welcomed.' Again—'Another great advantage in the alpaca is, that he is not liable to the many diseases incidental to common sheep, and which have so often raged like a pestilence among the tenants of the Scotch hills. In Peru, where the circumstances are as near as possible alike, the llama and alpaca are not hurt by changes of diet incidental to the seasons. This may arise partly from their greater abstemiousness and discernment, and partly from their having a wider range, and consequently more choice of food. It is, however, a fact, which I have ascertained from natives, that the Peruvian breeds are not so liable to bowel complaints as ours; and their constitution being much stronger, they are consequently less affected by sudden transitions from one food to another. The distemper called pining, or daising, very usual in the west of Scotland, which occasions a thinness of blood, and when, though the animal continues to feed greedily, it pines away to a mere skeleton, is unknown on the Andes; neither are the fawns there liable to the many accidents which attend the feeding, herding, and folding of lambs among us. As regards vermin, they are much clearer.' With respect to other diseases, though the alpaca is not exempt from some of them, its hardy constitution seems to render their influence less extended and destructive.

In reality, the experiment of keeping the alpaca in Great Britain has already been tried on a considerable scale, and the wool has been found to be even improved by the change of site. 'The Earl of Derby, with that patriotic spirit and splendid taste which have distinguished him through a long life, also stepped forward among the first breeders, and his lordship has now at Knowsley a little flock of llamas and alpacas, amounting to fourteen, two of which were bred on the spot, whose wool is finer, softer, and more beautiful than that on the backs of their parents. The proof that the wool improves with our pasture is, in fact, established in this instance. The young are eight-and-twenty months old, and already the first has wool upon it six inches long. A fine male alpaca, shorn three years ago, has at present a coat upon it from eighteen to twenty inches long, thus proving that the wool grows from six to eight inches yearly, if regularly shorn. Speaking of the practicability of introducing the Peruvian sheep more generally, in a letter addressed to William Danson, Esq. of Liverpool, who, accompanied by a friend, visited Knowsley at the beginning of the current month [April 1841], his lordship says, that "he certainly knows of nothing likely to prevent the propagation of the animal in this country. On the contrary," he adds, "the gentlemen will see in these grounds living specimens that they can and will do so, one female having produced in each of the two last seasons, and the young are doing well." His lordship then expresses his anxious desire "to obtain the remainder of the species, more especially the vicuna." Already does this interesting animal adorn the pleasure-grounds of the Marquis of Breadalbane at Aberfeldy, Perthshire; J. J. Hegan, Esq. Harrow Hall, Cheshire; Charles Tayleure, Esq. Parkfield, near Liverpool; Mr Stephenson of Oban; R. Bell, Esq. Villahouse, near Listowel, county Kerry; A. G. Stirling, Esq. Craigbarnet, near Glasgow; and others.'

From the tone in which this notice has been drawn up, it may be observed that the statements before us have been convincing in our eyes, in so far at least as regards the propriety of making fair and full experiments on the subject of the alpaca. This animal, we conceive, without infringing materially on the keeping of sheep, might prove the means of enlarging the profession of the pastoral farmer, and of varying, extending, and improving our manufactures. From the alpaca wool which we do procure at present, yarn is spun, which the French import at from 6s. to 12s. per lb. In conclusion, we give a few additional words from Mr Walton. 'When we consider the great improvement which we have attained in sheep's wool, there is every reason to look for a similar success in that of the alpaca; and in devising means to increase the productive power of the country, we ought never to forget that there have been periods in our history when we were dependent upon foreign supplies for the raw material required for our woollen manufactures, and that the best way to be independent, is not to be under the necessity of buying that which it is in our own power to grow. The task of obtaining suitable breeds of the alpaca is by no means a difficult one; and in our attempts to naturalise them, we ought to feel the more encouraged when we reflect on the recent changes in the growth and supplies of sheep's wool, and how soon a farming stock propagates under judicious management. It must be equally borne in mind, that in using alpaca wool, we are not competing with that of our own sheep, but rather with that of the Angora goat (mohair) and silk; and the manufacture, it has been ascertained, does not cost half so much as that of the latter.'

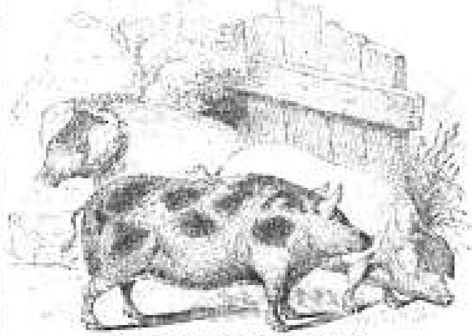
One other point calls for notice. Our present breeds of sheep are of essential importance as food to man. The flesh of the alpaca is spoken of as excellent by Acosta, Garcilasso de la Vega, and other writers on Peru. General O'Brien, an Irish gentleman in the Peruvian service, speaks of the flesh as 'delicious,' and likely also to improve much on the animal being placed on milder pastures than those of the Andes. In point of flavour, alpaca meat has, by good judges, been compared to North American venison, and even to our heath-fed mutton. The nature of pasture unquestionably affects both the quality and taste of meat; and there is, therefore, every reason to expect that, fed upon our downs or heaths, the alpaca would yield a good and marketable flesh, thus increasing our supply of one of the necessary commodities of life. In this kind of stock the breeder would find another good quality; namely, the largest quantity of flesh on the least possible weight of bone. The quarters weigh from 35 to 45 lbs., or nearly triple those of an ordinary sized sheep.

PIGS—RABBITS—POULTRY—CAGE-BIRDS.

As a source of sustenance and emolument to the humbler classes of society, the pig is only second in importance to the cow, and in many instances is found to be more available and useful than that animal. As an object of natural history, it is placed amongst the *Pachydermata* or thick-skinned order of the Mammalia—the hog, wild boar, and probably also the peccary of South America, being varieties of the same family (see ZOOLOGY, p. 140). The most remarkable characteristic of the common pig is its long roundish snout, furnished with a strong cartilage at the extremity, for the purpose of grubbing in the earth for roots and other kinds of food. The feet are cloven, and each possesses four toes, two of which are large, and furnished with stout hoofs, the other two being small, posteriorly situated, and scarcely touching the ground. The body is of a cylindrical form, low set, and thinly covered with bristles, which rise into a strong mane in many of the varieties. The tail is small, short, and in general twisted, and in some varieties is altogether wanting; the ears are either large and pendulous or short and pointed. The jaws of the pig are powerful, and the teeth with which they are furnished are very formidable, particularly in the wild varieties. Swine do not ruminate, and from this and other peculiarities, they can feed either on vegetable or animal substances—thus forming a kind of link between the herbivorous and carnivorous classes of animals. They are, in fact, omnivorous, and scarcely any sort of food comes amiss to them: the term 'voracious' is that most commonly applied to them.

BREEDS—GENERAL MANAGEMENT.

The breeds of pigs most esteemed in Great Britain are the Berkshire, Chinese, and Improved Essex. These are also the breeds best marked by distinctive features; though by crossings, and peculiarities of feeding and position, varieties differing in a slight degree from one another have been raised up in almost every county in England. The Berkshire breed, the parent stock of most of them, is of a reddish-brown tint, with black spots; moderately large ears, inclining forward, but erect; is deep in the body, with short legs and small bone; arrives early at maturity, fattens easily, and with remarkable rapidity. This variety, under good management, grows to an enormous weight. Culley mentions a Berkshire hog, fed by Mr Lawton of Cheshire, which measured, from the point of the snout to the tail, nine feet eight inches; its height at the shoulder was four feet five inches and a half. When living, this huge animal weighed twelve hundredweight two quarters and ten pounds; and when slaughtered, cleaned, and otherwise dressed by the butcher, ten hundredweight three quarters and eleven pounds, or eighty-six stones eleven pounds! The Chinese breed, generally speaking, is of small size. 'The body,' says a recent authority, 'is very nearly a perfect cylinder in form; the back slopes from the head, and is hollow, while the belly, on the other hand, is pendulous, and in a fat specimen, almost touches the ground; the ear is small and short, inclines to be semi-erect, and usually lies rather backward; the bone is small, the legs fine and short; the bristles are scarcely deserving of the name, being so soft, as rather to resemble hair; the colour is usually white, sometimes black, and occasionally piebald. The white sort are deemed preferable, from the superior delicacy of their flesh. The face and head are unlike those of any other description of swine, somewhat resembling those of a calf; hence this variety, if once seen, will not be readily forgotten. Chinese hogs are good feeders, arrive early at maturity, and feed fat, so to speak, on less food, and become so circumstanced, fatter, and heavier within a given time than any of our European varieties.' The recently-Improved Essex ranks high, for certain purposes, amongst our British breeds of swine. The improvement is said to be due to a cross between the old Essex and the Neapolitan pig; but it is probable also that the Chinese or Berkshire has had something to do in the work of regeneration. The Essex pig is described as up-eared; has a long sharp head; a long and flat carcass, with small bone; colour most frequently black, or black and white; and skin delicate, and almost bare of hair. He is a rapid feeder, but requires a greater proportion of food than the weight he attains to justifies; besides which, he has the character of being restless and discontented. The sows are good breeders, and produce litters of from eight to twelve; but they have the character of being indifferent nurses.



Old British—Berkshire—Chinese.

Besides the above varieties—which are at present the favourites at our Agricultural Exhibitions—the gigantic white and black breed of Cheshire, the white pigs of Suffolk and Hampshire, and the piebald hogs of Sussex and Shropshire, may be mentioned as the best known among the district-breeds of England. They are coarser, generally speaking, than the Berkshire and Chinese. Both of these have been pretty extensively introduced into Scotland, where a less valuable white breed appears to have been earlier located, if not indigenous. There is also a small gray pig, apparently aboriginal, which feeds in herds on the natural pasture on the Highland hills, and furnishes very sweet flesh. By artificial feeding, it can be raised to a considerable bulk. But the breed most commonly esteemed both in England and Scotland, is a mixture of the Chinese dark-coloured swine with the Berkshire, or some of the large varieties of British swine. This cross possesses many good qualities, and is peculiarly prolific. Either belonging or allied to the Berkshire variety, is the Hampshire *brock*, a small black pig suitable for cottagers, for it is easily fed and fattened, and is therefore highly esteemed. In Ireland, where the native pig is described as 'tall, long-legged, bony, heavy-eared, coarse-haired, and by no means possessing half so much the appearance of domestic swine as they do of the wild boar,' the breed has been greatly improved of late years, and the old unprofitable stock is rapidly disappearing. The improved Irish breeds are now so nearly alike to those of England, that they are not readily distinguishable from each other.

Choice of a Pig.

By whatever name the crop or breed may be called, the following *points* are enumerated by Mr Richardson as those by which the rearer should be guided in his choice of a pig. 'In the first place, sufficient depth of carcass, and such an elongation of body as will insure a sufficient lateral expansion. Let the loin and breast be broad. The breadth of the former denotes good room for the play of the lungs, and a consequent free and healthy circulation, essential to the thriving or fattening of any animal. The bones should be small, and the joints fine. Nothing is more indicative of high breeding than this; and the legs should be no longer than, when fully fat, would just prevent the animal's belly from trailing upon the ground. The leg is the least profitable portion of the hog, and we therefore require no more of it than is absolutely necessary for the support of the rest. See that the feet be firm and sound; that the toes lie well together, and press straightly upon the ground; as also that the claws are even, upright, and healthy. Many say that the form of the head is of little or no consequence, and that a good pig may have an ugly head, it being no affair of anybody but the animal himself who has to carry it; but I regard the head of all animals as one of the very principal points in which pure or impure breeding will be most obviously indicated. A high-bred animal will invariably be found to arrive more speedily at maturity, to take flesh earlier, and with greater facility, and altogether to turn out more profitably than one of questionable or impure stock; and such being the case, I consider that the head of the hog is by no means a point to be overlooked by the intending purchaser. The description of head most likely to promise, or rather to be the concomitant of, high-breeding, is one not carrying heavy bone, not too flat on the forehead, or possessing a too elongated snout—indeed the snout should, on the other hand, be short, and the forehead rather convex, recurving upwards; and the ear should be, while pendulous, inclining somewhat forward, and at the same time light and thin. Nor would I have the buyer to pass over even the *carriage* of a pig. If this be dull, heavy, and dejected, I would be disposed to reject him, on suspicion of ill health, if not of some concealed disorder actually existing, or just about to break forth; and there cannot be a more unfavourable symptom than a hung-down, slouching head, carried as though it were about to be employed as a fifth leg. Of course, if you are purchasing a fat hog for slaughter, or a sow heavy with young, you are scarcely to look for much sprightliness of deportment; but I am alluding more particularly to the purchase of young stores, the more general, because the more profitable, branch of pig management. Nor is colour to be altogether lost sight of. In the case of pigs, I would, as in reference to any other description of live stock, prefer those colours which are characteristic of our most esteemed breeds. If the hair be scant, I would look for black, as denoting connection with the delicate Neapolitan; but if too bare of hair, I would be disposed to apprehend too intimate alliance with that variety, and a consequent want of hardihood, that, however unimportant, if pork be the object, renders such animals hazardous speculations as stores, from their extreme susceptibility of cold, and consequent liability to disease. If white, and not *too small*, I would like them as exhibiting connection with the Chinese. If light or sandy, or red with black marks, I would recognise our favourite Berkshire; and so on with reference to every possible variety of hue. These observations may appear trivial; but I can assure my readers that they are the most important I have yet made, and that the intending pig-buyer will find his account in attending to them.'

Breeding—Littering.

As in the case of other domesticated animals, so with the pig—a perfect, profitable race cannot be maintained without careful and judicious breeding.—'In selecting the parents of your stock,' says the authority above quoted, 'you must diligently bear in mind the precise objects you may have in view—whether the rearing for pork or bacon; and whether you desire to meet the earliest market, and thus realise a certain profit with the least possible outlay of money, or loss of time; or whether you mean to be contented to await a heavier, although somewhat protracted return. If bacon and the late market be your object, you will do well to select the large and heavy varieties, taking care to ascertain that the breed has the character of being at once possessed of those qualities most likely to insure a heavy return; namely, *growth*, and *facility* of taking fat. If, on the other hand, your object be to produce pork, you will of course find your account in the smaller varieties; such as arrive with greatest rapidity at maturity, and which are likely to produce the most delicate flesh. In producing *pork*, it is not advisable that it be too fat, without a corresponding proportion of lean; and on this account I would recommend that you rather take a cross-bred sow than a pure Chinese stock, from which the over-fattening results might most naturally be expected.

In every case, whether your object be pork or bacon, the points to be looked for are—in the Sow, a small, lively head, a broad and deep chest, round ribs, capacious barrel, a haunch falling almost to the hough, deep and broad loin, ample hips, and considerable *length* of body in proportion to its height. One qualification should ever be kept in view, and perhaps should be the first point to which the attention should be directed; namely, the *smallness of bone*. Let the Boar be less in size than the sow, shorter and more compact in form, with a raised and brawny neck, lively eye, small head, firm, hard flesh, and his neck well furnished with bristles: in other respects, look for the same points as I have described in reference to the sow. Breeding within too close degrees of consanguinity, or, as it is technically termed, *breeding in and in*, is calculated to produce degeneracy in size, and also to impair the animal's fertility; it is therefore to be avoided, although some breeders maintain that a first cross does no harm, but, on the contrary, that it produces offspring which are predisposed to arrive earlier at maturity, and take fat with greater facility. This may in some instances be the case: it is so with horned cattle; but as far as swine are concerned, it is not my own experience, and I still adhere to the recommendation I have given. Differences of opinion also exist as to the precise age at which breeding is most advisable. Pigs, if permitted, breed at the early age of six or seven months; but this is a practice not to be recommended. My advice is, to let the female be *at least* one year old, and the male *at least* eighteen months; but if the former have attained her second year, and the latter his third, a vigorous and numerous offspring are more likely to result.'

The sow is very prolific, compared with other large-sized quadrupeds, and for that end is provided with from twelve to sixteen teats. Her period of gestation is sixteen weeks; the number of young varies considerably, being frequently below ten, and occasionally rising to twenty. The young pig is exceedingly delicate; and the brood sow should not be allowed to farrow in winter, but in spring and autumn, when the weather is less severe and food more abundant. Another peril to the litter arises from the semi-carnivorous habits of the mother, which lead her to forget the dues of nature, and devour her own brood. She ought therefore to be well watched, and fed abundantly at such periods. The male, for the same reason, must be excluded altogether. Not unfrequently, moreover, the young are crushed to death by the mother, in consequence of their nestling unseen below the straw. To prevent this risk, a small quantity only of straw, dry and short, should be placed below them. The young are weaned when six weeks old; and after weaning, it is essentially necessary to feed them with meal and milk, or meal and water.

Many persons labour under the notion that swine, while breeding, should be kept lean; but nothing can be more erroneous; for, after farrowing, great part of those juices which would be converted into milk, were she in good condition, will naturally go towards nourishing her system. When required for the purpose of fattening, the male young pigs are cut, and the females spayed, which is an analogous process. These operations should always be intrusted to a farrier or other properly-qualified person. At weaning time, it is also customary to 'ring' the young pigs; that is, to insert a ring of iron in the cartilage of the nose, to prevent the animal from grubbing and turning up the floor of the piggery. In pigs intended to be turned to the woods or fields, this process is necessary; but where requisite, it is preferable to the barbarous and less effectual plan of cutting off the cartilage altogether.

Pig-houses.

Although swine are found to succeed in all countries, and their constitutions have been accommodated to every climate, yet they are found to degenerate and thrive ill either in the extremes of heat or cold. In a native state we find them, when inhabiting countries towards either extreme, seeking situations most adapted to their constitution. Swine, in a domesticated state, require to be kept very dry and warm, otherwise they will never thrive. It will be noticed that in cold weather they invariably bury themselves among the straw and litter with which they are supplied as bedding, thus pointing out their natural desire for heat. The piggery should therefore be in some well-sheltered spot, and, if possible, with a south or west exposure. If kept in small styes, there should be a small aperture at each end of them, so as to permit the free passage of air through them for ventilation. These may be kept open constantly during the summer months, but only allowed to be open for air once every second day in winter, and that in the forenoon, while they must be carefully shut up in the evening. Pigs will be found to grow notwithstanding the neglect of all these precautions; but we know, from experience, that they will grow and fatten much faster, and will be more healthy under them. When the weather is fine, a few hours' liberty will also serve the health, and consequently the condition, of a growing pig; and if he can obtain a little grazing it will be all the better.

In most cases, pigs are kept in a shamefully filthy condition; their stye ill ventilated, the straw dirty, their small courtyard no better than a wet dunghill, and consequently the skin of the animal begrimmed with scurf and all sorts of impurities. We cannot too strongly reprehend this infamous treatment of the pig, which is not naturally dirty, as some suppose, but loves to be kept dry and clean, as well as warm, as any one may observe by the delight it evidently takes in having its hide scratched and scrubbed. Let us then beseech all pig-keepers under whose eye this sheet may come, to preserve the stye in the driest and cleanest condition possible, to change the straw frequently, and to curry the skin of the pig at least once a week. By doing so, without a particle of additional food, the animal will thrive and fatten in a very superior degree, while the flesh will be more pure and delicate.

To insure comfort to the pig or pigs, let the stye consist of at least two compartments—a sleeping apartment, and an open courtyard, the one opening into the other. The sleeping apartment should be about seven feet square; well built and roofed, for the sake of dryness; and the floor, formed of strong planks, should slope outwards to the door. The outer court should be about ten feet square; paved in a substantial manner with large flag-stones, and sloping in a particular direction, to which the liquid refuse can flow into a gutter. It is advantageous for the erection to be near the dunghill, to which all liquid may run, and solid materials be carried without loss. Keep plenty of straw both in the pig-house and its court, in order to absorb moisture or dung, and let all be raked out regularly, and renewed. The money lost by allowing the dung to go to waste by mere evaporation—flying off into the atmosphere—no one can calculate. The open court of the pig-house should, if possible, lie to the sun, as the inmates are fond of basking in his beams. The feeding utensils placed in the court should consist of two strong troughs, which cannot be easily knocked over. These should be daily washed and scoured.

Feeding.

In rural situations, where extensive woods exist, and where the grass is otherwise of no value, the feeding and breeding of pigs will be found very profitable to the cottager; for, where they have a wide range, they will require little food save what they find for themselves in grazing under the trees, and in digging for worms and roots of various kinds—for which latter task their long and strong snouts peculiarly fit them. Artificial feeding is only resorted to in winter, and when the pigs are to be fattened for the market or table. It is more common, however, for the cottager to keep one or two pigs entirely within a stye, to add to the means of subsistence of his own family; and even when kept with this limited view, the pig is a creature of no little consequence. As Cobbett acutely and pithily observes—'The sight of a flitch or two of bacon on the rack tends more to keep a poor man from poaching and stealing than whole volumes of penal statutes. They are great softeners of the temper, and promoters of domestic harmony.'

When a young pig is to be purchased for feeding and killing, it is advisable to buy one which will be about sixteen months old at Christmas, that or some time in January being the preferable period of slaughtering the animal. Unless for delicate pork, it should not be killed less than a year old. During the summer, the pig may be fed on any refuse from the kitchen or garden, including turnip and potato parings, table-waste, cabbage leaves, &c.; but if barley-dust, or grains from a distillery, can be economically procured, either forms a good article of diet. Let it be kept in remembrance that the finer the feeding, the finer will be the pork. The food should at all events be of a vegetable kind, or principally so; nothing beyond slops from the table being to be tolerated in the shape of animal food. Whatever be given, let it be offered in small quantities, and frequently, it being a matter of importance never to allow the pig to become violently hungry. The half-starving system of feeding is poor policy, and is repaid by a lank poor carcass scarcely worth killing.

Farmers possess great advantages for feeding pigs. The straw-yard of itself affords continual support to them; and many pigs reach the age of one year without having received any food but what they themselves have gathered, yet are in good condition. What with the sweepings of the barn, and the straw, turnips, carrots, and clover, lying about a steading, with the refuse of the kitchen, a farmer, it has been calculated, may sustain swine in the proportion of one to every seven or eight acres of land under crop, without being conscious of the consumption made by them. In few instances are swine reared in such numbers as to have crops specially laid out for them, though some writers assert that they would yield, in such a case, greater and readier profits than other live-stock habitually reared in the same way. Where rearing on the large scale is attempted, a proper plant of sheds, courts, and feeding-troughs is erected; and besides the miscellaneous refuse of the farm, special crops of coarse potatoes, cabbage, carrots, and Swedish turnips, are grown for the piggery.

About the month of September, the process of fattening pigs should commence, whether they be designed for pork or bacon. If for pork, the fattening need not be carried to the same extent. In either case, a nourishing diet must be given, the only precaution being not to commence feeding too rapidly, otherwise surfeit may be produced. The best materials for feeding are barley and peas-meal; and if milk, either skimmed or churned, can be given at the same time, it will greatly facilitate the feeding, and improve the quality of the flesh. Many persons feed their pigs on potatoes; but in that case the flesh is not so solid and good, and the fat is somewhat loose and flabby. Soft meat may do very well for pigs when they are growing, but it is not the food which should be given when they are fed for killing. Those who feed pigs for their own use, generally give them a feed or two of corn daily for fourteen days before they are killed, and give them nothing else but churned or skimmed milk to drink; and for a day before killing, the pig should not get any food. Where people's circumstances will not permit any of the modes of feeding for killing which we have above pointed out, boiled potatoes, mixed with a handful or two of oatmeal, may be resorted to as a substitute. It is undeniable, notwithstanding what has been said above, that the Irish peasantry produce excellent pork by feeding their pigs almost entirely on potatoes. It is not so fat as the pork produced from peas and barley, but it is on that account the better suited to stomachs unaccustomed to very strong food. Swedish turnips, carrots, and broken corn, with a little bean or pease-meal, make an excellent fattening dietary, and can be procured at little more than half the expense of the old potato-and-meal system.

In concluding the subject of feeding, we cannot do better than reiterate the following sound injunctions by Mr Richardson:—'1. Avoid foul feeding. 2. Do not omit adding salt in moderate quantities to the mess given—you will find your account in attending to this. 3. Feed at regular intervals. 4. Cleanse the troughs previous to feeding. 5. Do not overfeed; give only as much as will be consumed at a meal. 6. Vary your bill of fare. Variety will create, or at all events increase appetite, and it is further most conducive to health. Let your variations be guided by the state of the dung cast: this should be of a medium consistence, and of a grayish-brown colour. If hard, increase the quantity of bran and succulent roots; if too liquid, diminish or dispense with bran, and let the mess be firmer: if you can add a portion of corn, that which is spoiled, and thus rendered unfit for other purposes, will be found to answer perfectly well. 7. Feed your stock separately, in classes, according to their relative conditions: keep sows in young by themselves; and bacon pigs and porkers by themselves. It is not advisable to keep your stores too high in flesh, for high feeding, however strange it may seem, is calculated to retard development of form and bulk. It is better to feed pigs intended to be put up for bacon *loosely*, and not too abundantly, until they have attained their full stature; you can then bring them into the highest possible condition in an inconceivably short space of time. It is by such a system of management as this that the monstrous swine, their weight exceeding frequently twelve hundred pounds, or at all events half a ton, are raised. 8. Do not neglect to keep your swine clean, dry, and warm. These are essentials, and not a whit less imperative than feeding; for an inferior description of food will, by their aid, succeed far better than the highest will without them. And while I speak of cleanliness, suffer me to reiterate the benefit derivable from washing your pigs; this will repay your trouble manifold.' To these we may add—when the time arrives for slaughtering, let it be done in a humane and neat style by a butcher, so as to avoid all mangling or injury to the flesh.

[The most approved modes of curing and preparing pork, brawn, bacon, and hams, will be detailed in a subsequent number—47.]

Diseases.

In a state of nature, the pig is a healthy animal, and even when domesticated, is not readily injured, if treated with anything like common humanity. Cribbed and confined, however; compelled to wallow in filth; exposed indiscriminately to all weathers; now surfeited, and now starved; this day receiving stale food, and to-morrow a diet scalding hot—it is not to be wondered at if the animal should be subjected to the attacks of dangerous and often fatal maladies. The principal diseases to which swine, as thus treated, are liable, are—Fever, leprosy, tumours, murrain, measles, foul skin, mange, crackings of the skin, staggers, swelling of the spleen, indigestion or surfeit, lethargy, quincy, heavings or inflammation of the lungs, catarrh, and diarrhoea. A large proportion of these, it will at once be seen, are the direct result of want of cleanliness and injudicious feeding, and might be wholly prevented by attending to the directions already given. In cases of fever and other sudden ailments, bleeding, purgatives, and a spare diet, are the safest and surest remedies. Bleeding may be performed by opening the vein behind the ear, or by cutting off a portion of the ears and tail. Castor or linseed oil, Epsom salts, jalap, and flour of sulphur, are simple purgatives, and can be readily administered in a small mess of enticing food; and when given, should always be followed by a spare and liquid diet. For skin diseases, frequent scrubbings with soap and water, and unguents of tar and sulphur, will be found most effectual. In the case of measles—one of the most common diseases to which pigs are liable—the following recipe has been recommended:—Suffer the animal to fast, in the first instance, for twenty-four hours, and then administer a warm drink containing a drachm of carbonate of soda, and an ounce of bole armeniac; wash the animal, cleanse the stye, and change the bedding; give at every feeding, say thrice a day, thirty grains of flour of sulphur, and ten of nitre. It is to filthiness, combined with a common fault too little thought of, namely, giving the steamed food or wash to the pigs at too high a temperature, that this troublesome malady is generally to be attributed.

RABBITS.

Rabbits belong to the family *Leporidæ*, members of the *Rodentia* or Gnawing Order of animals. Their form and appearance are too well-known to require any special description. In a wild state, rabbits live in holes in the earth; and where the proprietor permits of their accumulation for sport, they collect in great numbers, undermining with their burrows whole plains or tracts of land, and forming what are called *warrens*. Their amazing fecundity renders the keeping of a few of them in a tame state an object of some consequence in cottage economy. The rabbit litters seven times in the year, and generally produces eight young at a time. At the age of five months the animal begins to breed; and, taking an estimate perfectly within bounds, it is supposed that a pair of wild rabbits, which breed no oftener than seven times in a year, would multiply in the course of four years to the amazing amount of a *million and a quarter*, if the young were preserved. Many of them die, however, being injured by cold and damp, or devoured by the male or *buck*.

Experienced rabbit-keepers conceive too frequent breeding to be injurious; but even when proper rules are observed in this respect, three domesticated females (*does*) and a buck will give a family a rabbit for dinner at least twice a week. This is a matter of some consequence. By keeping a few of these pretty little creatures, which wild vegetables will almost entirely supply with food, the poor man may derive ten times the benefit to be gained by violating the laws, and poaching on the game-preserves of his rich neighbours. A stock of rabbits is easily set a-going: they may usually be bought under one shilling, and sometimes even at twopence a pair. It is of importance, in making such a purchase, to attend to the varieties which feed kindly and furnish the best flesh.

The short-legged stout rabbits are generally supposed to be the most healthy, and also the best breeders. The large hair-coloured variety is much esteemed by some people; but the white, or white-mottled with black or yellow, are more delicate in flesh. The gray, and some of the blacks, approach nearer to the flavour of the wild rabbit than any others. With respect to the colours of these animals, gray is considered the worst of all colours; black is the next in gradation; fawn, and white and gray, hold the third place in estimation; pure white, with red eyes, is by some reckoned equal with, and by others superior to these; tortoise-shell (a rich brown and white, and brown, gray, and white) and black and white rank the highest; a uniform mouse-colour, though little noticed by fanciers in general, is much admired by a few.

The most important part of the duty of the rabbit-rearer is to erect his rabbit-house or hutch on proper principles. Two objects are particularly necessary to be attended to. The house or rabbitry must be kept always dry and well-aired; because the animal, in its natural state, prefers a dry and airy habitation. Rabbits are sometimes placed in boxes; but whether kept in these or in regularly-erected houses, the place must be kept quite dry, as too much humidity will cause the stock to rot. Where considerable numbers are housed together, fresh air is of great moment; still, they should not be exposed to cold currents, which may bring on a disease called the snuffles—a dangerous and frequently fatal malady.

Persons who live in large towns will in general find considerable difficulty in keeping rabbits, as it is seldom they have open grounds behind their houses wherein they might construct their rabbitry. In cases of this nature, rabbits might be kept on a small scale in wooden hutches, open in front, with spokes like a cage, and having a division to separate the sleeping apartment from the feeding-place, and a small door betwixt the one place and the other. But it will be found, on trial, that rabbits do not thrive well when put in cages, or confined in this manner. The genuine rabbitry must be a small house constructed on purpose, where the animals will have liberty to feed and amuse themselves. These houses may be built about four feet square, and the same in height, with a sloping roof, covered with thatch, or some other substance that will carry off the rain. This house ought to be paved on the floor, so as to prevent the inmates from burrowing and undermining the walls. It should be well laid with dry straw or meadow-hay, and possess several boxes with the open side downwards, and holes for the rabbits to go in and out. It would also be as well for these holes to be provided with slide-boards, which could be shut when necessary. To this house there ought to be attached a little open court, also paved, and covered completely with open spokes, so as to give air and light, as well as to afford you an opportunity of seeing the creatures when sporting or feeding.

On the subject of feeding, the following extract may be offered from the 'Boys' Own Book'—a pleasing work addressed to the young:—'If too much food be given at once, the animals will get disgusted with, and refuse it, so that a rabbit may be nearly starved by affording it too great a quantity of food. Most persons feed their rabbits twice, but for our own part we feed ours thrice a day. To a full-grown doe, without a litter, in the morning we give a little hay or dry clover, and a few of such vegetables as are in season; in the afternoon we put two handfuls of good corn into her trough; and at night we give her a boiled potato or two, more vegetables, and, if her hutch be clear of what we gave her in the morning, but by no means otherwise, a little more hay or clover. If you give rabbits more hay than they can eat in a few hours, except it be to a doe just about to litter, they will tread it under foot, and waste it; if you give them but a moderate quantity at a time, they will eat and enjoy it. Generally speaking, rabbits prefer green or moist food to corn; but it is necessary to make them eat a sufficient proportion of solid food, to keep them in health; occasionally, instead of corn, we give our rabbits a few split or whole gray peas. When a doe has a litter by her side, and also for rabbits recently weaned, we soak the peas a few hours previously to putting them in the trough. If a rabbit will not eat a proper quantity of corn, we mix a small quantity of squeezed tea-leaves with her portion, and stint her proportionately in green meat. Tea-leaves, in small quantities, well squeezed, may at all times be given, by way of a treat; but it is highly improper to make them a daily substitute for green meat.

Almost all the vegetables and roots used for the table may be given to rabbits: in preference to all others, we choose celery, parsley, and the roots and tops of carrots; and in this choice the animals themselves heartily agree with us; lettuces, the leaves, and, what are much better, the stumps of cabbages and cauliflowers, they eat with avidity, but these must be given to them with a sparing hand; turnips, parsnips, and even potatoes in a raw state, we occasionally afford our stock, on an emergency, when better roots or good greens are scarce. In the spring time, no soft meat is better for them than tares, so that they be not wet; in fact no green meat ought to be given to rabbits when there is much moisture on its surface. We have heard of some country persons feeding their rabbits on marsh-mallows, but we never did so ourselves. Dandelions, milk-thistles, or sow-thistles, we know, by long experience, they take in preference to all other food, except celery, parsley, and carrots; and nothing, as green meat, we are convinced, can be better for them.

It must be remembered that a doe will eat nearly twice as much when suckling as at other times; and when her litter begin to eat, the allowance of food must be gradually increased. In our own rabbitry we never admit chaff, and grains only in a dearth of green food. If we can obtain neither greens, roots, nor grains, at feeding-time, we make it a practice to moisten the corn with water, milk, or, as we before stated, with tea-leaves. Though a rabbit must be restricted from rioting in green or soft meat according to its own appetite, for its own sake, yet it is cruel to afford it only such food as will increase rather than appease its thirst; for this reason, in such a case as we have mentioned, we moisten the grain; and some rabbits will even do well with an occasional tablespoonful of water, beer, or milk; but it is a dangerous experiment to try the effect of a liquid on their stomachs.

If well fed, and kept warm, does will breed all the year; but most fanciers are contented with five litters in one season, and let them rest during the winter. It is a disadvantage, rather than otherwise, to have above six produced in a litter, as the young rabbits, when that is the case, are almost invariably weak and puny; and even if they be reduced to a moderate number, by removing some of them to the care of another doe, or otherwise, they seldom or never become remarkable for their size or beauty.

Diseases may in a great measure be prevented by regularity in feeding, good food, and cleanliness. The refuse of vegetables should always be scrupulously rejected. For the liver complaint, to which rabbits are subject, there is no cure; when they are attacked by it, fatten them, if possible, for the table. The snuffles are occasioned by damp or cold. If there be any cure for this disorder, it must be dryness in their hutches and food. Squeezed tea-leaves generally restore a doe to health, if weak, or otherwise affected after littering. A little bread moistened with warm milk may also be advantageously given to a doe at this critical period. When old rabbits are attacked by a looseness, dry food will in general restore them; but do what you will, it is very difficult, and in most cases impossible, to save young ones from sinking under it; dry food for them, as well as for the old ones, is the only remedy.'

When rabbits are to be used as food, it is commonly deemed beneficial to feed them for a short time on hay, and afterwards on shellings and oats, when the flesh will grow very delicate in flavour. As an example of the ordinary extent to which rabbits may be made productive, with common care, the case of a labouring man in the country may be mentioned, who, in a small wooden house enclosed by a railing, fed a batch of rabbits, and killed annually about twenty dozen, still maintaining his stock unbroken. What with the skins, flesh, and sales of the young, he turned the animals to good account; yet he scarcely expended a penny upon their food, and even the care of them was spared to him, when he had once fairly put his children in the way of management.

POULTRY.

Poultry (from *poule*, French for hen) is a term applied to different kinds of large birds in a state of domestication, as the chicken or barn-door fowl, turkey, duck, goose, pea-fowl, and guinea-fowl. The most numerous and important in every respect are

Chickens.

The chicken is classed by naturalists in the tribe of the *Gallinaceæ*, forming part of the order *Rasores* or Scraping-Birds (ZOOLOGY, p. 149). It is needless to describe minutely the appearance of the barn-door fowl. The most prominent characteristics of the cock, or male bird, are a thin indented comb, with wattles on each side under the beak; a tail rising in an arch, and a great variegation of colours. The female, or hen, is smaller as regards body, comb, and wattles, and her tints are less vivid. The domestication of this useful bird seems to have taken place in the earliest times, and Persia is commonly supposed to have been the country of its origin.

Many varieties of it have been enumerated as existing in Britain; but the differences betwixt these, in the majority of cases, seem to lie as much in colour as in any more important features. The best-marked varieties are the following:—The Dunghill Fowl, Game Fowl, Dorking Fowl, Polish Fowl, Spanish Fowl, and Bantam. The first of these varieties is a mongrel one, arising from crosses with all the other breeds; but it is the common and most useful variety. The best fowls of this sort are of middle-size and dark colour, and have white, clean legs; the pure white dunghill fowls are held to be the weakest in constitution, and to lay fewest eggs. It has been usually agreed to call the game fowl the proper English fowl. The body is erect and slender, and the colours showy, particularly those of the cock. In comparison with other breeds, the game bird is like the race-horse beside that which draws the cart and plough. The flesh, moreover, is peculiarly white and delicate in flavour, while, though small, the eggs are also of a very superior quality. There is a peculiarity of disposition, however, in this variety of the domestic fowl, which, while for ages the source of a cruel species of sport, has always impaired the real utility of the creature to a very great degree. We allude to the pugnacious spirit which has gained for the fowl its peculiar name. So strongly-marked is this propensity, that broods scarcely feathered are found occasionally to have reduced themselves to utter blindness by reciprocal battling. Even when the breed is crossed and recrossed, a tincture of the love of fighting still remains, rendering such admixtures the source of risk and trouble, though in other respects advantageous. Where persons prefer to have a game-cock in their poultry-yard, their choice, according to the best authorities, should be directed to a bird of one or other of the following colours:—dark-red, dark black-breasted red, dark-gray, mealy-gray, and reddish-dun.

The Dorking fowl is named from a town in Surrey, where it has long been bred in great numbers. It is a large bird, well-shaped, with a long capacious body, short legs, and five claws upon each foot instead of four. One spur characterises other breeds of the common fowl, but the Dorking fowl has two spurs on each leg. These distinctive marks seem to be of old standing in peculiar breeds, as both Aristotle and Pliny mention five-toed fowls. Though from repeated crossings the Dorking fowls are now found of all colours, white or yellowish-white is supposed to have been the primitive and genuine tint. They lay large eggs, and in great plenty. The Poland (Polish or Paduan) fowl is much valued by breeders, but is seldom found perfectly pure in Britain. The species was imported principally from Holland, and when unmixed, was uniformly of a black colour, with a white crest or tuft on the heads of both cock and hen. Their form is plump and deep, and the legs of the best sorts not too long. They are called *everlasting* layers, from the number of eggs produced by them, and from their disinclination to sit and hatch, which office is usually done for their eggs by other hens. The Spanish fowl is of large size, and lays large eggs. It is of the Polish family, and is almost uniformly marked by a black body, black legs, and large red combs. In London and its vicinity, the breed is now extremely common, being valued for the size of the eggs; but it is supposed to be inferior in some respects to other breeds, though yielding good food. The bantam fowl is well known for its small size, and its feathered grotesque-looking limbs. It was originally a native of India, and the nankeen-coloured and black birds are the most esteemed. The bantam should have a rose-comb, a full tail, and a lively carriage, and should not weigh above one pound. It has been recently discovered that the characteristic of feathered legs is not an improvement, the birds with clean bright limbs being the best. The flesh of this diminutive breed is said to be peculiarly delicate.

Besides these well-marked varieties of the common domestic fowl, there are a number of others, brought from foreign countries, which have produced mixtures pretty familiar to breeders. The Turkish, Malay, Rumkin, Russian, and Barbary species, may be mentioned as the principal of these. It need only be observed here, that all the crested mixtures or varieties are much esteemed, as possessing the best qualities of the race. All or any of the breeds of the domestic fowl are valuable to the cottager, even one good laying hen being a treasure to a humble family.

Hen-house.—The artificial assistance given by the cottager in housing the birds is usually of the scantiest order. The upper part of the space at the door of the cottage, or the *baulks* (loft), is often the nightly roost of two or three hens, and the roadside is their daily walk. Yet, with the petty scraps of food furnished in addition to their own pickings there, these hens will lay good eggs, and produce fine birds. At farm-steadings, it is common for the hens to roost among the beams of the stables or cattle sheds, and to lay in holes formed by scraping away a portion of lime on the top of the side walls. Very little pains might give to the humblest families much better and ampler accommodation for poultry. We quote on this subject the directions given in a little work by Mr Peter Boswell of Greenlaw:—'Always in the building of a cottage, and sometimes even where there was no intention of the kind when it was built, very ample accommodation for poultry can be provided, almost without a shilling of additional expense. To this purpose a part of the space next the roof, so often unoccupied and useless, might easily be devoted. To accomplish the object, a part of it next the kitchen fire gable end should be partitioned off, floored, and fitted up with baulks and laying-places. This could be done either on a large or a small scale, according to the inclination or the means of the projector. An opening of sufficient width should be made in the wall, at the height of the lower ceiling, through which the fowls could be conducted, by means of a *hen-ladder*, to the enclosure prepared for them below. There must be a hatchway somewhere, to afford access for the purpose of inspection and cleaning. If the attics are sufficiently high, it may be placed anywhere, but evidently with greatest convenience in the passage of the house; but if they are low, the nearer it is to the space portioned off for the reception of the fowls the better. This is a location for poultry possessing many advantages. Having their berth immediately above the cottage kitchen, they are secured in a proper degree of dryness and warmth, which in winter, especially with the spring-hatched pullets, will tell well in the production of eggs. Perhaps this is the best hen-house locality for securing eggs in winter which can be suggested to the frugal and judicious. Besides, the fowls are here free from many dangers, and safe from many enemies, to which they are exposed in a lower and more open situation.'

Another simple poultry-house of small size may be formed by building a shed against the gable of the house, opposite to the part warmed by the kitchen fire, and placing cross-bars in it for roosting, with boxes for laying in, or quantities of fresh straw. There should always be an opening, to allow of the cleaning out, once a week at least, of the poultry-house—a process too often neglected, but very essential to the health of the poultry. They never will thrive long amid uncleanness; and even with the utmost care, a place where poultry have been long kept becomes what the housewives call tainted, and there they will thrive no longer. The surface of the ground becomes saturated with their exuviæ, and is therefore no longer healthy. To avoid this effect, some poulterers in the country frequently change the sites of their poultry-houses, to obtain fresh ground; and to guard against the same misfortune, farmers who cannot change their hen-houses and yards, purify the houses by fumigations of blazing pitch, by washing with hot lime-water, and by strewing large quantities of pure sand both within and without the poultry-houses. Washing the floor of the house every week is necessary; for which purpose it is of advantage that it be paved either with stones, bricks, or tiles. But as these three modes are expensive, a good flooring, which is cheaper, may be formed by using a composition composed of lime and smithy ashes, together with the riddlings of common kitchen ashes; these having been all finely broken, must be mixed together with water, and put on the floor with a mason's trowel, and nicely smoothed on the surface. If this is put on a floor which is in a tolerably dry situation, and allowed to harden before being used, it will become nearly as solid and compact as stone, and is almost as durable. The inside of the laying-boxes requires frequent washing with hot lime-water, to free them from vermin, which greatly torment the sitting hens. For the same purpose poultry should always have a heap of dry sand or fine ashes laid under some covered place, or thick tree, near their yard, for them to dust themselves in; this being their resource for getting rid of the vermin with which they are annoyed.

The office of keeping and managing domestic fowls should be performed by the same individual, as the voice and presence of a stranger scare them, and disturb the operations of the hen-house. To distribute food and drink at regular hours, to visit the nests, to remove eggs as soon as laid, and carry them to a cool place, to examine by candle-light what eggs are fecundated, and to place these under the hen, and mark the time, are among the daily duties to be performed by the keeper. When the hens lay in a secret corner or covert, the keeper may readily discover it by placing a few grains of salt in the oviduct, which hurries on the process of laying, and causes the animal to retire to the spot anew.

Feeding.—Most persons are doubtless aware that fowls swallow food without mastication. That process is rendered unnecessary by the provision of a *crop*, an organ which is somewhat similar to the first stomach of the cow, and in which the food from the gullet is macerated, and partly dissolved by secreted fluids. From the crop, the food passes downwards into a second small cavity, where it is partly acted on by a digestive juice; and finally, it is transferred to the gizzard, or last stomach, which is furnished with muscular and cartilaginous linings of very great strength. In the gizzard, the partially-softened food is triturated, and converted into a thin paste, fit to be received into the chyle-gut, and finally absorbed into the circulation. Such is the power of the gizzard in almost all kinds of poultry, that hollow globes of glass are reduced in it to fine powder in a few hours. The most rough and jagged bodies do no injury to the coats of the gizzard. Spallanzani even introduced a ball of lead, with twelve strong needles so fixed in it that their points projected a fourth of an inch from the surface, and the result was, that all the needles, with the exception of one or two, were ground down in a short time to the surface of the ball, while those left were reduced to mere stumps. It is remarkable that, to add to the triturating powers of the gizzard, fowls are gifted with the instinct of swallowing gravel with their food.

Fowls, when left to roam at large, pick up all sorts of seeds, grains, worms, larvæ of insects, or any other edible substances they can discover, either on the surface of the ground or by scraping. They also pick a little grass as a stomachic. The more that hens can be allowed to run about to gather their own food, the better for their own health and the pockets of their keeper. When secluded, and fed altogether in an artificial manner, their keep becomes expensive, and is, on the whole, seldom compensated by their produce. We have indeed great hesitation in advising any one to keep fowls who cannot unexpensively give them plenty of refuse from the table, or permit them to range in a field or lane in quest of what seems proper for their natural appetite. The very pleasure of ranging and scraping seems advantageous to them.

If kept in a courtyard or pen, and requiring altogether artificial feeding, their natural tastes should be consulted as far as conveniently practicable. They should be fed regularly, and with a miscellaneous kind of diet; allowed at all times access to clean water for drinking, and have earth, sand, or dust, to scrape at pleasure and roll themselves in. A certain quantity of chalk or lime should also be scattered about for them to pick up, as that material is required by them in the production of eggs. Speaking on this subject, Professor Gregory of Aberdeen, in a letter to a friend, published in a newspaper, observes—'As I suppose you keep poultry, I may tell you that it has been ascertained that, if you mix with their food a sufficient quantity of egg-shells or chalk, which they eat greedily, they will lay, other things being equal, twice or thrice as many eggs as before. A well-fed fowl is disposed to lay a vast number of eggs, but cannot do so without the materials for the shells, however nourishing in other respects her food may be; indeed a fowl fed on food and water free from carbonate of lime, and not finding any in the soil, or in the shape of mortar, which they often eat off the walls, would lay no eggs at all, with the best will in the world.'

In a state of domestication, the hard food of which fowls seem most fond are peas and barley (oats they do not like); and besides a proportion of these, they may be given crumbs of bread, lumps of boiled potatoes, not too cold, or any other refuse. They are much pleased to pick a bone; the pickings warm them, and excite their laying propensities. If they can be supplied with caterpillars, worms, or maggots, the same end will be served. Any species of animal food, however, should be administered sparingly; and the staple articles of diet must always be of a vegetable nature. When wanted for the table, the quantity of food may be increased, and be more substantial; they should also be kept more within the coop, and as quiet as possible. A fortnight's feeding in this way will bring a fowl of a good breed up to a plump condition.

Laying.—The ordinary productiveness of the hen is truly astonishing, as it usually lays, in the course of a year, two hundred eggs, provided it be allowed to go at liberty, is well fed, and has a plentiful supply of water. Many instances have been known of hens laying three hundred in a year. This is a singular provision in nature, and it would appear to have been intended peculiarly for the use of man, as the hen usually incubates only once in a year, although she will occasionally bring out two broods. Few hens are capable of hatching more than from twelve to fifteen eggs; so that, allowing they were all to sit twice a year, and bring out fifteen at a time, there would still be at least one hundred and seventy spare eggs for the use of man. It is therefore evident, that in situations where hens can pick up their food, they must prove very profitable; for supposing that the eggs of one fowl during the year were sold, without any of them being hatched, they would bring (if near a large city) on an average ninepence per dozen, or fourteen shillings, and the hen herself would be worth two shillings at least. As the number of eggs which are annually brought out by a hen bear no proportion to the number which she lays, schemes (to be subsequently noticed) have been imagined to hatch all the eggs of a hen, and thus turn her produce to the greatest advantage; so that, in place of twelve or fourteen chickens, upwards of two hundred may be produced from the annual produce of a single fowl.

Hens will lay eggs which have received no impregnation, but from these, as a matter of course, no hatching can take place; they are equally good, however, for eating. When the chief object is to breed chickens, a cock should be allowed to walk with ten or twelve hens; but when eggs are principally required, the number of hens may be from fifteen to twenty. Endeavour to procure a cock of a good breed, not game, and let him be in his prime, which is at eighteen months to two years old. Cocks will last two years, after which they lose their liveliness of colours, and become languid, inactive, and mere consumers of food. It is fit, therefore, that younger cocks should then take their place in the poultry-yard. It is common to make choice of a young cock, by pitting one or two against each other, and selecting the most courageous, which is always sure to be the favourite of the yard.

Some remarks have been made on the colours of the best hens of the different varieties. As to other qualities, M. Parmentier recommends that they should be chosen of a middling size, robust constitution, large head, bright eyes, and pendant comb. Crowers should be rejected, and those that are of quarrelsome tempers, such hens being rarely good hatchers or layers. Old hens, or those above five years old, are of little use when added to a stock; and when the comb and claws are rough, it is a sign that they have ceased to lay.

If left to themselves, hens would produce, like some wild birds, two broods in the year. Early spring, and, after a cessation, the end of summer, are the two seasons in which they begin naturally to lay. In the depth of winter, under ordinary circumstances, hens very rarely lay eggs, though by artificial means they can be made to do so. If the temperature of the place where they are kept be raised by a stove, or otherwise, they will produce eggs. The fowls of the Irish peasantry, which are usually kept in the cabins of the owners, lay often in winter, in consequence of the warmth of their quarters; and there can be no doubt that warmth affords the most effective means of procuring new-laid eggs in winter, though stimulating food may aid in producing the same result. The fecundity of hens varies considerably. Some lay but once in three days, others every second day, and others every day. In order to induce laying, each hen should have its own nest, made with soft straw, and furnished with a piece of chalk as a decoy. The signs which indicate when a hen is about to lay are well known. She cackles frequently, walks restlessly about, and shows a brighter redness in her comb and wattles. After the process of laying is over, she utters a loud and peculiar note, to which the other fowls usually respond. Shortly after the egg is laid, it should be removed, for the heat of the hen soon corrupts it. When the eggs are taken away by the poultry-keeper, they should immediately be laid in a cool and dry place. If allowed to absorb damp, they soon spoil; indeed one drop of water upon the shell quickly taints the whole egg.

Various methods have been tried to prevent the absorption of air through the shell, and preserve the freshness of the eggs. A not uncommon plan is to keep them secluded from the air in bran, rye, or ashes, which may do very well where the eggs are to be kept in this way till eaten, but is utterly useless if quantities of them have to be sent to market. We beg to offer a plain piece of advice to cottagers on this subject, which, if properly acted upon, will give them the means of at all times commanding the highest price for *fresh eggs*, although situated a hundred miles or more from the place of sale. *Smear all your eggs with a bit of fresh butter the moment you get hold of them.* Do not load the shell with grease, but merely give a light varnish. The butter must be good. By this simple process of smearing, which does not taint the interior in the slightest degree, the egg is as fresh at the breakfast-table when three months old as if just newly laid, and possesses all the delicious milkiness which the freshest eggs possess. Scarcely anything is more common than to hear complaints of the difficulty of getting fresh eggs, and all a result of the sheer negligence of fowl-keepers. By the plan we mention, there need never be such a thing as a bad egg heard of. Dipping in lime-water and some other processes, which will be noticed in No. 47, are said to be equally effectual.

Hatching.—When eggs are to be hatched, it is necessary to pay attention to the choice of proper ones for the purpose. The company of the male bird renders the hen productive of fecundated eggs; and, as already noticed, it is only eggs of this kind which are available for producing young. The eggs must also be fresh; from the time they are laid, they should lie aside in a cool place. It is said to be possible to ascertain, from the appearance of the egg, whether the forthcoming progeny is to be male or female; but we greatly doubt the truth of the popular notions on this subject. When eggs are left to be brought forth by the hen, a certain number is placed under her in the nest, when she is in the full inclination to sit. From nine to twelve eggs are placed, according to the extent of the breast and wings; and the time required for hatching is twenty-one days. Sometimes a hen will desert her eggs, a circumstance which may occasionally be traced to an uncomfortable condition of the skin, caused by vermin or want of cleanliness, and this affords a strong reason for keeping the hen-house clean, and giving the animals the means of purifying their feathers. Occasionally the hen is vicious, or, in short, a bad sitter, and experience in pitching on the best hatching hen is the only remedy. Sometimes a hen will break her eggs with her feet; and in such cases the broken eggs must be removed as soon as observed, otherwise she may eat them, and from that be tempted to break and eat the sound ones, and thus spoil the whole.

It has generally been found that hens which are the best layers are the worst sitters. Those best adapted have short legs, a broad body, large wings, well furnished with feathers, their nails and spurs not too long or sharp. The desire to sit is made known by a particular sort of clucking; and a feverish state ensues, in which the natural heat of the hen's body is very much increased. The inclination, or, as physiologists term it, the *storge*, soon becomes a strong and ungovernable passion. The hen flutters about, hangs her wings, bristles up her feathers, searches everywhere for eggs to sit upon; and if she finds any, whether laid by herself or others, she immediately seats herself upon them, and continues the incubation.

With a proper provision of food at hand, warmth, quiet, and dryness, a good hatching hen will give little trouble, and in due time the brood will come forth; one or two eggs may perhaps remain unhatched or addled, but their loss is of little consequence. As soon as the hen hears the chirp of her young, she has a tendency to walk off with them, leaving the unhatched eggs to their fate; it is therefore advisable to watch the birth of the chicks, and to remove each as soon as it becomes dry, which may be in a few hours afterwards. By this means the hen will sit to hatch the whole; yet she should not be wearied by too long sitting. If all the eggs are not hatched at the end of twelve or fifteen hours after the first chick makes its appearance, in all probability they are addled, and may be abandoned. The chicks must be kept in a warm place during the first day, and at night restored to the mother, who now assumes her maternal duties. The food given to the young chicks should be split grits, which they require no teaching to pick up; afterwards the ordinary food of the poultry-yard, or what the mother discovers for their use, is sufficient. Some give the yolks of hard-boiled eggs or curd, when a nourishing diet seems advisable. The extreme solicitude of the hen for her young, or the brood which may be imposed upon her, is well known. She leads them about in quest of food, defends them by violent gesticulations and the weapons which nature has given her, calls them around her by a peculiar clucking cry, and gathers them carefully under her wings to shelter them from danger, or to keep them warm at night. This maternal care is bestowed as long as the chickens require her assistance; as soon as they can shift for themselves, the mutual attachment ceases, and all knowledge of each other is very speedily lost. The young now go to roost, and the mother again begins to lay. Young hens, usually called pullets, begin to lay early in the spring after they are hatched.

Artificial Hatching.—As heat is all that is necessary to incubation, eggs may be hatched artificially, without the intervention of the hen. This practice was common in Egypt in very early times, and has since been adopted in many other quarters, but with indifferent success. In the neighbourhood of London, attempts at artificial hatching have from time to time been made—one of the most successful being that of the *Eccaleobion*, or life-evoker, established several years ago. An oven, consisting of eight floors or compartments, was employed to contain the eggs, while they were subjected to heat from steam-pipes. Each compartment held from 200 to 300 eggs, and the whole exhibited the hatching process in all its various stages. The regularity with which the temperature was maintained, as well as accommodated to each peculiar stage of the process, brought out the chick with much greater certainty than when the incubation was performed by the hen, which sometimes cannot be kept steadily to the work. A visitor to the Eccaleobion gave the following account in 'Chambers's Edinburgh Journal,' No. 400, of the management of the chick after hatching:—'The superintendent of the oven politely exhibited a compartment in which the eggs were chipping. Some had chipped the day before, others that day, and some would not be chipped till the morrow; in a few cases, we observed the beak of the chick boring its way through the shell, and getting itself emancipated. When the little creatures are ushered into the world, they are not immediately removed out of the oven, but are allowed to remain for a few hours till they become dry; they are then removed and put into a glass-case, on the table at the end of the room. This case is very shallow, and the glass cover can be easily pushed aside to permit the superintendent handling them if required. They are here for the first time fed, though not for twenty-four hours after being hatched; the material scattered among them is small bruised grits, or particles little larger than meal; these they eagerly pick up without any teaching, their instinctive desire for food being a sufficient monitor. After the brood has been kept in the glass-case, which is partially open, for two or three days, and been thus gradually accustomed to the atmosphere, they are removed to one of the divisions in the railed enclosure on the floor. Here hundreds are seen running about, uttering peepy cries, picking up grits, or otherwise amusing themselves, all being apparently in as lively and thriving a condition as if trotting about in a barn-yard. At six in the evening they are put to bed for the night in the coops, twelve together in a coop: these coops are small wooden boxes lined with flannel, and furnished with a flannel curtain in front, to seclude and keep the inmates as warm and comfortable as if under the wing of a mother. At six or seven in the morning they are again allowed to come forth into their court-yard, which, being strewed with sand, and provided with food and water, affords them all the advantages of a run in an open ground.

I made some inquiries respecting the failures in hatching, and deaths, and received the following information:—The eggs are usually purchased from Leadenhall market, and consequently, not being altogether fresh, or otherwise suitable, one-half of them fail in hatching. Once hatched, they are safe, for not more than one dies out of fifty which are brought into existence. If good and suitable eggs could be procured in all seasons, the failures in hatching would be comparatively trifling. Bad eggs, therefore, are the weak point in the establishment; and I should recommend the proprietor to complete his arrangements, by adding an egg-laying department to those which he has for hatching. This might be done by keeping a regular poultry-yard, either in connection with the place or in the country. The apparatus for hatching is capable of producing forty thousand chickens in a year; and making allowance for failures, the actual produce cannot fall far short of half of that number. When three weeks old, as I was informed, the chickens are taken to market, and sold for a shilling each. Thus, we should suppose, the Eccaleobion turns out at least a thousand pounds' worth of chickens annually—no bad revenue, it will be said, after paying expenses, but not greater than the ingenious contriver and proprietor, Mr William Bucknell, deserves.' The writer concludes by calling the attention of the public to the case with which similar establishments might be got up in all large towns. The price of poultry, he argues, might be greatly lowered in the market, and the dietary resources of the common people materially improved and extended. He forgets, however, that the rearing or feeding, and not the hatching, is the main difficulty; and that it is not possible for any establishment of this kind to compete with the cottager and farmer's wife, the fattening of whose chickens cost little, or next to nothing. Unless the price can be reduced, the mere creating of greater numbers will never have the effect of causing a greater demand than at present.

Capons.—The best modes of fattening fowls for the table have been adverted to. The process of converting chickens into capons, however, ought also to be noticed here. By removing the reproductive and oviparous organs from the male and hen chickens respectively, a great change is produced in them as regards voice and habits, and they can be made remarkably fat for the table. Capons are chiefly reared in Sussex, Essex, and one or two other counties around London. They can be trained to watch chickens, hatch eggs, and do many useful offices of the poultry-yard. Upon the whole, however, the special benefit derived from rearing capons does not counterbalance the trouble which they give and the danger of the primary operation, for an account of which, as practised in different countries, see Dickson on Poultry.

Diseases.—Chickens are liable to various diseases, demanding attention from the poultry-keeper. The *pip* is the most common; it consists of a catarrhal thickening of the membrane of the tongue, causing a dangerous and obvious obstruction to respiration. It may be cured in most cases by throwing the fowl on its back, holding open the beak, and scraping or peeling off the membrane with a needle or the nail. The part may be wetted with salt or vinegar afterwards, and a little fresh butter pushed over the throat. Dr Bechstein recommends giving a mixture of butter, pepper, garlic, and horse-radish, as an internal remedy. But the operation is most effective. *Thirst* sometimes attacks fowls like a fever, and often arises simply from dry food, though more frequently symptomatic of indigestion or some internal and deep-seated derangement. Careful attention to diet is the first and great point in all such cases. If *constipation* appear to be present, bread soaked in warm milk, boiled carrots or cabbages, earth-worms, chopped suet, or hot potatoes with dripping, will be found useful. A clyster of sweet oil should be tried in severe cases. Where a tonic seems to be required, a little iron rust may be mixed with the food, and will generally relieve atrophy or loss of flesh. Where diarrhoea or scouring is observed, iron or alum may be given in small quantities. There is also a species of influenza, called the *roup*, which is often epidemical in the poultry-yard, and causes much havoc among the young birds. The eyes become swollen, a discharge comes from the nostrils, and the fowl gapes continually, showing much difficulty of breathing. Some observers have ascribed this complaint to worms in the windpipe, and have recommended their extraction by an operation; but warmth, cleanliness, soft food, and such laxatives as sulphur, with frequent ablutions of the eyes and nostrils, are more likely perhaps to do good, and are not attended with danger. Where general fever has been observed in fowls, the use of a little nitre has been found very advantageous. Saffron is another remedy very often employed in relieving the symptoms of sickness in fowls.

Many of these remarks will apply equally well to the diseases of geese and the other species of domestic poultry yet to be noticed; and this subject, therefore, need not again be adverted to in detail.

Turkeys.

The turkey, like the common chicken, has been included by naturalists in the *Gallinaceous* family of birds, and possesses the main characteristics common to the whole. It is a native of the woods of North America, and is certainly one of the most valuable fowls which have been naturalised in this country, but is very difficult to rear. The turkey-hen lays from fifteen to twenty eggs, and then sits upon them. She will bring out two broods in a year. The eggs are of a pale yellowish-white colour, finely streaked and spotted with reddish-yellow. They are a most delicious food, much more delicate in their flavour than those of the common hen. In England or Scotland, however, the eggs are comparatively seldom to be met with for sale, being deemed too valuable to be used as food. In Ireland, they are to be got in the markets in great abundance, especially in the midland counties, where we have bought them at ninepence per dozen. In that country, when the hen has laid about half-a-dozen eggs, they afterwards take away one daily, by which means the hens are induced to produce a greater number of eggs than otherwise. This they assist by means of stimulating food, such as hemp-seed and buck-wheat. There is an interval of a day between the laying of each egg. It is said that the first two eggs which she lays are unfruitful. A turkey-hen can seldom hatch more than from sixteen to eighteen eggs. The time of incubation varies from twenty-seven to twenty-eight days, at which time the young begin to pierce their shelly prison, and emerge from it.

General Treatment.—When turkey chicks first come forth, they are extremely weak, and much assiduous care is necessary to rear them. The first thing to be attended to is, to remove them to a situation where they are not exposed to the sun's rays, which at first are too powerful for them. A woody place is the most suitable to their natural habits. Nothing is so destructive to them as rain, from which they must be protected. When young turkeys accidentally get wet, they should be brought into a house, carefully dried by applying soft towels to them, and then placed near a fire, and fed upon bread which has been mixed with a small proportion of ground pepper or ginger. It should be made up in the form of small peas. If the bread is too dry for this purpose, it may be moistened with a little sweet milk. Should the turkey-poults refuse to eat it, a few of these pellets may be forced down their throats. Even heavy dews prove destructive to them, and frost is no less injurious in its effects. These must therefore be most carefully guarded against when the hens incubate in March or early in April. Dry and sandy situations are most congenial for breeding turkeys, and especially elevated situations where large woods are contiguous. A single male turkey is sufficient for twelve or sixteen females, although the former number is probably the safest, to prevent sterility in the eggs, which is frequently the case with those of turkeys. Eggs should never be intrusted to the care of a female until she is at least two years of age, and they may be kept for the purpose of incubation till they reach their tenth year. The largest and strongest hens should always be kept for this purpose. During the time the hen is sitting, it becomes necessary to place food near her; as otherwise, from her assiduity, she may be starved to death, as turkey-hens seldom move from their nest during the whole time of incubation.

Where farmers rear turkeys in great numbers, they do not indulge the hen by allowing her to sit as soon as she has done laying, but keep them from her until all the other hens have ceased to lay, as it is of consequence that they should all be hatched about one time. When hens are unhappy during this interval, they may be indulged with hens' eggs. When they have all ceased to lay, each of them is provided with a nest ranged close to the wall, in a barn or other convenient place, and each is supplied with from sixteen to twenty of her own eggs. The windows and doors are then closed, and only opened once in the twenty-four hours for the admission of air, and for the purpose of feeding the hens. They are taken off their nests, fed and replaced, and again shut up. On the twenty-sixth day, the person who is intrusted with the management of the birds examines all the eggs, and removes those that are addled; feeds the hens, and does not again disturb them till the poults have emerged from their shells, and have become perfectly dry, from the heat of the parent bird; as to be subjected to cold at this time would certainly kill them. When the young birds are thoroughly dried, two of the broods are joined together, and the care of them intrusted to a single hen; and those which have been deprived of their offspring are again placed on hens' or ducks' eggs, and subjected a second time to the tedious operation of incubation, in which case it is not unusual for them to bring out thirty eggs. We cannot recommend this practice in point of humanity; for the poor hens, when they have accomplished their second sitting, are literally reduced to skin and bone, and frequently so weak as hardly to be able to walk.

As before hinted at, great care should be taken of the young turkey-poults; besides warmth, proper food, and shade, the nearer they are to a pure running stream the better, as they drink a great deal, and nothing is of greater importance to their being successfully reared than fresh drink. They must be also carefully protected from strong gusts of wind, and on the slightest appearance of a thunder-storm, should be immediately taken into a house. They should get no food for twenty-four hours after they leave the egg. Their first food should be hard-boiled eggs finely chopped, and mixed with crumbs of bread. Curd is also an excellent food for them. When they are about a week old, boiled peas and minced scallions are given to them. If eggs are continued, the shells should be minced down with their food, to assist digestion, or some very coarse sand, or minute pebbles. They should be fed thrice a day; and as they get older, a mixture of lettuce-milk will be found beneficial, together with minced nettles. Barley boiled in milk is another excellent food at this period, and then oats boiled in milk. In short, the constitution of young turkeys requires at all ages every kind of stimulating food. When about three weeks old, their meat should consist of a mixture of minced lettuce, nettles, curdled milk, hard-boiled yolks of eggs, bran, and dried camomile; but when all these cannot be readily obtained, part of them must be used. Fennel and wild endive, with all plants which are of a tonic character, may be safely given to them. Too much lettuce, however, has been found to be injurious. When poults are about a month old, they should be turned out, along with the parent bird, into the fields or plantations, where they will find sufficient food for themselves. Grass, worms, all kinds of insects and snails, are their favourite food, and nature dictates to them such vegetables as are conducive to their general health. As their feet are at first very tender, and subject to inflammation from the pricking of nettles and thistles, they ought to be rubbed with spirits, which has the effect of hardening the skin, and fortifying them against these plants.

The glandulous fleshy parts and barbles of their heads begin to develop when they are from six weeks to two months old. This is a critical period with the poults, and unusual care must be bestowed on them, as they now become weak, and often sickly. A little brine mixed with their food will be found very beneficial, or spirits much diluted with water. A paste made of fennel, pepper, hemp-seed, and parsley, has been found an excellent remedy when afflicted with an inflammation in the wattles, to which they are liable when growing. They are very subject to this if the weather happens to be broken and changeable at the time these tubercles are growing. These parts swell and grow very red, which frequently proves fatal to them. If, therefore, such be the state of the weather at this critical period, the paste above recommended should be given although they are perfectly healthy, which will be found an excellent preventive. When the inflammation becomes very great, recourse is often had to bleeding in the axillary vein, which frequently has the effect of recovering them.

Soon after the turkey-poults have acquired their first feathers, they are liable to a disease which is very fatal to them, if not attended to. This distemper produces great debility, and the birds appear languid and drooping, and almost totally neglect their food. Their tail and wing-feathers assume a whitish appearance, and their plumage has a bristled aspect. This is occasioned by a disease in two or three of the rump-feathers. On examination, the tubes of these will be found filled with blood. The only remedy for this disease is to pluck them out, when the bird will speedily acquire its wonted health and spirits.

In fattening turkeys for the table, various methods are resorted to. Some feed them on barley-meal mixed with skim-milk, and confine them to a coop during this time; others merely confine them to a house; while a third class allow them to run quite at liberty; which latter practice, from the experience of those on whose judgment we can most rely, is by far the best method. Care should, however, be taken to feed them abundantly before they are allowed to range about in the morning, and a meal should also be prepared for them at mid-day, to which they will generally repair homewards of their own accord. They should be fed at night, before roosting, with oat-meal and skim-milk; and a day or two previous to their being killed, they should get oats exclusively. We have found from experience that when turkeys are purchased for the table, and cooped up, they will never increase in bulk, however plentifully they may be supplied with food and fresh water, but on the contrary, are very liable to lose flesh. When feeding them for use, a change of food will also be found beneficial. Boiled carrots and Swedish turnips, or potatoes mixed with a little barley or oat-meal, will be greedily taken by them. A cruel method is practised by some to render turkeys very fat, which is termed cramming. This is done by forming a paste of crumbs of bread, flour, minced suet, and sweet milk, or even cream, into small balls about the bulk of a marble, which is passed over the throat after full voluntary meals.

Pea-Fowl.

The peacock, also one of the gallinaceous tribe of birds, came originally, it is said, from India, and was well known to the ancient Greeks and Romans, who introduced it into their mythology. The great beauty of its tail, so ample in extent and so rich in colours, rendered it indeed not unworthy of such preferment.

One peacock is usually kept with three or four hens. The female is extremely fastidious about a spot to lay in, and generally leaves any artificial nest for the grass of some neighbouring coppice, where she lays under the branches of a shrub, in a well concealed situation. One reason for this is the propensity of the cock to break the eggs if he discover them. When the eggs of the pea-hen are gathered in sufficient numbers, whether from a natural or artificial nest, it is a common practice to place them under a common hen, which hatches them in thirty days, and makes an excellent stepmother to the young chicks. These are very tender at first, but soon grow vigorous, even in a chilly climate. Barley-meal paste, mixed with cheese or curd prepared from milk, with alum, ants' eggs, meal-worms, and hard-boiled egg, are among the common articles of diet given to the young. The grown-up pea-fowl feeds on boiled barley or other common grains, and is a dangerous neighbour to corn or wheat fields and gardens. On the other hand, they are voraciously fond of such creatures as frogs, lizards, and the like, and keep grounds clear of such annoyances. In moulting-time, it is requisite to be more careful of these fowls than at other times, and to give them good grain, with a little honey, and fresh water.' Though the tongues and livers of peacocks were ranked among the dainties of the Roman epicures, the bird is rarely killed for table now-a-days. Yet it always bears a high price, being one of the most beautiful of the feathered race, and an object on which the eye ever delights to dwell, though its screaming note by no means gives a corresponding pleasure to the ear.

The Guinea-Fowl.

This stranger is found native in Africa, as its name indicates, and it also exists in an indigenous state in South America. The Guinea-fowl (*Numidia meleagris*) is about the size of the common hen, and the male differs very little in appearance from the female. Three species exist in considerable numbers in Europe—namely, the crested, the mitred, and Egyptian varieties. A very beautiful sort is marked by a pure white tint of body, but the most familiar hues are dark-grey and black. The bird is less tame than other common poultry, and prefers to live in a half-wild condition in its native regions, perching and living on trees like undomesticated birds. It is a spirited creature, and will battle even with the turkey. Guinea-hens require great attention at the time of laying, making their nests by preference in corners of the woods. Their eggs are small, but much esteemed; and the common hen is usually made to rear their broods. In the market, guinea-fowls always bear a high price, both on account of their flesh, which is of a good quality, and because they form a very pretty variety of the poultry stock. Their food is grain, of the various kinds given to ordinary barn-door fowls, with which they assimilate closely in habits. On the whole, they may be said to be kept more from curiosity than for profit.

The Goose.

The goose differs in many respects from the fowls already noticed, being aquatic in its habits. It is marked by a flat bill and webbed feet, characters also possessed by the duck and swan, which, in conjunction with the goose, may be held as forming a distinct family (*Anatidæ*) of the feathered aquatic tribes.

Our common tame goose is the wild species domesticated, known to naturalists by the name of the fen or stubble-goose. Where people have a right of common, or live in the vicinity of marshy heaths, the breeding and rearing of geese will prove very profitable, for in such situations they are kept at a trifling expense; they are very hardy, and live to a great age. If properly kept, and fed regularly, although sparingly, they will lay upwards of a hundred eggs yearly. If these are set under large hens, each having half-a-dozen, with the assistance of the goose herself, they may be nearly all hatched. For the first three or four days, they must be kept warm and dry, and fed on barley-meal or oat-meal mixed with milk, if it is easily procured; if not, let these ingredients be mixed with water. They will begin to grow in about a week. For a week or two the goslings should not be turned out till late in the morning, and should always be taken in early in the evening. In Ireland, the tenantry depend much on the breeding of these birds and turkeys to pay their rent; and with those who are industrious and favourably situated for rearing geese, they even do more in many instances. In the early part of the year they are allowed to feed on grass, on heaths, meadows, commons, and road-sides; and as most of the peasantry have small bits of corn land of their own, the geese are turned out on the stubble to pluck what grass is left; and they also fatten upon it, and improve the flavour of their flesh.

Although water be the natural element of geese, yet it is a curious fact that they feed much faster in situations remote from rivers and streams. To fatten geese, it is necessary to give them a little corn daily, with the addition of some raw Swedish turnips, carrots, mangel-wurzel leaves, lucerne, tares, cabbage leaves, and lettuces. They should not be allowed to run at large when they are fattening, as they do not acquire flesh nearly so fast when allowed to take much exercise. Therefore those who can only afford to bring up a goose or two, should confine them in a crib or some such place about the beginning of July, and feed them upon the ingredients above recommended, with a daily supply of clean water for drink. If, on the contrary, from a dozen to twenty are kept, a large pen of from fifteen to twenty feet square must be made, and well covered with straw in the bottom, and a covered house in a corner for protection against the sun and rain when required, because exposure to either of these is not good. It will be observed that about noon, if geese are at liberty, they will seek some shady spot, to avoid the influence of the sun; and when confined in small places, they have not sufficient room to flap their wings and dry themselves after being wetted; nor have they room to move about so as to keep themselves warm. There should be three troughs in the pen, one for dry oats, another for vegetables—which ought always to be cut down—and a third for clean water, of which they must always have a plentiful supply. It must be remembered that the riper the cabbages and lettuces with which they are supplied, the better. In the neighbourhood of large towns, the most profitable way of disposing of geese is in a dead state; as nearly the same sum can be obtained for them as if they were alive; and then you have the feathers, which are valuable, and may be sold to much advantage by themselves when you have collected a stone weight or more.

Geese are kept in vast quantities in the fens of Lincolnshire, several persons there having as many as a thousand breeders. They are bred for the sake of their quills and feathers, as well as for their carcase; it is therefore customary to strip them partially of the fine downy feathers, and leave them to grow afresh, and also to take quills from their wings—both practices barbarous in the extreme, however they may be attempted to be justified. Geese breed in general only once a year, but if well kept, they sometimes hatch twice in a season. The best method for promoting this is to feed them with corn, barley, malt, fresh grains, and, as a stimulant, they should get a mixture of pollard and ale. During their sitting, each bird has a space allotted to it, in rows of wicker pens placed one above another, and the goose-herd who has the care of them drives the whole flock to water thrice a day, and bringing them back to their habitation, places every bird (without missing one) in its own nest. One gander is generally put to five geese. The time of incubation varies from twenty-seven to thirty days. The goose begins to lay in March, but the time of the month depends upon the state of the atmosphere. When goslings are first allowed to go at large with their dam, every plant of hemlock which grows within the extent of their range should be pulled up, as they are very apt to eat it, and it generally proves fatal to them. Nightshade is also equally pernicious to them, and they have been known to be poisoned by cropping the sprigs of the yew-tree.

Ducks.

Ducks are easily kept, particularly near ponds or streams of water. In such situations, even the poorest families may have half-a-dozen of them running about without the least inconvenience. In keeping them in a domestic state, one drake is usually put to half-a-dozen ducks. The ducks begin to lay in February; their time of laying being either at night or early in the morning. They are extremely apt to deposit their eggs in some sequestered spot, and to conceal them with leaves or straw. From eleven to fifteen eggs is the number which a duck can properly cover. The time of incubation is about thirty-one days. The place where they incubate should be as quiet and retired as possible; and if they have liberty, they will give no trouble whatever in feeding, as the duck, when she feels the call of hunger, covers her eggs carefully up, and seeks food for herself, either by going to the streams or ditches in her neighbourhood, or, if such are not at hand, she will come to the cottage and intimate her wants by her squalling. When the young are hatched, they should be left to the care of the duck, who will lead them forth in due time; and when she does so, prepare a coop for them, which should be placed on short grass, if the weather is mild; and if cold or stormy, they should be kept under cover. The future strength of the brood will depend much upon the care that is taken of them for the first three or four weeks after they have emerged from the shell. Ducklings will begin to wash themselves the first day after they are hatched, if they find water at hand; therefore a flat dish filled with that element should be always within their reach. Many persons are in the practice of clipping the tail, and the down from beneath it, in ducklings, if the weather is wet during the first weeks of their existence. This is to prevent them from draggling themselves, which has a tendency to produce intestinal diseases. From a fortnight to three weeks is all that is necessary to confine them to the coop.

The first thing on which ducklings are fed is a mixture of barley, peas, or oat-meal, and water. They may afterwards be fed upon a mixture of buck-wheat and any of the above-named meals. The greatest attention must be paid to keeping their bed warm and dry; and with young ducks, a frequent change of straw is absolutely necessary, as their beds soon get dirty, wet, and fetid.

Ducks are not such attentive guardians of their young as hens, and therefore it is a common practice to place duck eggs under a sitting hen, and leave her to hatch them as her own progeny. When the young ducks so hatched make their appearance, the hen does not appear aware of the imposition, but takes at once to her duties with all a mother's fondness. The natural desire of the ducklings to plunge into water and swim away from the shore vexes her, but she watches for their return, and does all in her power to provide the means of subsistence. She scrapes for them, which a duck would not; she shelters them under her dry and warm bosom and wings, and altogether makes a better nurse than their own proper parent.

In feeding ducks for use, peas and oat-meal are to be preferred. It is said that barley-meal renders their flesh soft and insipid. Bruised oats should be given to them freely for some weeks before they are killed, which renders their flesh solid and well tasted; and the same general principles recommended in the feeding of geese should be kept in view. It has been found that the offal of butchers' shops feeds ducks quickly, and that this does not impair the flavour of their flesh. In very many instances, ducks are reared in situations where there are no pools of clean water for them to dabble in, and the poor animals are compelled to grub with their bills in all sorts of nauseous puddles, which of course makes their flesh rank and offensive. They should in all cases have a pool of clean water to swim in, and are best reared near a natural meadow, lake, or pond, where they can search for their appropriate food.

Those who have paid much attention to the management of domestic poultry, assert that geese and ducks should be kept apart from other fowls. The former should have their houses ranged along the banks of a piece of water with a fence, and sufficiently extensive for walks in front, with doors for their access to the water, which can be closed at pleasure.

Swans.

Swans are generally kept for ornament rather than use. The flesh, even of the young, is black, hard, and rank, while that of the old is too tough for mastication. The eggs also are not peculiarly palatable; and there is little inducement to rear them; in short, if mere pecuniary advantage be looked to, excepting on the score of the skin, feathers, and down, which are articles of considerable value. At the same time, if the swan be not a productive bird, few animated objects can be compared with it as regards ornament. Its great size, snow-white plumage, and graceful form, render it a most attractive spectacle upon the bosom of a pool or loch. It is a hardy, long-lived fowl, and associates in pairs. The food of the swan consists usually of seeds, roots, and plants, rendered succulent by water. When fed in a barn-yard, it seldom thrives, being more decidedly aquatic in its habits than ducks or geese. From the colour of the European swan being so uniformly white, a black swan used once to be proverbially spoken of as an impossibility; but black swans occur abundantly in Australia, from whence they are now frequently brought, as curiosities for the pleasure-ponds of the wealthy.

Pigeons.

Pigeons are among the most ornamental and useful appendages of a rural dwelling. If permitted to fly abroad to seek their food, little expense will be incurred for their keep, while the value of their young will be of some importance to cottagers. The pigeon has a great power of flight, and will go to a distance of many miles in quest of the means of subsistence; but wherever it may fly, it never fails to return home. The leading features of the district around its habitation appear to be impressed on its memory; and flying at a great height, and with a wonderful power of vision, it sees the well-remembered landmarks, and directs its path homeward. This habit of seeking for the place at which it was reared, makes it difficult to keep pigeons in any new home; the best plan of inducing them to settle in a new abode is to clip one wing, which prevents their flying, and keep them in a cot near the ground till they get accustomed to the place.

Many persons keep their pigeons in the space between the garret and roof of their dwelling-house, with holes at which they go out and in; and this arrangement answers very well, for the animal's lodging must be dry and comfortable. A more regular plan is to furnish them with a properly-constructed dovecot, aloof from any building. The cot should consist of a substantial wooden box, with a sloping roof, and divided interiorly by partitions into as many cells as pairs are to be kept, for each pair requires a distinct cell. Each compartment should be twelve inches deep from front to back, and sixteen inches broad; the entrance hole should not be opposite the centre of the cell, but at a side, so that the pigeons may build their nest a little out of sight. In front of each cell there should be a slip of wood to rest and coo upon; but as different pairs incessantly quarrel about the right of walking on these slips, and are apt to fight for the possession of cells, it is best to separate the slips with upright partitions; and it would be an improvement to have two or three small cots instead of one large one. The cot, of whatever size or form, should be elevated on a wall facing the south-east, or otherwise placed at such a height as will be out of the reach of cats and other vermin. The cot should be painted white, as the pigeon is attracted by that colour. Gravel should be strewed on the ground in front of the dove-cot, the birds being fond of picking it; and a little straw or hay is necessary for the nests. Cleanliness is indispensable to the health of the birds, and a scouring out of the cot should therefore take place regularly. The quantity of dung produced in the nests is very great, and its removal to the compost heap will amply repay the trouble of cleaning.

In commencing to keep pigeons, a pair or two should be procured which have not flown, and they should be shut up for a time, and well fed. Their chief food is grain, and the kind which they prefer to all others is dried tares. Small horse-beans are another favourite article of diet, and very nutritious to them. Wheat, barley, oats, and peas, with rape, hemp, and canary-seeds, are also prized by them, but should not be made constant articles of food under any circumstances.

The house-dove or common pigeon, as is well known, begins to breed about the age of nine months, and breeds every month. During breeding time, they associate in pairs, and pay court to each other with their bills; the female lays two eggs, and the young ones that are produced are for the most part a male and female. When the eggs are laid, the female, in the space of fifteen days, not including the three days during which she is employed in laying, continues to hatch, relieved at intervals by the male. From three or four o'clock in the evening, till nine the next day, the female continues to sit; she is then relieved by the male, who takes his place from ten till three, while his mate is feeding abroad. In this manner they sit alternately till the young come out. Kept with ordinary care, a pair will give to the breeder nine pairs or so in a year, and will continue to do this for four years. The bird lives for eight years, but is useless for breeding long before attaining that age. On the whole, the cottager who keeps a few pairs may have a palatable addition to his diet frequently during the year with very little trouble or expense.

With regard to the best breeds of the common domesticated pigeon, it is difficult to give any useful instructions. They have been cultivated to a great extent, and many distinct varieties have been formed, but the differences rest chiefly in colours, and the special value of each lies in the taste of the *fancier*. The leading varieties of fancy pigeons are known by the names of the English Pouter, the Dutch Cropper, the Horseman, the Uploper, the Dragoon, the Tumbler, the Leghorn and Spanish Runt, the Trumpeter, the Nun, the Fan-tail, and the Capuchin. The peculiarities of some of these breeds are very odd. The tumbler, for instance, derives its name from a practice of tumbling in the air while on the wing. Instead of pursuing a steady straightforward flight, it turns over, or casts somersets backward, whirling round heels over head as expertly as a first-rate rope-dancer does when he makes the back spring. The fan-tail derives its name from the circumstance of its having a remarkably broad tail, which it has the power of spreading out like the tail of a turkey-cock. The prime quality of the bird consists in its ability to make its tail touch its head, and surround it with a wide glory of feathers. If it cannot do this, it is valueless to the fancier, no matter how excellent are its other properties. Amusing as this absurdity is, it is not so laughable as the qualities which recommend the English pouter to public favour. This bird, which is a cross between a horseman and a cropper, possesses the remarkable property of blowing out its breast or crop to such an extent, that it rises to a level with its beak, and the bird appears to look over the top of an inflated bladder.

Carrier-Pigeons.—Pigeons have been put to the remarkable purpose of acting as carriers for letters or other light objects. A particular species, larger than common, is trained for the purpose, and in some countries the rearing of them forms a lucrative employment. The instinct which has rendered the carrier-pigeon so serviceable, is the strong desire manifested by all pigeons to return to the place of its ordinary residence; and man has adopted various precautionary measures in order to make its return on particular occasions more certain. A male and female are usually kept together, and treated well; and one of these, when taken elsewhere, is supposed to have the greater inducement to come back. It is even considered necessary by some that the bird should have left eggs in the process of incubation, or unfledged young ones, at home, in order to make the return certain; but probably these are superfluous precautions. It is obvious that the carrier-pigeon can only be put to use in conformity with some contemplated plan, for which the proper preparations have been made. It must have been taken from a place to which it is wished that it should return, and it must, at the moment when its services are wanted, be temporarily at the place from which the intelligence is to be conveyed. It is usually taken to that place hoodwinked, or in a covered basket; the instinct by which it finds its way back upon its own wings must of course be independent of all knowledge of the intermediate localities. When the moment for employing it has arrived, the individual requiring its services writes a small billet upon thin paper, which is placed lengthwise under the wing, and fastened by a pin to one of the feathers, with some precautions to prevent the pin from pricking, and the paper from filling with air. On being released, the carrier ascends to a great height, takes one or two turns in the air, and then commences its forward career, at the rate of about forty miles an hour.

CAGE-BIRDS.

The birds usually domesticated in cages in Britain are canaries, siskins, goldfinches, bullfinches, larks, linnets, thrushes, blackbirds, starlings, and parrots. The only means by which these or any other species of birds can be reared and preserved in a healthy condition, is to accommodate each as far as possible with the food, space for exercise, and other conveniences which the animal would enjoy in a state of nature. The most difficult thing to afford is space: where a room or aviary can be fitted up with all requisite accommodations—perches to resemble trees and branches, grass, moss, and other plants, patches of gravel or sand, secluded places for nests, a trough of clear water, &c.—the birds will thrive, breed, and be cheerful; but such accommodations can rarely be afforded, unless in the mansions of the great; and the aviary, for the most part, is only a tiny cage, more or less ornamental, formed of wood and wires.

Placed in this state of confinement, no birds can possibly exist unless great care is bestowed in furnishing them with food and fresh water daily, keeping their habitation very clean, and placing them in a cheerful situation in a parlour, where they can enjoy the light. Birds that are produced in confinement are more contented than those who have known freedom; but the latter may be reconciled to this new state, and made to sing with their accustomed gaiety. A good plan of reconciling a newly-caught bird to the cage is said to be as follows:—For two or three hours leave it in tranquillity, and then plunge it into fresh water. This exhausts it; but on recovery, it arranges its feathers, becomes hungry, and takes at once to its food. The wetting, however, should take place only during sunshine, so that the feathers may be speedily dried.

The food of cage-birds is very various. 1. Canaries, goldfinches, and siskins, live only on seeds; 2. quails, larks, chaffinches, and bullfinches, feed on both seeds and insects; 3. nightingales, redbreasts, thrushes, and blackbirds, take berries and insects. Referring to these classes of birds, Bechstein observes—'Experience teaches me that a mixture of crushed canary, hemp, and rape-seed, is the favourite food of canaries; goldfinches and siskins prefer poppy-seed, and sometimes a little crushed hemp-seed; linnets and bullfinches like the rape-seed alone. It is better to soak it for the young chaffinches, bullfinches, and others; in order to do this, as much rape-seed as is wanted should be put into a jar, covered with water, and placed in a moderate heat, in winter near the fire, in summer in the sun. If this is done in the morning, after feeding the birds, the soaked seed will do for the next morning. All of them ought to have green food besides, as chickweed, cabbage-leaves, lettuce, endive, and water-cresses. Sand should be put in the bottom of the cages, as it seems necessary for digestion.

Amongst those of the second class, the quails like cheese and the crumbs of bread; the lark, barley-meal, with cabbage, chopped cress, poppy-seed mixed with bread crumbs, and in winter, oats; the chaffinches, rape-seed, and sometimes, in summer, a little crushed hemp-seed. Too much hemp-seed, however, is hurtful to birds, and should only be given as a delicacy now and then, for when they eat too much of it they become asthmatic, blind, and generally die of consumption. Yellow-hammers like the same food as the larks, without the vegetables; the tits like hemp-seed, pine-seed, bacon, meat, suet, bread, walnuts, almonds, and filberts.' The same author proceeds to describe two kinds of paste, simple and cheap, and which may be termed a universal food for birds.

'To make the first paste, take a white loaf which is well baked and stale, put it into fresh water, and leave it there until quite soaked through, then squeeze out the water and pour boiled milk over the loaf, adding about two-thirds of barley-meal with the bran well sifted out, or what is still better, wheat-meal; but as this is dearer, it may be done without.

For the second paste, grate a carrot very nicely (this root may be kept a whole year if buried in sand), then soak a small white loaf in fresh water, press the water out, and put it and the grated carrot into an earthen pan, add two handfuls of barley or wheat-meal, and mix the whole well together with a pestle.

These pastes should be made fresh every morning, as they soon become sour, particularly the first, and consequently hurtful. For this purpose I have a feeding-trough, round which there is room enough for half my birds. It is better to have it made of earthenware, stone, or delft ware, rather than of wood, as being more easily cleaned, and not so likely to cause the food to become stale.

The first paste agrees so well with all my birds, which are not more than thirty or forty, at liberty in the room, that they are always healthy, and preserve their feathers, so that they have no appearance of being prisoners. Those which live only on seeds or only on insects, eat this food with equal avidity; and chaffinches, linnets, goldfinches, siskins, canaries, fauvettes, redbreasts, all species of larks, quails, yellow-hammers, buntings, blue-breasts, and red-starts, may be seen eating out of the same dish. Sometimes, as a delicacy, they may be given a little hemp, poppy, and rape-seed, crumbs of bread, and ants' eggs. One of these is necessary for the birds of the third and fourth class.

Every morning fresh water must be given to the birds, both for drinking and bathing. When a great many are left at liberty, one dish will do for them all, about eight inches long and two in depth and width, divided into several partitions, by which means they are prevented from plunging entirely into the water, and in consequence making the place always dirty and damp. A vessel of the same size and shape will do for holding the universal paste, but then it must have no partitions. Quails and larks require sand, which does for them instead of water for bathing.

Some birds swallow directly whatever is thrown to them: great care must be taken to avoid giving them anything with pepper on it, or bad meat. This must be a general rule. I shall also remark, that food sufficient for one day only must be given to birds kept in cages, for they are accustomed to scatter it about, picking out the best, and leaving only the worst for the next morning; this makes them pine, and puts them out of humour.'

Canaries—Siskins.

Canaries are the chief pets of the parlour, and the method of treating them requires to be given at some length. Being originally from a warm climate, they are tender, and must be kept in rooms of an agreeable temperature; if exposed to cold either in rooms or the open air, they pine and die. In dry weather in summer, their cage should be hung in the open air, or at least in the sunshine. If the apartment is kept too hot, they will moult at an improper season, and this must be avoided. Only one male should be allowed in a cage. Females for breeding are the better for having a large cage, as it affords them space for exercise. The greatest care must be taken to clean the cage, of whatever dimensions, and to scatter a little fine sand on the bottom of it. Each should be provided with three cross-sticks as perches, a small glass trough for water fixed outside at the extremity of one of the sticks. The water must be changed daily, or even more frequently.

Some persons, from mistaken kindness, offer pieces of rich cake and other inappropriate food to canaries, and the little creatures being fond of these things, they do themselves a great injury by eating of them. A canary in high song will at once be rendered mute by partaking of any improper food of this sort. As already mentioned, the food must be of a simple and natural kind; besides the seeds and other things described, they should be supplied daily with a little green vegetables; such as chickweed in spring, lettuce and radish leaves in summer, endive, water-cress, and slices of sweet apple in winter. As they like to wash their feathers, a cup of fresh water may be placed in the cage daily. In the moulting season, it is recommended to put a nail into the water they drink, in order to strengthen the system by the slight infusion of iron matter.

The breeding of canaries requires additional accommodations. The breeder must have a large cage, into which the pair of birds is put about the middle of April. At the upper part of the cage, at one end, boxes for the nests are placed, with holes to go out and in by; and in the centre of the cage, near a perch, a net-work bag is hung filled with cotton, wool, moss, hair, and other soft materials, for the birds to use for their nests. The female only builds; and in about ten days after pairing, she lays the first egg. She ordinarily lays six eggs, one every day; but each egg is to be taken away as laid, leaving an ivory one only; and when done laying, replace all the six. The period of incubation is thirteen days. When the young are hatched, finely-minced egg and bread should be placed near the feeding-trough, to enable the parents to carry suitable food to their young. Canaries will mate with siskins, linnets, several of the finches, and other allied birds, producing in many instances highly-esteemed mules.

The system of treatment now described is also well adapted for the Siskin, of which there are several varieties, as the black, white, and speckled. This bird, which is somewhat smaller than the canary, is of a handsome shape, lively, and intelligent. In a wild state, it is found throughout Europe, particularly in Germany and the central districts. In the house, whether caged or not, it soon becomes familiar, and may be taught to perform many tricks and amusing operations. It is a sweet and busy songster, with notes fully more varied and less piercing than those of the canary. It pairs readily with the canary, particularly the green variety, the produce being a prettily-spotted mule, partaking of the qualities of both parents. Being naturally very lively, the siskin does not take with too close confinement; it requires also more food (poppy or hemp-seed, and the first universal paste described) than the canary, and not less water, though it is not quite so fond of bathing.

Linnets—Finches—Larks.

The species of these birds which thrive in confinement are too well known to require description. In a wild state, the Linnets are scattered over all Europe; in summer frequenting the skirts of large forests, thickets, hedges, and bushes, particularly furze; but as soon as September arrives, they pass in large flights to the open fields. In confinement, it is best to keep them in square cages, as they are less subject to giddiness in these than in round ones, and sing better. On the whole, it has been found better to keep linnets pretty closely to the cage, as they are not naturally of a very lively or roaming disposition. In the wild state, their food consists of all kinds of seeds which they can shell; and in confinement, summer rape-seed has been found to agree with them well. If allowed the liberty of the room, the common universal paste may be given, along with green vegetables, plenty of water, and sand for dusting. Most of the linnets are naturally slow and indolent, and are therefore apt to become too fat if fed abundantly.—The Finches are also well known, being found in all parts of Europe, frequenting orchards, brambles, thickets, and mountainous districts, interspersed with woods and fields. They are greedy devourers of all kinds of small seeds, and are, on the whole, healthy and hardy birds. The most common cage species are the goldfinch and bullfinch—both, however, more esteemed for their beauty and docility than for the sweetness or variety of their notes. A square cage is recommended by Bechstein as better suited to the habits of the birds; and as to food—poppy, hemp, lettuce, rape, and canary-seed, either pure or in mixture, are found to agree with them. The common paste, chickweed, lettuce leaves, endive, and the like, are occasionally beneficial as alteratives or correctives.—Of the Larks, which are all somewhat delicate, and difficult to rear in confinement, the common field or skylark is that most frequently to be found in the cage of the bird-fancier. In a wild state, the skylark is found all over the world, frequenting fields and meadows, and by preference plains. 'In rooms,' says the authority above quoted, 'it is usual to let it hop about; it is, however, also kept in cages, where it sings best. Whatever form may be given to these cages, they must be at least 18 inches long, 9 wide, and 15 high: the bottom should have a drawer, in which enough of river sand should be kept for this scratching bird to be able to roll and dust itself conveniently. It is also a good plan to have in a corner a little square of fresh turf, which is as beneficial as it is agreeable. The top of the cage must be of linen, since, from its tendency to rise for flight, it would run the risk of wounding its head against a covering of wood or iron wire, especially before it is well tamed. The vessels for food and drink must be outside, or, which I prefer, a drawer for the food may be introduced in the side of the cage: sticks are not necessary, as the lark does not perch. When it is allowed to hop free in a room, the latter must be very clean and neat, otherwise a thread or hair may entangle the feet, and if not removed, it easily cuts the skin, maims the bird, and the entangled toes shrink and fall off. When wild, the food consists of insects, especially ants' eggs, also of all kinds of seeds, and in autumn of oats, which these birds skin by striking them against the ground. In the spring, the sprouting seeds and young buds, also the blades of young grass, are eaten, and grains of sand to help digestion. In the house, if the lark is hopping about, nothing is better than the first universal paste described; but if caged, the second will suit it better. Poppy-seed, bruised hemp, crumbs of bread, and plenty of greens, as lettuce, endive, cabbage, or water-cress, according to the season, must be added. A little lean meat and ants' eggs are favourite delicacies, which make the bird gay, and more inclined to sing.'

Blackbirds—Thrushes—Starlings.

The male Blackbird is a handsome creature, lively in manner, and possessing some sweet 'wood-notes wild,' which sound most agreeably from a garden or the outside of a window. The bird requires a large wicker cage, which, whenever weather permits, ought to be hung in the open air. In a state of nature, the blackbird eats berries, seeds, insects, larvæ, and worms. It loves to run about a grass plot, in the spring mornings, and pick up any stray worm which is straggling from its hole. This habit suggests the propriety of giving it, when in confinement, both vegetable and animal food. The universal paste will answer; but if too heating, which it is liable to be, give bits of bread, flies, cockchaffers, worms; and failing these, chopped raw meat. A rough bone from the table will also not be inappropriate. A short experience will show upon which kinds of food the creature thrives best, and let that be adhered to. Give also plenty of pure water to drink; and once a week, when the sun shines, set a basin of water in the cage for it to bathe in and clean itself. Let the cage be carefully and regularly cleaned.

Belonging to the same family are the Thrushes, of which the song-thrush is the smallest and most attractive. It is found all over Europe, frequenting woods near streams and meadows, and is naturally somewhat shy and timid. In confinement, it may be lodged and treated like the blackbird, though less luxuriously. When wild, it lives on insects and berries; and in the cage, the two common pastes, oatmeal moistened with milk or water, or even bran moistened with water, have been found to answer. It also requires a great deal of water for bathing and drinking; but is much more cleanly than the blackbird. It is an excellent songster, but takes less kindly to the cage than the blackbird, and is not so easily taught any artificial note.—The Starling, another of our cage favourites, is found all over the world, but is not so easily reared as found. It is by no means cleanly, and requires to be kept in the cage, which should be particularly large and roomy. In a wild state, insects, grains, and berries, are devoured indiscriminately; in confinement, starlings eat minced meat, worms, bread, the universal paste, indeed any food, provided it be not sour. If well treated, the starling soon becomes exceedingly familiar, and may be taught to whistle various airs, and pronounce words and short sentences with accuracy. For these ends no cutting or slitting of the tongue is requisite—an operation as stupid and unnecessary, as it is cruel and barbarous.

Parrots.

Under this head may be classed a number of beaked birds of similar character, as parrots, parroquets, cockatoos, and maccaws, all possessing beautiful plumage of green, crimson, yellow, or grayish tints. They are chiefly from South America, and require the warmth of a dwelling-house to keep them alive in this country. All possess harsh voices, and would on that account be considered a positive nuisance by most persons, except for the oddity of their being able to repeat certain words; but this is a quality possessed by some in greater perfection than others. Each species of these birds may be treated much in the same manner. They are allowed a large cage, formed of strong wires, with thick round bars to perch upon, and a ring at top to swing from by their hooked beak. All the parts must be of tin, for they would soon peck wood to pieces. In Zoological Gardens, they are usually seen perched on a cross-bar of tin at the top of a staff, but chained by the leg to prevent their escape; but this method is not so favourable for their climbing, swinging, and grotesque manœuvres as a large roomy cage.

The food offered to parrots, maccaws, &c. is chiefly bread steeped in milk, nuts, or any other simple article. Care must be taken never to give them anything with salt or pepper. On the subject of feeding them, Bechstein makes the following observations:—'In its native country, the fruit of the palm-tree is its principal food; our fruit it also likes, but white bread soaked in milk agrees with it better; biscuit does not hurt it; but meat, sweetmeats, and other niceties, are very injurious; and though at first it does not appear to be injured, it becomes unhealthy, its feathers stand up separate, it pecks and tears them, above all those on the first joint of the pinion, and it even makes holes in different parts of its body. It drinks little; this is perhaps occasioned by its eating nothing dry. Many bird-fanciers say that the best food for parrots is simply the crumbs of white bread, well baked, without salt, soaked in water, and then slightly squeezed in the hand. But though this appears to agree with them pretty well, it is, however, certain that now and then something else ought to be added. I have observed, indeed, that parrots which are thus fed are very thin, have hardly strength to bear moulting, and sometimes even do not moult at all; in that case they become asthmatic, and die of consumption. It is clear that feeding them only on this food, which has very little, if any, moisture in it, is not sufficient to nourish them properly, at least during the moulting season, and while the feathers are growing again. I never saw a parrot in better health than one which belonged to a lady, who fed it on white bread soaked in boiled milk, having more milk than the bread would absorb, which the parrot drank with apparent pleasure; there was also put into the drawer of its cage some sea biscuit, or white bread soaked in boiling water; it was also given fruit when in season. It is necessary to be careful that the milk be not sour.

Some young maccaws are fed on hemp-seed, which must always be of the year before, as the new would be too warm and dangerous. Yet they must not be fed entirely on this food, but there must be added white bread soaked in milk or water, as has already been mentioned, some fruit and nuts, but never bitter almonds, as they will infallibly kill all young animals. In all cases the excrements of the birds will indicate the state of their health, and whether the food ought to be changed or not. Although maccaws rarely want to drink, as their food is very moist, yet they must not be left without water, which is generally placed in one of the divisions of their tin drawer. It is also a good thing to entice them to bathe; nothing is more favourable to their health, or better facilitates the painful operation of moulting, or keeps their feathers in better order. A little attention to these favourites—deprived of their liberty, their natural climate, and food—cannot be too much trouble to amiable persons who are fond of them, and to whom these pretty birds soon become greatly attached.'

The cockatoo is generally esteemed as of milder temper than the parrot. Of this species, Buffon observes—'Cockatoos, which may be known by their tuft, are not easily taught to speak; and there is one species which does not speak at all; but this is in some measure compensated for by the great facility with which they are tamed; in some parts of India they are even so far domesticated that they will build their nests on the roofs of the houses: this facility of education is owing to their intelligence, which is very superior to that of other parrots. They listen, understand, and obey; but it is in vain that they make the same efforts to repeat what is said to them; they seem to wish to make up for it by other expressions of feeling and by affectionate caresses. There is a mildness and grace in all their movements, which greatly add to their beauty. In March 1775, there were two, a male and female, at the fair of St Germain in Paris, which obeyed with great docility the orders given them, either to spread out their tuft, or salute people with a bend of the head, or to touch different objects with their beak and tongue, or to reply to questions from their master with a mark of assent, which clearly expressed a silent *yes*; they also showed by repeated signs the number of persons in the room, the hour of day, the colour of clothes, &c.; they kissed one another by touching their beaks, and even caressed each other; this showed a wish to pair, and the master affirms that they often do so even in our climates. Though the cockatoos, like other parrots, use their bill in ascending and descending, yet they have not their heavy disagreeable step; on the contrary, they are very active, and hop about very nimbly.' For ornamental pets, parroquets—many of which are not much larger than the common house-sparrow—are now very generally preferred; and though not quite so showy in plumage as the maccaws, lories, and cockatoos, yet their tints are often extremely beautiful, and they never become offensive by screaming, which is too often the case with their larger congeners.

THE HONEY-BEE.

The subject of Bees, which is equally extensive and interesting, has for many ages attracted the attention of mankind. The Sacred Writings, the most ancient of which we have any knowledge, show in numerous places how strongly the fathers of the Jewish people had been impressed by the peculiarities in the natural history of the Bee; and we know that Aristotle and other philosophers of old Greece deemed the subject worthy of years of patient investigation. Virgil, also, and many other Roman authors, dwelt on it with enthusiasm in their writings; while, in much later times, Swammerdam and other distinguished cultivators of science have pursued the same track with undiminished ardour. The most zealous of these inquirers was Francis Huber (born at Geneva 1750, died 1831), who, though labouring under the deprivation of sight, by the aid of his wife formed a most valuable collection of observations on the habits of bees, and to whose work —as yet the best of its kind—we shall have frequent occasion to refer. Societies have also been formed for the sole purpose of investigating this portion of natural history. A mere summary of the interesting essays, therefore, which this insect, so universally appreciated, has called forth, would occupy a very large space. On the present occasion, an attempt can only be made to cull from the most approved sources such details as may form a complete history of the Honey-Bee, though at the same time it must necessarily be a concise one, along with directions for the practical management of this most useful insect.

Bees are arranged by zoologists into the family of the *Apidæ* (*apis*, a bee), in the order *Hymenoptera* (having four unequal membranaceous wings) of the insect class. The Social Bees form the principal division of the family, their type being the *Apis mellifica*, the Honey-making, or, in common phrase, the Honey-Bee. It is so called not from an exclusive peculiarity, but because it is the species which has long yielded to man the rich product indicated in its name. As the observations to follow will have reference to the Honey-Bee, it may simply be mentioned that the description of this species involves the leading features in the natural history of its less important congeners, the Wild or Humble Bees. (See Zoology, p. 168.)

ANATOMY AND PHYSIOLOGY.

Of the family of the Social Bees, two species seem to exist in Europe, the one found in the north, and the other in the south; but, making allowance for a slight deepening of tint from brown to red in the rings of the body in the case of the more southerly insect, the description of the common hive-bee of Britain will apply to the other in all important respects. A hive of honey or garden-bees contains three ranks or sexes of inhabitants, the external characters of which differ considerably, while their uses and functions in the community are most obviously distinct. The most important, and by far the most numerous rank, is that of the *workers*, or working-bees, formerly regarded as neuters in respect of sex, but now more properly considered as undeveloped females. The second rank is composed of the males of the hive, termed the *drones*. There is usually but one perfect member of the third sex present at a time in a hive, and this is the *queen*, or mother-bee, the sole female of the community.

Workers.

The working honey-bee has a body about half an inch in length, blackish-brown in hue, and covered with close-set hairs, which are feather-shaped, and assist the creature materially in collecting the farina of flowers. The *head*, which is a flattened triangle in shape, is attached to the chest by a thin ligament; and the chest or *thorax*, which is of a spherical form, is united in a similar way to the *abdomen* (see No. 11). The abdomen is divided into six scaly rings, which shorten the body by slipping over one another to a certain extent. These three external divisions of the insect's body have all of them appendages of peculiar interest and utility. The head is provided with a double visual apparatus. In front are placed two *eyes*, consisting each of numerous hexagonal plates, studded with hairs, to ward off the dust or pollen of flowers; and three small eyes are also to be found on the very top of the head, intended, doubtless, both to heighten the general sense of seeing, which the creature so peculiarly requires, and to give a defensive vision upwards from the cups of flowers. The *antennæ*, however, which are two slender tubes springing from betwixt the front eyes, and curving outwards from each side, most probably fulfil many of the purposes of vision in the dark interior of the hive. These instruments have each of them twelve articulations, and terminate in a knob, gifted with the most delicate sensitiveness. By the flexibility of the antennæ, the bee is enabled to feel and grasp any object in its way; and there can be little doubt that it is chiefly by means of these it builds its combs, feeds the young, fills the honey-cells, and performs the other operations of the hive. Bees also use these appendages for the recognition of one another.

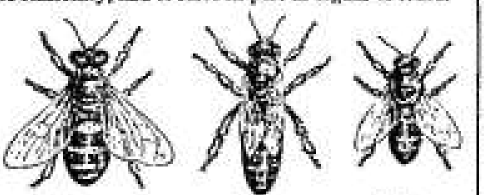
The mouth of the bee is a very complex structure, and one wonderfully fitted for its duties. Its most important parts are the *mandibles*, the *tongue*, the *proboscis*, and *labial feelers*. The mandibles are merely the two sides of the upper jaw, split vertically, and movable to such a degree as to enable the insect to break down food betwixt them, to manipulate wax, and use them otherwise as serviceable tools. They are furnished with teeth at their ends, two in number. The tongue of the bee is extremely small, and indeed is scarcely admitted by some naturalists to exist at all, the proboscis being often signified by that name. Many of the usual functions of such an instrument are indeed performed by the proboscis, a long slender projection, composed of about forty cartilaginous rings, fringed with fine hairs. From the base of this, on each side, rise the labial feelers, instruments also fringed or feathered interiorly; and outside of these are the lower jaws, similarly provided with hairs. When the feelers and jaws close in on the proboscis, they form a sheath or defence to it. Naturalists used to term the proboscis a tube; but they now know that it acts by rolling about and lapping up, by means of the fringes around it, everything to which it is applied. The gathered material is then conveyed into the gullet at its base, whence it passes into the internal organs. Thus we find the mandibles of the upper jaw ready to break and prepare the food for the sweeping-up apparatus of the lower parts. While perfect in action in an expanded state, the whole, moreover, can be so folded or coiled together, as to form one strong well-protected instrument.

To the trunk or thorax of the bee exteriorly are attached the muscles of the wings and legs. The wings consist of two pairs of unequal size, which are hooked to one another, in order to act in concord and steady the movements in flying. The bee has three pairs of legs, of which the anterior pair are the shortest, and the posterior the longest. All of them are formed upon the same principle as the limbs of man, having articulations for the thigh, leg, and foot, with some minor joints in the latter part. The hind-legs are marked by a special and beautiful provision: this is a cup-like cavity on the *tibia* or fore-leg, intended for the important purpose of receiving the kneaded pollen which the bee collects in its wanderings. The legs are all thickly studded with hairs, and more particularly the cavity mentioned, in which the materials require to be retained securely. Another provision of the bee's limbs consists in a pair of hooks attached to each foot, by means of which the animal suspends itself from the roof of the hive or any similar position. Beneath or behind the wings, the *spiracles* or air-openings are found, which admit air for the purpose of permeating the chest, and probably the whole body, for the oxygenation of the circulating system. Huber completely proved both that respiration is essentially necessary to bees, and that the spiracles are the instruments by which it is effected. He found that they die in an exhausted receiver, and become asphyxiated when shut up in numbers in close bottles. They perish in water only if the spiracles are under the surface; and the use of these apertures is then made apparent by the bubbles which escape from them under water. As will be shown, also, bees carefully ventilate their hives. Therefore, though no blood has been detected in bees or other insects, these tiny spiracles are of no slight consequence in the physical economy of the insect, oxygen being apparently not less necessary to the vitality of its circulating fluids than to those of warm-blooded animals.

Besides these appendages and contents of the chest, that region is traversed by the *œsophagus* or gullet, on its way to the digestive and other organs situated in the abdomen. These organs consist of the *honey-bag*, the *stomach*, the *wax-pockets*, and the *intestines*, with the *venom-bag* and *sting*. The honey-bag, sometimes called the first stomach, though digestion never takes place there, is an enlargement of the gullet into a pea-sized bag, pointed in front, with two pouches behind. In this receptacle is lodged the fluid or saccharine portion of the bee's gatherings, and by the muscularity of the coats it can be regurgitated to fill the honey-cells of the hive. A short passage leads to the second or true stomach, which receives the food for the nourishment of the bee, and also the saccharine matter from which the wax is secreted. The small intestines receive the digested food from the stomach, and from them it appears to be absorbed for the purposes of nutrition. Wax, it was once thought, was pollen elaborated in the stomach and ejected by the mouth; but it is entirely derived, it is now known, from the honey or saccharine matter consumed by the insect; and John Hunter discovered two small pouches in the lower part of the abdomen, from vessels on the surface of which it is secreted. After accumulating for a time in these pouches, scales of it appear externally below one or other of the four medial rings of the abdomen, and are withdrawn by the bee itself or those around it. Close to the stomach is found the last important organ of the abdomen, the sting. Much beautiful mechanism is observed on a microscopical examination of this weapon, so powerful in comparison to its bulk. It consists of two long darts, adhering longitudinally, and strongly protected by one principal sheath. This sheath is supposed to be first thrust out in stinging; and its power to pierce may be conjectured from the fact that, when viewed through a glass which magnifies a fine needle-point to the breadth of a quarter of an inch, the extremity of the sheath ends so finely as to be invisible. The sheath once inserted, then the two still finer darts follow, and make a further puncture. The use of this is to receive the poison, which is conducted to the end of the sheath in a groove; and in order that the conjoined darts may not be withdrawn too soon for this purpose, they have each nine or ten barbs at the point to retain them. When the weapon is withdrawn, the poison is thus left with a cavity to enter, causing a deeper festering. The insect ejects the poison by means of a muscle encircling the bag at the base of the sting, in which bag the venom is secreted. The chemical composition of the poison has not been discovered, though it has so far the nature of an acid as to redden the vegetable blues. Altogether, Paley, in his 'Natural Theology,' is fully justified in pointing to the defensive weapon of the bee as a wondrous union of mechanical and chemical perfection.

The manner in which the bee collects the food which forms the various secretions alluded to, is worthy of note. The hairs with which its body and feet are covered, are the main instruments used for this end. By means of the hairs on the feet, the insect usually begins its collection of the pollen in the corolla which it has entered, and after kneading the dust into balls, finally places it in the baskets of the hind-legs. But the creature is not content with the product of this process. Rolling its body round and round, it brushes off the pollen still more cleanly, gathers it into two heaps with its active brushes, and loads its baskets to the brim. Even afterwards, they sometimes fly home like dusty millers, and brush their jackets when unloaded. The pollen is understood to be brought home by the working-bees more peculiarly as food for the young. The fluid secretions contained in the nectaries of flowers, and honey-dew, which is a deposition of certain aphides on plants, serve as other natural varieties of the bee's food. The insect is also at certain periods a liberal drinker of water.

The senses of bees have been in part touched upon already. The means of vision bestowed on them, it was mentioned, consist of the many-lensed eyes in front, and the supplementary organ above. Inquirers have been staggered by the seeming contradictions connected with the vision of the bee. After collecting its store of food, its first movement is to rise aloft in the air, and look for the site of its home. Having determined this in an instant, however distant the hive may be, it goes for the point with the directness of a cannon-ball, and usually alights at its own door, though the whole country be crowded with hives. Yet if the hive, or its door, has been shifted to a slight extent, the insect seems confused, and cannot find its way. The conclusion from this is, that the eyes of the bee have a lengthened focus, suiting them for the main purposes of its existence. But the consequent inability to determine accurately on short distances has been compensated to the creature by the antennæ, which then become a highly serviceable resource. The sense of *taste* in bees has been the subject of much argumentation. Huber was of opinion that it was the most imperfect of their senses, and they have been observed to resort to putrid marshes for water, even when they were not restricted in their choice. Xenophon found his men seriously injured by taking honey produced by bees which had fed on deleterious plants. But, on the other hand, it has been noticed that they reject many substances, and prefer others, when a choice is allowed them; and it has been conjectured that they go to marshes purposely for the salt in their waters. Moreover, what renders the honey deleterious to man, may not be hurtful to bees. Honey formed from a particular flower in the Jerseys, was found unfit for use from its intoxicating qualities; yet the bees throve wonderfully upon it all the while. Their taste in selecting the richest flowers is likewise unquestionable. No doubt the sense of *smell* comes into operation on these occasions, as well as the sense of taste. Betwixt the influence and effects of the two, indeed, it is scarcely possible to discriminate. Even in the case of the human being, it is an established fact, that the powers commonly ascribed to the sense of taste are to a remarkable degree dependent on the sense of smell. If the eyes be bandaged, and the apertures of the nose well shut up, the most experienced judge will be at a loss to determine between any two kinds of ardent spirits, or other pungent substances. The most nauseous medicines, also, much as they may usually seem to affect the taste, will be found almost insipid if the site of the sense of smell be closed up while they are swallowed. In bees, the site of the two senses seems to be almost one and the same. Many experiments of Huber seem to prove that the sense of smell lies in the mouth, and that it is very acute. He found that they hate the odour of turpentine, yet on plugging up the mouth, they showed no disgust when placed beside that liquid. He concealed honey at considerable distances, and they in a very short time detected the hidden treasure. The acuteness of their sense of smell, in truth, is sufficiently proved by their admirable skill in tracking out, over hill and dale, the most fragrant flower-parterres and beds of mountain heath. The sense of *hearing* has been denied to bees by many observers, while others describe the antennæ as their organs of hearing. The probabilities are in favour of the latter position. Noise, produced by the wings, and varied to suit particular purposes, is well known to be used as a mean of inter-communication; and Huber, though doubtful about the faculty, avers that by a particular sound, emitted from the mouth apparently, the queen will render the whole hive silent and motionless in one instant. A certain sound, too, heard in the hive before swarming, is always followed by definite consequences. Such facts as these go far to establish the possession of hearing by bees; as signals by sound, made when the eyes could not detect the movement attending their production, would otherwise be valueless. The antennæ have been mentioned as possessed, if not of hearing, at least of a delicate sense of *touch*. Huber points out a moonlight night as the best time for observing the uses of the antennæ in this respect. The bees, guarding against the intrusion of moths, have not light enough to see fully, and they circumambulate their door with the antennæ stretched right before them. The instant a moth is felt, it is destroyed. When the queen of a hive is lost, the antennæ form a curious means of spreading intelligence. Bee after bee protrudes its antennæ, and crossing them with those of his next neighbour, disseminates in this way the sad news over the hive. Besides the antennæ, the feelers have been shown by experiment to possess a considerable degree of sensibility, and to serve in part as organs of touch.



Drone. Queen. Worker.

Such are the anatomical and physiological characteristics of the common or working-bee. The duties of this order include almost the whole business of the bee community, as will be shown afterwards in detail. Hives differ greatly, of course, in the number of their inmates, taking them even at the same season. Some contain but a few thousands; others from twenty to thirty, forty, and even fifty thousand. Of these the drones compose but a thirtieth part, or little more; all the rest, with the exception of the queen, are workers.

Drones or Males.

The drones differ considerably in outward appearance from the workers. They are bulkier and flatter in body, with a round head, a shorter proboscis, and antennæ with an additional articulation; they have no basket-cavity on their hind-legs, and their abdomen contains the means of secreting neither honey, wax, nor poison, while the reproductive organs are there found instead. They are called drones, from the peculiarly loud noise which they make with their wings. It has been already stated that the drones are the males of the hive. They live but for the reproduction of the race, and when the object of their existence is accomplished, they are doomed to die. The workers, who have their own winter food and that of the coming young to provide, instinctively pass sentence of death at the fitting time; despatch the defenceless males with their stings, and cast them forth from the hives, in which, from their size and voracity, their presence has now become a positive evil. With these exceptions, the description given of the worker-bee applies also to the drone.

Queen-Bees.

The queen-bee is of larger size than either the drone or the worker. She has an elongated body, blackish above, and tinted with yellow inferiorly, while the presence of two ovaries or egg-receptacles in the abdomen, demonstrate her sex. She has also a sting, considerably bent. The Germans call the queen the *mother-bee;* and this is the most appropriate name, since her functions are those of a parent rather than a potentate. Her sole province is to lay the eggs, from which issue those annual multitudes that perpetuate the race in new communities. The progress of all kinds of bees, from the larva state to maturity, will fall to be described in an ensuing section; but it may in the meantime be observed, that the queen usually commences laying eggs on the fifth day after she has assumed the perfect state, and often continues without intermission from early spring to the end of September, laying in the warmest season about two hundred eggs a day. Such are the distinguishing characteristics and functions of the mother-bee.

We propose now to give an account of the natural and regular operations of a colony of bees, from the moment of their introduction to an unfurnished habitation, to the establishment of a perfect hive.

NATURAL ECONOMY OF THE HIVE.

The breeding of young bees commences in February, and a hive, however thinned by the previous winter, becomes, under ordinarily favourable circumstances, crowded to excess in midsummer. Besides the developed bees, it abounds in eggs and young ones not matured. That fine instinct which, in the case of bees, occasionally prompts to acts almost above the power of reason, relieves this crowded state of things. The queen-bee, the proper mother of at least the great body of the hive, resolves upon departure with a swarm. The phenomena attending that departure will be noticed under a separate section; in the meantime, let it be supposed that the queen has led off a colony, and that, by the care of the owner of the bees, the swarm is lodged in a new and empty hive.

The first object of the community is to clean out their new lodging thoroughly, if they find this not done beforehand. The next great object is to block up all the chinks of the hive, smooth its projecting parts, and lay a stable foundation for the future works of the interior. Besides the wax which they use so extensively in their architecture, bees also employ, particularly at first, a remarkable substance called *propolis*, from the Greek words *pro* and *polis* (before the city), as indicating its use on the superficial parts of the hive. Propolis is a grayish-brown resin, of an aromatic odour, and better fitted by its tenacity for cementing than wax. Huber first showed distinctly that the bees gather this from the poplar, alder, birch, and willow trees, but more especially from the first of these trees. The ingenious naturalist alluded to, suspecting Reaumur to be wrong in referring the propolis to the pine, placed near his hives some wild-poplar branches, which the bees soon discovered, and flocked to in great numbers. In the heat of the day, when the viscous matter is ductile, it is thus carried off by the insect. A small thready portion is detached, kneaded with the mandibles, and then, by means of the fore-feet, placed in the basket of the hind-legs, a smart pat or two being given to secure it there. Another portion, similarly kneaded to make it portable, and a little drier, is basketed in the same way, till as much is procured as the insect can carry. Sometimes the patient creature will spend half an hour in the mere kneading of a portion of propolis; and occasionally other bees will come behind and rob the little labourer of its whole load, for a succession of times, without eliciting the slightest symptom of impatience. When a bee reaches the hive with its load, the propolis adheres so firmly, that the insect has to present its limbs to the workers in the hive, who detach it, and immediately use it, while yet ductile, to fill all the crevices of the hive, and smooth the projecting parts, so as to prevent hurts being received in the dark. Another remarkable use is made of the propolis. From the hour of their entrance into the hive, bees are liable to the intrusion of other creatures. A fly they can soon remove, but what are they to do with a snail? They can sting it to death, to be sure, in an instant, but their puny strength is totally insufficient to remove the carcass. In this dilemma, they completely obviate the disagreeable effects of the presence of a large putrefying body, by covering it with propolis, which hardens over the mass, and gives them a pleasant aroma in place of a fetid odour. With the propolis, moreover, they often narrow the entrance to the hive, forming a secure barrier, when they have reason to dread the intrusion of the death's-head moth, their great enemy in some countries.

In the meantime, while some workers are using the propolis for the purposes first stated, others are commencing the preparation of the cells or combs. The propolis is employed to attach these to the edges of the hive, but wax is the component material of the cells themselves. We shall find, in noticing the after-arrangements of the completed hive, that the working-bees are naturally divided into two great classes; but at the outset of their labours, when the cells are being constructed, they form *three* sections, each of which pursues its allotted toil with admirable order and regularity. One section produces the material for the combs, and forms it roughly into cells; the second division follows the first, examines and adjusts the angles, removes all the superfluous wax, and perfects the work; while the third band passes continually out and in, seeking and bringing provisions, chiefly pollen, for the second section, which never quits the hive. The first class flies abroad at intervals, it being necessary that they should have rich saccharine food for the secretion of the wax. As the secretion goes on best in a state of repose, bands of the wax-producers, after feeding fully, suspend themselves in clusters from the roof, each hanging from the hind-legs of the one above, till the wax-scales are formed, and they are prepared to take up the work. This clustering occurs on the very entrance of a swarm into a hive, when a seeming inactivity of several hours takes place, till the production of wax is set a-going. It will be seen that the second section, the architects proper, have the most unremitting toil to perform. They never quit it when once begun, excepting to turn to the little waiters of the third section, and indicate their hunger by holding out their trunk, when the caterer either spirts out a drop or two of honey, or furnishes pollen from the stores brought in.

Cells.

But if the labour of the architect class be severe, their work, when complete, is a marvel of instinctive ingenuity. Bees always begin their work, in ordinary circumstances, at the ceiling, suspending their structures from it. Their combs, or clusters of cells, are arranged in vertical and parallel plates, with a space of about half an inch betwixt contiguous pairs; and each comb is nearly an inch in thickness. At the outset, when one wax-making bee leaves the suspended cluster alluded to, and lays the foundation of a cell, others follow in rapid succession, not only adding their wax to that of the first, but soon commencing new combs, one on each side; and so the work goes on, in most cases, until the whole roof is covered with foundations. The architects proper, also, are meanwhile at their finishing work. They have, says Reaumur, to solve this difficult geometrical problem: 'A quantity of wax being given, to form of it similar and equal cells of a determinate capacity, but of the largest size in proportion to the matter employed, and disposed in such a manner as to occupy the least possible space in the hive.' Wonderful to reflect upon, this problem is solved by bees in all its conditions, in their construction of hexagonal or *six-sided* cells. The square and the equilateral triangle are the only other two figures of cells which could make them all equal and similar without interstices. But cells of those figures would have either consumed more material or have been weaker; and they would also have consumed more space, being less adapted to the form of the bee. In short, the hexagonal form combines all the requisites of economy and capacity. Another wonderful arrangement is seen in the construction of the bottoms of the cells. Each of these is composed of three rhombs, or plates of wax in the shape of card-diamonds, disposed in such a manner as to form a hollow pyramid, the apex of which forms the angles of the bases of three cells on the opposite side, giving to each of them one of the three diamond-shaped plates which is required to form their bases. Now, the three rhombs, composing each cell-bottom, have the two obtuse angles each of 110 degrees, and consequently, each of the two acute angles of 70 degrees. Koenig, on being desired by Reaumur to calculate the exact angle which would give the greatest economy of wax in a cell of such capacity, found that the angle should be 109 degrees 26 minutes, or 110 degrees nearly. Other geometricians have arrived at similar conclusions. The problem is one of great difficulty, yet the bee practically solves it at once, under the guidance of the Great Geometrician who made both the bee and the law on which it proceeds. Attempts have been made to ascribe the form of the cells to the peculiar shape of the head of the bee, and the instruments which it employs; but all such explanations have been found liable to insuperable objections.

The cells of the bee are extremely delicate, two or three plates or sides being of the consistence only of a common leaf of paper. They are made strong, however, by mutual support and other means. Besides a sort of froth which the insect mixes with the wax, the cells, at first of a dull white, soon appear yellow on the interior, the change arising from the plastering over them of a compound varnish of wax and propolis. Each cell is soldered, too, at its mouth by a similar compound of a reddish colour, having in it more propolis; and threads of the same substance are laid around the walls, to bind and strengthen them. It is now to be observed that all cells are not alike. They have four different uses in the economy of the hive, and are constructed variously to suit these. One set of cells is for holding the eggs or embryos of worker-bees; a second for those of males or drones; a third for those of young queens, hence called royal cells; and a fourth set are for the reception of honey and pollen. The first are generally about five lines in depth (or less than half an inch), and two lines and two-fifths in diameter. The cells of the young males are much less numerous, and measure from six to seven lines in depth, by three and a half in diameter. It is worthy of note, that in passing from the construction of worker-cells to those of drones, in the same comb, the architects do not alter the size at once, but gradually, thus disordering in the slightest possible degree the delicate arrangement of the bases of the cells. In shifting from larger to smaller, the same rule is observed. A small number only of royal cells, about ten or twelve, are constructed on ordinary occasions. They are about an inch in depth, and nearly one-third of an inch in width, with walls about an eighth of an inch in thickness. After the breeding season is over, the cells both of worker and male bees are used for holding honey. Those made purposely for that end are chiefly marked by a greater divergence from the horizontal plane, that the honey may be better secured; and it is curious to observe that, in a very warm season, these wise insects give the floor a still greater dip from the mouth inwards. As the store enlarges, they seal up the mouth with a ring of wax, to which they gradually add concentric layers till the cell is filled, when they close it altogether—reserving its treasure for use during winter and spring. Pollen, as brood food, is kept in cells of considerable size.

Laying of Eggs.

A very short time elapses ere a great number of cells are constructed; for, in the height of the honey season, a good swarm has been known to build *four thousand* in a day. The queen-mother very soon begins the task of laying eggs. A thousand conjectures have been hazarded as to the mode in which the fecundation of the female bee takes place. No observer has yet been able to discover any contact with the drones in the hive. It was supposed by Swammerdam that a certain aura or odour from the males was all that was necessary to render the eggs of the queen productive; while M. Debraw imagined that the eggs, as in the case of frogs and fishes, were fecundated by a fluid from the drone after being laid. M. Hattorf thought, again, that the queen was fecundated by herself alone. All these opinions Huber refuted in a satisfactory manner, by separations and confinements of the insects in various ways. He at length came to the belief, founded on experiments which appear almost decisive of the question, that the female bee never becomes fruitful in the hive, but requires to go abroad for that purpose; and it has been also thought probable that the fecundation takes place by contact in the air, as is known to occur in the case of winged ants. The number of drones in a hive has been thought a most unintelligible circumstance. Huber's views explain the matter fully. It is essential that they should be numerous, that the female may have a chance of meeting them abroad; and it is to be observed that she always quits the hive at the hour when the drones leave it, or immediately afterwards. One intercourse is sufficient, according to Huber's experiments, to render the female bee productive for at least two seasons; and if the intercourse takes place at the end of the year, the consequent laying of eggs may be deferred till the ensuing spring. The cold weather has a powerful influence in this respect. These conclusions may be more fully ascertained by reference to Huber's interesting work, a translation of which was published by J. Anderson, Edinburgh, in 1808, and another by Tullis, Cupar-Fife, in 1840.

M. Huber discovered that the queen begins to lay eggs forty-six hours after returning from the flight during which fecundation takes place. For the space of eleven months, under ordinary circumstances, a queen, at her first laying, produces the eggs of worker-bees alone. At the end of the space mentioned, a considerable laying of the eggs of drones commences; and soon after the appearance of these, the workers of the hive, with a strange instinct, begin to prepare royal cells for the queen-eggs that are certain to follow. Altogether, the fruitfulness of the female bee is amazing, from one to two hundred eggs a day being the usual amount of her produce. One hundred thousand is said to be no very uncommon number of young for her to give origin to in a single season. A swarm consisting of 2000 or 3000 in the beginning of the year, will throw off in June swarms amounting to 40,000 or 50,000; in many cases the first swarm, and in some the cast or second swarm, throw off colonies of 10,000 or 12,000; and yet the original stock is left augmented to the number of 18,000 or 20,000. Occasionally, an early and numerous first swarm casts even twice.

Transformation of Worker-Bees.

A fertilised queen is so impatient to begin her laying of worker-eggs, that, in a new hive, she only waits till a few inches of comb are erected. Before depositing the egg, she carefully examines the cell, and, if satisfied, turns and drops into it from the oviduct an egg of an oval shape and bluish-white tint. Here the egg remains for three days attached by a viscous fluid to the corner of the cell; and, on the fourth, the thin outer shell of the egg bursts, exposing a small lively worm. Now come into play the *nurses* or nursing-bees, one of the two great sections into which Huber and others consider the labourers of the hive to be divided. The other class are the *wax-workers*. Both elaborate honey, but the latter class alone make wax and form combs. Again, the nurses, whose figure may be distinguished from its being more ovoidal than the others, are those who alone take care of the young. As soon as the egg is hatched, they watch over the larva or worm with the tenderest and most incessant care, administering copious supplies of mixed pollen, honey, and water, which the nursling devours with avidity. Like other larvæ, it soon grows so as to cast its cuticle; and, five days after chipping the shell, it has become large enough to fill the cell, lying coiled up like a ring. It now ceases to eat, and the bees seal up the cell with wax. Left to itself, the larva begins the process of spinning a cocoon round its body, which it does in thirty-six hours, the material being a fine silken thread from the mouth of the spinner. In three days more it is converted into the state of *pupa* or chrysalis, when all the parts of the future bee become gradually visible through the transparent covering, assuming a darker hue day by day, and progressing to the state of the complete *imago* or insect. On the twentieth day from the deposition of the egg, the young bee begins to cut through its prison-door with its mandibles, and in half an hour makes its escape. Old writers say that the elder bees fondly caress and feed the new-comer; but later observers, of no mean authority, declare that, on the contrary, they seem to think their duty ended with the closing up of the cell, and leave the young stranger to shift for itself in the busy world upon which it has entered. One thing, however, is done by the elder bees. They instantly clean out the vacated cell, and prepare it again for eggs or honey, leaving at the same time the silk cocoon adhering to the walls.

Male Eggs—Royal Eggs.

The passage of male eggs through the larva and pupa state is attended with the very same phenomena as in the case of the eggs of workers, with the exception that the process occupies a little more time, twenty-four days in all being spent in the change. The cause of male eggs being laid, in ordinary circumstances, only after eleven months have been passed in the laying of worker-eggs, was explained by Huber. He conceived eleven months to be necessary to perfect the male eggs, and was of opinion that the arrangement of the eggs in the ovaries was such as to permit, and even compel, the retention of both male and royal eggs until they were fully matured. This idea seems to be confirmed by the ordinary course of things in the hive, but certain anomalous facts startlingly contravene it. Huber himself found, that if a young queen had not the opportunity of proving fertile within twenty days of her birth, all her after-product consisted of drones, and drones alone; and, what is still more curious, he discovered that she began to produce these drones at the time when she should have laid worker-eggs—namely, within forty-six hours after fecundation. The gestation of eleven months seemed totally unnecessary in such cases of retarded fecundation. Huber confessed himself incapable of explaining this remarkable circumstance. Though we do not understand it, however, it only tends to make us marvel more and more at the perfection of order in the bee economy. The queen-bee is never voluntarily guilty of that breach of the laws of her being which produces such remarkable effects; and, if artificially confined till she is twenty days old, her violent agitation shows her instinctive sense of the departure from the order of nature into which she is compelled.

The raising of workers and drones from the egg to the insect state is a simple matter in comparison with the same transition in the case of queen-bees. The royal eggs, which the queen begins to lay twenty days after she has commenced the deposition of male ones, differ in no respect from common eggs. But on the royal larva, when it breaks from its three days' confinement in the shell, the nurses bestow peculiar attentions. They watch it incessantly, and feed it with a rich *jelly*, slightly acescent, and given in such quantities that the royal cell is usually wet with it. In five days the young majesty of the hive has grown, so as to be able to spin her web, and the bees wax up the cell. The cocoon is spun in twenty-four hours; two days and a half of inactivity follow; the larva is then transformed into a pupa, or a *nymph*, as the insect in this state is more frequently termed; and after other four or five days have passed, the royal insect is complete—the whole time occupied in the metamorphosis being about sixteen days.

Young Queens.

We have now arrived at one of the most extraordinary points in the history of the hive. The young queen, or rather queens, do not issue from their cells when perfect, like workers and drones. They are not permitted, unless the old or regnant queen has quitted the hive with a swarm, or the seat of royalty is in any other way vacated. They therefore close the royal cells more firmly, leaving only a small aperture to introduce food; and, acting as if aware that they may need a queen in case of swarming, they at such times will not permit the old queen to approach the cells. Her struggles to do so are often violent, and her dire hostility to her own sex leads her, if she gets near the cells, to destroy them instantly, whether in the state of full insect or nymph. The strength of this instinctive hate is even such, that a young queen no sooner leaves her own cell than she feels its stirrings.

According to Huber, there can only be a single queen in a hive. The mere offspring of two could scarcely co-exist in the same hive; and it is wonderful to observe by how many accessory circumstances nature has insured the death of one or other of any two placed in the same community. The first thought of a young queen, it has been seen, is to kill her yet undeveloped rivals. Nature has given her the chance, for, as more queen-eggs than one are seldom laid daily, one is usually the oldest. If, however, two do quit the cell at the same instant, they rush into combat with the most headlong fury. If a stranger enters a hive, its queen-regnant flies to the field without a moment's hesitation. In short, in all ordinary circumstances, two queens brought into contact, fight. But they might *both* die in the contest, and the community be left without a queen. Nature demands but one victim, and she has arranged that but one victim shall fall. Bees are only vulnerable in the belly; and Huber observed that, whenever two royal combatants were so locked together that they could mutually plant their stings in the fatal part, their instinct caused them to separate precipitately, without harm on either side. The combat only closes when one can get an advantage of position, and kill its rival with safety. Again, the worker-bees might interpose to prevent these mortal combats. On the contrary, their instinct is to prevent the queens from parting, and force on a fatal issue. Alluding to one battle, Huber says that it seemed as if 'the bees anticipated the combat in which these queens were about to engage, and were impatient to behold the issue of it, for they retained their prisoners only when they appeared to withdraw from each other; and if one less restrained seemed desirous of approaching her rival, all the bees forming the clusters gave way, to allow her full liberty for the attack; then if the queens testified a disposition to fly, they returned to enclose them.'

Another remarkable provision for insuring the existence of but one queen in a hive, is beheld in the peculiar mode in which the royal larvæ spin their cocoons. Other bees spin perfectly close cases; the queen-larvæ spin cocoons which envelop only the head, thorax, and first ring of the abdomen, leaving a part open behind. Huber thus explains this minute but important peculiarity:—'Of several royal nymphs in a hive, the first transformed attacks the rest, and stings them to death. But were these nymphs enveloped in a complete cocoon, she could not accomplish it. Why? Because the silk is of so close a texture, that the sting could not penetrate, or if it did, the barbs would be retained by the meshes of the cocoon, and the queen, unable to retract it, would become the victim of her own fury. Thus, that the queen might destroy her rivals, it was necessary the last rings of the body should remain uncovered; therefore, the royal nymphs must only form imperfect cocoons. You will observe that the last rings alone should be exposed, for the sting can penetrate no other part: the head and thorax are protected by connected shelly plates, which it cannot pierce. Hitherto philosophers have claimed our admiration of nature in her care of preserving and multiplying the species. But from the facts I relate, we must now admire her precautions in exposing certain individuals to a mortal hazard.' Examining further into the causes of the open cocoon of the royal nymphs, Huber came to the conclusion that it arose from the figure of their cells, and was designed for the purpose of exposing them to the certainty of destruction.

Loss of a Queen.

If bees, by death or artificial means, are deprived of their queen, the event has a marked influence in the hive. We do not allude to the case in which a stranger kills the queen-regnant; for if such a thing happens, as naturalists conceive it scarcely ever can do under natural circumstances, on account of the wariness of the bees to prevent intrusion, the victorious stranger mounts the vacant throne, and reigns in peace. We refer, however, to the removal of a queen without the introduction of any other. In such a case, the following results ensue, according to Huber:—'Bees do not immediately observe the removal of their queen; their labours are uninterrupted; they watch over the young, and perform all their ordinary occupations. But in a few hours agitation ensues; all appears a scene of tumult in the hive. A singular humming is heard; the bees desert their young, and rush over the surface of the combs with a delirious impetuosity. Then they discover their queen is no longer among them. But how do they become sensible of it? How do the bees on the surface of the comb discover that the queen is not on the next comb?' It is supposed that the alarming intelligence of the loss is communicated by the strokes on the antennæ, which bees are uniformly observed to give to each other at these times. The insects then appear to seek for their lost queen, some rushing hurriedly out to make the search abroad. At the end of five hours, the commotion greatly ceases, and an instinctive recourse to the means of supplying the vacancy takes place. If they have royal larvæ, they turn their whole attention to them. If they have only the larvæ of working-bees, they immediately select two or three of them, pull down the neighbouring cells, at the cost of the lives of the young within them, and construct a royal cell around each of the selected larvæ—the consequence of which proceeding will be immediately explained. If they have no larvæ at all on the loss of their queen, still they build several royal cells, as if so far at least to supply the emergency. If a stranger queen be introduced in such a state of things, within twelve hours after the loss of their own sovereign, the new-comer is treated as an intruder, and the bees surround her so closely that she commonly dies from privation of air, suffocation being the resource of bees in such cases. If the stranger be introduced within eighteen hours, they also surround her, but leave her sooner. To show that they possess memory, it is only necessary, now to re-introduce their own queen, when they will show every symptom of recognition and joy. But their memory is short-lived; for, if the stranger be not introduced till twenty-four hours elapse, she receives a treatment very different from that experienced at an earlier period. 'I introduced,' continues the ingenious naturalist, 'a fertile queen, eleven months old, into a glass hive. The bees were twenty-four hours deprived of their queen, and had already begun the construction of twelve royal cells. Immediately on placing this female stranger on the comb, the workers near her touched her with their antennæ, and passing their trunks over every part of her body, they gave her honey. Then these gave place to others that treated her exactly in the same manner. All vibrated their wings at once, and ranged themselves in a circle around their sovereign. Hence resulted a kind of agitation, which gradually communicated to the workers situated on the same surface of the comb, and induced them to come and reconnoitre, in their turn, what was going on. They soon arrived; and having broke through the circle formed by the first, approached the queen, touched her with the antennæ, and gave her honey. After this little ceremony they retired, and, placing themselves behind the others, enlarged the circle. There they vibrated their wings, and buzzed without tumult or disorder, and as if experiencing some very agreeable sensation. The queen had not yet left the place where I had put her, but in a quarter of an hour she began to move. The bees, far from opposing her, opened the circle at that part to which she turned, followed her, and formed a guard around. She was oppressed with the necessity of laying, and dropped her eggs. Finally, after an abode of four hours, she began to deposit male eggs in the cells she met with.

While these events passed on the surface of the comb where the queen stood, all was quiet on the other side. There the workers were apparently ignorant of a queen's arrival in the hive. They laboured with great activity at the royal cells, as if ignorant that they no longer stood in need of them: they watched over the royal worms, supplied them with jelly, and the like. But the queen having at length come to this side, she was received with the same respect that she had experienced from their companions on the other side of the comb. They encompassed her, gave her honey, and touched her with their antennæ; and, what proved more satisfactorily that they treated her as a mother, was their immediately desisting from work at the royal cells: they removed the worms, and devoured the food collected around them. From this moment the queen was recognised by all her people, and conducted herself in this new habitation as if it had been her native hive.'

Making of a Queen.

If one queen is not so introduced to supply the loss of another, and no royal larvæ exist, one of the most wonderful phenomena of the hive takes place. It has been stated that bees, on losing their queen, build a royal cell around an ordinary worker-bee larva, or several of them, if the larvæ are abundant. These, by peculiar feeding, are formed and developed into *queens*, thus proving that the worker-bees, commonly viewed at one time as neuters, are in reality undeveloped females. This remarkable discovery was made by Schirach. Having used smoke about a hive, he so annoyed the queen that she flew away, and the circumstance of the bees immediately building royal cells around common larvæ, when they had no royal larvæ, revealed to him the truth. Huber proved the same thing by the succeeding experiment:—'I put some pieces of comb, containing workers' eggs in the cells, of the same kind as those already hatched, into a hive deprived of the queen. The same day several cells were enlarged by the bees, and converted into royal cells, and the worms supplied with a thick bed of jelly. Five were then removed from these cells, and five common worms, which, forty-eight hours before, we had seen come from the egg, substituted for them. The bees did not seem aware of the change; they watched over the new worms the same as over those chosen by themselves; they continued enlarging the cells, and closed them at the usual time. When they had hatched on them seven days, we removed the cells, to see the queens that were to be produced. Two were excluded, almost at the same moment, of the largest size, and well formed in every respect. The term of the other cells having elapsed, and no queen appearing, we opened them. In one was a dead queen, but still a nymph; the other two were empty. The worms had spun their silk cocoons, but died before passing into their nymphine state, and presented only a dry skin. I can conceive nothing more conclusive than this experiment. It demonstrates that bees have the power of converting the worms of workers into queens, since they succeeded in procuring queens by operating on the worms which we ourselves had selected.' This curious provision seems intended to preserve the communities of bees, in any emergency, from the danger of wanting that all-important member, the queen; and it is reasonably conjectured that the evolution of a queen from a worker-larva is dependent on the effects of the royal food upon the ovarian system.

Fertile Worker-Bees.

Another most remarkable fact observable in the economy of the hive was discovered by M. Riem. Common worker-bees, that naturalist proved, sometimes lay fertile eggs. It was reserved for Huber to determine this, and also to explain the cause. He in the first place found that, in a hive deprived of its queen, the eggs of drones were laid. Though he did not put faith in what had been said by some naturalists respecting the existence of *small* queens, he nevertheless satisfied himself, by directing a careful examination to be made of each individual bee in the hive, that no queen was amongst them, every one having the little basket on the hind-leg, and a straight sting. Thus convinced of the reality of Schirach's discovery, Huber, having detected several workers laying eggs, examined them, and found the ovaries partially developed. He now bethought him that the only known cause of such development is the use of the food or jelly given to the royal larvæ. Led into this strain of thought, he speedily discovered that all the fruitful worker-bees are born in hives where no queen exists, and where worker-larvæ are transformed to queens; and he further found that they are always born in cells adjacent to those of these larva-queens. Continued investigations brought him to the belief, finally, 'that when bees give the *royal treatment* to certain worms, they either by accident or by a particular instinct, the principle of which is unknown to me, drop some particles of royal jelly into cells contiguous to those containing the worms destined for queens;' whence the expansion of the ovaries to a certain degree. That expansion is imperfect. As in the case of retarded fecundation in queens, the fruitful worker-bees produce nothing but drones. In this fact, it seems to us, may possibly be found the principle of the unexplained instinct in question. May the instinct which leads them to create queens from worker-larvæ, not also prompt them so to dispense the royal food to common larvæ, as to supply the hive with new drones for the new queens? This end is at least gained by the mode in which the worker-bees become productive. Ovaries, in a rudimental or undeveloped state, have been found by late observers in all working-bees.

Mutilations of Queens.

Before leaving the particular subject of queens, the remarkable effects of mutilations upon them may be mentioned. Huber cut off one antenna from a queen without any marked effects; but when he cut off both, the case was different. 'From this moment there was a great alteration in her conduct. She traversed the combs with extraordinary vivacity. Scarcely had the workers time to separate and recede before her: she dropped her eggs without taking care to deposit them in any cell. The hive not being very populous, part was without combs. Hither she seemed particularly earnest to repair, and long remained motionless. She appeared to avoid the bees; however, several workers followed her into this solitude, and treated her with the most evident respect. She seldom required honey from them; but when that occurred, she directed her trunk with an uncertain kind of feeling, sometimes on the head, and sometimes on the limbs of the workers, and if it did reach their mouths, it was by chance. At other times she returned upon the combs, then quitted them, to traverse the glass sides of the hive; and always dropped eggs during her various motions. Sometimes she appeared tormented with the desire of leaving her habitation. She rushed towards the opening, and entered the glass tube adapted there; but the external orifice being too small, after fruitless exertion, she returned. Notwithstanding these symptoms of delirium, the bees did not cease to render her the same attention as they ever pay to their queens; but this one received it with indifference. All that I describe appeared to me the consequence of amputating the antennæ.' Another similarly mutilated queen was placed beside her; they had both lost their natural combativeness. Finally, on being again left alone, the poor mutilated queen quitted the hive, unheeded, and abandoned to her fate. This evidence of the indispensable utility of the antennæ was gained, on the whole, in a manner for which even a Huber's ardour for science can scarcely form an excuse.

Massacre of the Drones.

Another of the great natural phenomena of the hive is the massacring of the drones. It was at one time asserted that the worker-bees did not use their stings against the stingless males, but merely pushed them out to die. This idea, however, resulted from the massacre being always committed at the bottom of the hive, whither the poor drones retire in clusters in July and August, as if aware of the doom impending over them. As usual, by one of his ingenious expedients, Huber discovered the truth. Six swarms were put on glass tables, beneath which the watchers placed themselves. 'This contrivance succeeded to admiration. On the 4th of July, we saw the workers actually massacre the males, in the whole six swarms, at the same hour, and with the same peculiarities. The glass table was covered with bees full of animation, which flew upon the drones as they came from the bottom of the hive; seized them by the antennæ, the limbs, and the wings, and after having dragged them about, or, so to speak, after quartering them, they killed them by repeated stings directed between the rings of the belly. The moment that this formidable weapon reached them, was the last of their existence; they stretched their wings and expired. At the same time, as if the workers did not consider them as dead, as they appeared to us, they still struck the sting so deep, that it could hardly be withdrawn; and these bees were obliged to turn round upon themselves, with a screw-like motion, before the stings could be disengaged.

Next day, having resumed our former position, we witnessed new scenes of carnage. During three hours, the bees furiously destroyed the males. They had massacred all their own on the preceding evening, but now attacked those which, driven from the neighbouring hives, had taken refuge amongst them. We saw them also tear some remaining nymphs from the combs; they greedily sucked all the fluid from the abdomen, and then carried them away. The following days no drones remained in the hives.

These two observations seem to me decisive. It is incontestable that nature has charged the workers with the destruction of the males at certain seasons of the year. But what means does she use to excite their fury against them! This is a question that I cannot pretend to answer. However, an observation that I have made may one day lead to a solution of the problem. The males are never destroyed in hives deprived of queens; on the contrary, while a savage massacre prevails in other places, they there find an asylum. They are tolerated and fed, and many are seen even in the middle of January. They are also preserved in hives which, without a queen, properly so called, have some individuals of that species that lay the eggs of males, and in those whose half-fecundated queens, if I may use the expression, propagate only drones. Therefore the massacre takes place in none but hives where the queens are completely fertile, and it never begins until the season of swarming is past.'

Swarming.

We have now only another of the great natural operations of the hive to advert to, before coming to the consideration of the artificial provisions which have been discovered and employed by man for augmenting the usefulness of this interesting insect. Swarming is the operation referred to, which usually takes place, in temperate climes, in May and June, though additional swarms, and swarms from swarms, are commonly later. In noticing the proceedings of a community from its first settlement, it was mentioned that the old queen led off the first swarm, and did so as if under alarm at the number of royal embryos, usually from twelve to twenty, which were in progress to maturity, and which the worker-bees would not allow her to approach. Other causes also operate, beyond doubt, in a certain degree. The increased heat of the hive from crowding, for example, in all likelihood influences the movement. Bees cannot do without freedom of respiration and fresh air, and it has surprised many observers to find the air usually pure, and below 80 degrees, in a hive ordinarily filled. The insects, however, have been discovered to manage this by active ventilation in their own way. A number of them are always to be seen near the inner, and sometimes the outer side of the opening of the hive, vibrating their wings with great rapidity, and sending the entering air backwards in a smart current. One band relieves another at this task. These means of ventilation, however, seem to become comparatively ineffective when the hive gets overcrowded. The heat often rises to about 100 degrees; the bees are driven to the door in clusters, while the warmth makes the hive visibly moist. At the same time, the old queen's alarm at the growth of the royal young seems to have its influence. She would fain kill them, but the worker-bees lose all respect for her, biting and beating her off with violence. The way in which they defend the royal young at swarming time is indeed most remarkable. If, at any other season, they bring up queens from worker-larvæ, the first queen that leaves the cell is allowed to kill the rest at pleasure. But when casting colonies, the workers, as if from the sense that various swarms may be cast off, and various queens required, will not permit the old queen to touch the young, whom nature has given them the strange power of keeping alive, for better security, in their cells. Nor will they allow the first young one to whom they grant freedom to touch the rest. Huber illustrates this subject beautifully. Suppose an old queen to have left a very populous hive, as described, with a swarm—'After the departure of the colony, the remaining workers set another queen at liberty, and treat her with equal indifference as the first. They drive her from the royal cells; she also, perpetually harassed, becomes agitated, departs, and carries a new swarm along with her. In a populous hive, this scene is repeated three or four times during spring. The number of bees being then so much reduced, they are no longer capable of preserving a strict watch over the royal cells; several females are therefore enabled to leave their confinement at once; they seek each other, fight, and the queen at last victorious reigns peaceably over the republic.

The longest intervals we have observed between the departure of each natural swarm, have been from seven to nine days. This is the time that usually elapses from the period of the first colony being led out by the old queen until the next swarm is conducted by the first young queen set at liberty. The interval between the second and third is still shorter; and the fourth sometimes departs on the day after the third. In hives left to themselves, fifteen or eighteen days are usually sufficient for the throwing of the four swarms, if the weather continues favourable, as I shall explain.

A swarm is never seen except in a fine day, or, to speak more correctly, at a time of the day when the sun shines and the air is calm. Sometimes we have observed all the precursors of swarming—disorder and agitation—but a cloud passed before the sun, and tranquillity was restored: the bees thought no more of swarming. An hour afterwards, the sun having again appeared, the tumult was renewed: it rapidly augmented, and the swarm departed.

Bees generally seem much alarmed at the prospect of bad weather. While ranging in the fields, the passing of a cloud before the sun induces them precipitately to return. I am led to think that they are disquieted by the sudden diminution of light. For if the sky is uniformly obscured, and there is no sudden alteration in clearness, or in the clouds dispelling, they proceed to the fields for their ordinary collections, and the first drops of a gentle shower do not make them return with much precipitation.

I am persuaded that the necessity of a fine day for swarming is one reason that has induced nature to admit of bees protracting the captivity of their young queens in the royal cells. I will not deny that they sometimes seem to use this right in an arbitrary manner. However, the confinement of the queens is always longer when bad weather lasts several days together. Here the final object cannot be mistaken. If the young females were at liberty to leave their cradles during those bad days, there would be a plurality of queens in the hive, consequently combats; and victims would fall. Bad weather might continue so long, that all the queens might at once have undergone their last metamorphosis, or attained their liberty. One victorious over the whole would enjoy the throne; and the hive, which should naturally produce several swarms, could give only one. Thus the multiplication of the species would have been left to the chance of rain or fine weather, instead of which, it is rendered independent of either by the wise dispositions of nature. By allowing only a single female to escape at once, a regular and successive formation of swarms is secured. This explanation appears so simple, that it is superfluous to insist further on it.'

Our author adds, that another important circumstance resulting from the captivity of queens is, that they are in a better condition to fly when the bees have given them liberty, and are therefore capable of profiting by the first moment of sunshine to depart at the head of a new colony.

Dangers during Swarming.

The capture of the queen, when a swarm has settled on some bush or tree, is, it should be added, the first step towards lodging a swarm in a new hive. If she be placed in it, with two or three bees, the rest will soon follow. A strong glove will enable any one to handle the bees without risk, as they are less disposed to sting when they are swarming than at other times. It sometimes happens, however, that a swarm may settle on the person of any individual who may be near, in which case presence of mind is absolutely necessary for the preservation of life. The following anecdote, related by Thorley, is strikingly illustrative of what has now been advanced:—

'One of my swarms settled among the close-twisted branches of a codling-tree; and not to be got into a hive without help, my maid-servant, being in the garden, offered her assistance to hold the hive while I dislodged the bees. Having never been acquainted with bees, she put a linen cloth over her head and shoulders to guard and secure her from their swords. A few of the bees fell into the hive, some upon the ground, but the main body upon the cloth which covered her upper garments. I took the hive out of her hands, when she said that the bees had got under the covering, and were crowding up towards her breast and face, which put her in a trembling posture. When I perceived the veil was of no farther service, she gave me leave to remove it. This done, a most affecting spectacle was presented, filling me with the deepest distress and concern, as I thought myself the unhappy instrument of drawing her into so imminent hazard of her life. Had she enraged them, all resistance had been vain, and nothing less than her life would have atoned for the offence. I used all the arguments I could think of, begging her, with all the earnestness in my power, to stand her ground, and keep her present posture. The bees had now got in a great body upon her breast, about her neck, and up to her chin, and I began to search among them for their queen. I immediately seized her, taking her from among the crowd, along with some of the commoners, and put them together into the hive. Here I watched her for some time; and as I did not observe that she came out, I conceived that the whole body would quickly abandon their settlement; but instead of that, I soon observed them gathering closer together, without the least signal for departing. Upon this I immediately reflected that either there must be another sovereign, or that the same was returned. I directly commenced a second search, and in a short time, with a most agreeable surprise, found a second, or the same. She strove, by entering farther into the crowd, to escape me; but I reconducted her, with a great number of the populace, into the hive. And now the perilous scene began to change to one infinitely more pleasing and agreeable. The bees, missing their queen, began to dislodge and repair to the hive, crowding into it in multitudes, and in the greatest hurry imaginable; and in the space of two or three minutes, the maid had not one single bee about her, neither had she received so much as one sting, a small number of which would quickly have stopped her breath.'

ARTIFICIAL MANAGEMENT—THE APIARY.

The artificial management of the hive forms, in some measure, a branch of the present subject perfectly distinct from the consideration of the natural operations of bees, of their various classes, of the phenomena attending their transformation, and of their social economy in general. Many able writers of recent date have given to the public their experience of the best modes of preserving these insect communities, and rendering them most productive. And, in the first place, the local situation of an apiary, or accumulation of beehives, has been held of especial consequence.

Site of Apiaries.

The hives must be sheltered in a particular manner from the action of high winds. A wall or hedge is not sufficient to yield the requisite protection; houses or lofty trees are necessary to insure it. The reason of this is, that the bees, returning homewards, require a calm air at a considerable height above their dwellings, otherwise, when they attempt to alight, they are dashed to the ground and killed, their exhausted strength disabling them from coping with a wind of any force. A low position, enclosed with woods, suits them best. Bees drink much, and a fountain or brook is essential to them; deep pools or cisterns very often cause their death by drowning. Shallow troughs, filled with moss or floating wood, are recommended as a substitute for shallow rills. It is an error, according to the experienced bee-keeper De Gelieu, to suppose that hives should be placed full in the sun. Bees, he says, live and thrive in shady places of moderate and uniform temperature; hence their partiality for forests. Besides, exposure to all the extremes of the solar heat melts and spoils the honey. In fine, if exposure to the sun be beneficial at all, that exposure should last only for a comparatively short time, or from about ten o'clock till noon. Hives should not be placed on upper floors, on account of the increased danger from wind. At the same time, a bee-house ought to be so made as to cause a free passage of air, though not of strong currents, at all periods, with openings both anteriorly and posteriorly. A covered shed or veranda is perhaps the best form of a bee-house, yielding both a shade from the heat and shelter from the wet. Where hives are simply placed on open stands, these should be about sixteen inches from the ground, and each three or four feet apart. Shifting is condemned by almost all observers as very hurtful to the bees. Quiet is also necessary to their successful operations; and it has been found that they do not thrive well in the neighbourhood of smithies, mills, steam-engines, and the like, partly, we believe, on account of the noise, and partly owing to the smells emitted from such works.

As to the district of country, that of course will always be preferable which yields such vegetable productions as the insect can turn to account. 'Large heaths, sheltered with woods,' says the Naturalists' Library, 'are extremely productive of honey, as the wild thyme and other flowering plants with which they abound are not cut down by the scythe; and the heath itself remains in bloom till late in the season. The plane-tree, the whole willow tribe, the furze or whin, the broom, especially the Spanish kind, furnish a rich store both of honey and farina. Bees do not feed indiscriminately on every species of flowers; several of the most splendid and odoriferous are wholly neglected by them, while they select others, the flowers of which are extremely small, and not apparently possessed of any valuable qualities. Moreover, they give a decided preference to those spots where a *great quantity* of their favourite flowers grow together. On the continent, fields of buck-wheat afford a copious supply, though the honey extracted from it is of a coarser kind; and in our own country, the white clover will, in fine weather, be found thronged with them, while scattered plants that afford more honey are neglected. When a variety of bee-flowers flourish in the same field, it is said they will first collect from those which furnish the best honey; if, for example, several kinds of thyme grow together, they prefer the lemon variety, which is of a sweeter and richer fragrance.

But while mainly depending, as they must always do, on the natural products of the country, the bee-master will do well to supply his favourites with such flowers, &c. as are not found growing spontaneously in his neighbourhood. In addition to the gooseberry, currant, and raspberry bushes, and the several orchard trees, the flower-borders in his garden should be well stocked with snowdrops, crocuses, wallflower, and, above all, the mignionette, which affords honey of the richest flavour, and which continues flowering till the near approach of winter. The rich melliferous blossoms of the *Buddlea globosa*, too, the bees are very fond of; and some of the *Cacalia* tribe afford an ample store. "The *Cacalea suaveolens*," says Darwin, "produces so much honey, that on some days it may be smelt at a great distance from the plant. I remember once counting on one of these plants above two hundred painted butterflies, which gave it the additional appearance of being covered with additional flowers." Besides these, the plants of borage and viper's bugloss yield a very considerable quantity of the rich liquid. The former is eagerly resorted to by the bees; it is an annual, and blossoms during the whole season, till destroyed by the frost. In cold and showery weather, the bees feed on it in preference to every other plant, owing to its flowers being pendulous. The bugloss appears as a troublesome weed among corn, and grows on dry soils in great profusion: it is a biennial plant. Turnips, particularly the early garden kind, should be sown, and allowed to remain in their beds during the winter; and they will in consequence, by their early flowering, afford a seasonable supply of farina, and also a small portion of honey early in spring. The whole cabbage tribe also may be made to contribute their share; and mustard, when sown in successive crops, will continue to blossom for many weeks together.'

Hives.

The important question of the size, form, and materials of the hive, or artificial habitation, has of course received much attention. Whatever be the form adopted, it is found that bees accommodate their labours to it, and fashion their combs of honey accordingly.

Straw hives, of which a sketch is given in the preceding page, are those most commonly used in cottage gardens; and being easily and cheaply constructed, they still maintain their place, though much better habitations could be suggested. They are of a roundish form, ordinarily measuring about twelve inches deep and nine inches wide in the lower part. Made of unbroken rye straw, or any other straw of a strong and elastic fibre, and well bound, they will, if tolerably well sheltered, last many years. It is customary to place sticks across the interior, from an idea that such are necessary for supporting the combs; but Mr Taylor, in his 'Bee-Keeper's Manual,' combats this opinion. 'The sticks,' observes that intelligent writer, 'are only an annoyance to the bees; and there is little fear of the combs falling, except in very deep hives; at anyrate it may be prevented by contracting the lower part a little. The best way of doing this is by working a wooden hoop inside the bottom band of the hive, as recommended by Dr Bevan, who says, "It should be perforated through its whole course, and the perforations made in an oblique direction, so distant from each other as to cause all the stitches of the hive to range in a uniform manner." The hoop gives greater stability to the hive, preserves the lower edge from decay, and affords facility in moving it. I advise a circular piece of wood (turned with a groove at the edge, to retain it in its place) to be worked into the crown, having through it an inch and a half hole. With a little ingenuity, the bees may be fed through this opening—a better method than the ordinary one at the bottom of a hive. A piece of wood or tin will commonly cover the hole; but at times, and especially in winter, it may be used for the purpose of ventilation, and allowing escape to the impure air of the hive. In this case, a bit of perforated tin or zinc should be placed over it, which, when stopped up by the bees, can be replaced by a clean one. An earthen pan is a common cover to a straw hive, and this may be slightly raised by wedges on the four sides, to permit a small space underneath. Of whatever material the outer covering consists, it must project so far on all sides as to protect the hive from moisture. This cannot be too much guarded against; and whether of wood or straw, hives ought to be well painted at the beginning, and periodically afterwards.'

Wooden hives are superior to those made of straw, the square shape being better adapted for the deposit of combs than the round form. Mr Taylor's observations may be likewise quoted on this important point. 'It matters not much of what wood the boxes are made, provided it is sound, thoroughly seasoned, and well put together. Different opinions are entertained as to the best size of bee-boxes, but I think that much must depend on the number of bees they are to contain, and on the honey locality; there must also be a reference to the proposed mode of working them; for where no swarming is permitted, a larger hive may be advantageously used. A good size is twelve inches square and nine inches deep within; the thickness throughout being not less than an inch. The top of the box ought to project on all sides nearly three-quarters of an inch, for better protection and appearance, and as affording convenience for lifting. On the top a two-inch hole should be cut in the centre, for placing a bell-glass, and for the purpose of feeding; and another hole, to receive a ventilator, may be made near the back window, that position being better for inspection, and less in the way of the bees, than the centre of the hive, which is, or ought to be, the seat of breeding, and should not be disturbed. A window may be placed at the back and front, five inches high, and six or seven inches wide. The best and neatest way of securing the windows that I have seen, is by a sliding shutter of zinc. Round the window there must be a projecting moulding, mitred at the corners. On one side the piece of moulding is movable, and to the back of this is screwed a plate of sheet zinc. This passes into a rabbet to receive it, cut, on the remaining three sides, at the back of the lower edge of the moulding. To prevent any wet from lodging at the bottom moulding, an opening or two may easily be cut through on the under side to allow its escape. For the sake of uniformity of appearance, blank windows may be made opposite to the real ones. Hives of this construction require to be placed under some cover or shed, as a protection from wet and a hot sun.'

To these explanations it should be added, that the hive of either form must be placed on a clean wooden floor or board; and if there be several hives together, each should have its own separate floor. Do not cement the hives to the board, that being a duty which the bees will themselves perform; all that may be given is a slight luting of clay, or any easily removable material. The entrance to the hive requires to be small, a little larger than a shilling, but rather wider than deep, and ought to be at the lower edge of the hive, on the side which is exposed. Numberless have been the plans invented to enlarge hives as may be required, both to permit of the greater accumulation of honey, and to render swarming unnecessary. Capes or hoods are the simplest of these inventions. In order to use capes, hives must have a stoppered hole at the top. A small additional hive, of light structure, is placed over this at the proper time, the stopper being removed. This serves as a second magazine for honey. Storeyed hives are merely hives made originally with one or two storeys, for the same end. Wildman's hive, the Grecian hive, and Lombard's hive, are specimens of hives made on this principle. Collateral hives, again, such as Nutt's, effect the same ends by being placed side by side, and giving increased accommodation, when necessary, either for swarms or stores. But of all such hives, our readers will probably prefer to know the one used by Huber.

Huber's Leaf hive, as he called it, 'consists of eight frames, each 18 inches high [a height of 14 inches is preferable] and 10 inches wide inside, having the uprights and top cross pieces one and a-half inch broad, and one thick, so that the eight frames, when placed close together, constitute a hive 18 inches high, 12 inches between end and end, and 10 inches between back and front, all inside measure. The frames are held together by a flat sliding-bar on each side, secured by wedges and pins. To the first and eighth of these frames is attached a frame with glass, and covered with a shutter. The body of the hive is protected by a sloping roof, and the entrance is made through the thickness of the floor-board. We (Naturalist's Library) dislike the sliding-bars, with their pins and wedges, which are so far inconvenient, that in drawing them out, all the frames are liable to open, and the observer is exposed to some hazard of annoyance, from the bees issuing out at every joint; and we have substituted for them hinges on one side, and a hook-and-eye on each frame on the other; we can thus open any particular leaf without meddling with the rest. In taking honey from this hive, the bee-master has the whole interior completely under his eye and at his disposal, and can choose what combs best suit his purpose, both as to quantity and quality; taking care, however, to do so only at such periods as will leave the bees time to replenish the vacancy before the termination of the honey season. It is also well adapted for artificial swarming. By separating the hive into halves, the honey, brood-combs, and bees, will, generally speaking, be equally divided; and by supplying each half with four empty frames, we shall have two hives, one half empty, equal in number of bees, of brood, and even of stores. One of the new hives will possess the queen; and if the operation has been performed at the proper time—that is to say, a week or ten days before the period of natural swarming—the probability is, there will be royal broods coming forward in the other; at all events, there will be plenty of eggs and larvæ of the proper age for the production of another queen.'

Use of Capes.—It will be observed from these quotations, that experienced apiarians, who work on a large scale, now employ for the most part hives so contrived as to remedy all the inconveniences resulting from the straggling of swarms and the old custom of killing by brimstone. As the use of single straw hives, however, formed upon the simplest plan, still prevails among those who have but one or two hives in all, the cape may be regarded as the easiest means of affording enlarged accommodation in such cases, and the mode of taking away the honey from it is very plain and easy. It is only necessary to remove the cape, invert it, and cover it with a handkerchief, leaving a little opening on one side. A few taps will cause the bees to quit the cape and return to the hive, after which the honey can of course be readily removed. This may be done frequently in the same season. De Gelieu mentions, that in one season he drew from one of his straw hives that did not swarm 72 lbs. of fine honeycomb, by merely emptying the capes as they were filled.

Union of Swarms.

It is strongly recommended by experienced men that swarms should be more often united than they are. Five thousand bees are estimated to weigh a pound; and, according to most bee-keepers, a swarm ought to weigh nearly four pounds. As a hive often casts off successive colonies, each far below this weight, it then becomes proper to unite two or more of them; seeing that one strong population supports itself better, and is incomparably more profitable, than several feeble colonies, which must be frequently in want of assistance. To those who keep bees on a small and cheap scale, convenience also dictates the junction of swarms in such cases. De Gelieu thus describes his mode of practice:—'When two small swarms come off the same day, I gather them separately, and leave them at the foot of the tree or bush on which they have alighted. Towards evening I spread a tablecloth on the ground, on which, by a smart and sudden movement, I shake all the bees out of one of the hives, and immediately take the other and place it gently over the bees that are heaped together on the cloth, and they instantly ascend into it, flapping their wings, and join those which, not having been disturbed, are quiet in their new abode. Early next morning I remove this newly-united hive to the place it is destined to occupy. This doubled population works with double success, and in the most perfect harmony; and generally becomes a powerful colony, from which a great profit is derived. Two feeble swarms may be united after the same manner, although one of them may have come off some days later than the other, and the first may have constructed combs; taking care, however, not to make the first one enter the second, but the second the first, as the bees will ascend more readily to join those that have already begun to make honey and to hatch brood; and next day they will proceed together with increased ardour with the work which the first had already begun, and which will now advance more rapidly from the increase of the labourers. It is to be understood that, after this union, the hive should be placed early next morning in the same place where the oldest of the swarms has already passed some days.' On many occasions, the circumstance of two queens passing out at once is the cause of a colony going off in two halves, and the removal of one of the queens is necessary, to facilitate their cordial junction into one community.

Besides the union of young swarms, it is often advisable to reunite weak swarms with their parent stocks, to unite weak stocks with each other, or even to add to some weak community a portion of one more numerous and healthy. In either case the object is the same—namely, to obtain well-filled, strong, and consequently more active hives. The three usual modes—we abridge partly from Bagster—by which union has been attempted, and indeed, their advocates say accomplished, are—fuming them, immersing them in water, and aspersing them with sugared or honied ale. To these we may add a fourth—namely, operating upon their fears, by confining them for a time, and then alarming them by drumming smartly upon the outside of their domicile. It was operating on their fears that enabled Wildman to perform such extraordinary feats with bees. When under a strong impression of fear, says he, they are rendered subservient to our wills to such a degree as to remain long attached to any place they afterwards settle upon, and will become so mild and tractable, as to bear any handling which does not hurt them without the least show of resentment.

The neatest and most scientific mode with which we are acquainted of uniting weak families together in harmony, was invented by the Rev. Richard Walond, whose experience in the management of bees, for nearly half a century, entitle his opinions concerning them to great respect. His theory and practice upon this subject are as follow:—'Bees,' says he, 'emit a peculiar odour, and it is by no means improbable that every family of bees emits an odour peculiar to itself; if so, as their vision seems to be imperfect, and their smell acute, it may be by this distinctive and peculiar odour that they are enabled to discriminate betwixt the individuals of their own family and those of a stranger hive. Upon this supposition, if the odours of two separate stocks or swarms can be so blended as to make them completely merge into each other, there will then probably be no difficulty in effecting the union of any two families that it may be desirable to unite.' To accomplish this end, therefore, Mr Walond had recourse to a very ingenious contrivance: he procured a plate of tin, the size of a divider, and thickly perforated with holes, about the size of those in a coarse nutmeg-grater. Having confined, in their respective hives or boxes, the two families to be united, and placed over each other, with only a divider between them, he introduced his perforated tin plate upon the divider, which was then withdrawn. Immediately the bees began to cluster with hostile intentions, one family clinging to the upper, the other to the under side of the perforated plate; when, after remaining in this state for about twenty-four hours, they had so far communicated to each other their respective effluvia, and so completely commixed were the odours in both hives, that on withdrawing the perforated plate, the bees mingled together as one family: no disturbance was excited, but such as arose from the presence of two queens, the custom being always in such case to dethrone one of them. According to Huber, this is effected by single combat between the queens. Keys has observed that these incorporations seldom turn to account unless they be effected in summer; and when it is considered that the principal gathering months are May and June (excepting in those neighbourhoods that abound in lime, sycamore, and other trees that are apt to be affected with honey-dew), we cannot of course expect them to be very successful.

This plan of the Rev. Richard Walond is very ingenious, and unquestionably, on his authority, proves our position—that smell is one of the senses used by the bees to detect a stranger—and lead us to doubt the authenticity of accounts which state that the system of union by means of driving has been uniformly successful. Our aim, however, is not to condemn, but to show that fumigation is the easiest and surest operation. The plan is as follows:—In autumn, three or four fuzz-balls or puff-balls (a kind of fungus growing in the meadows, and commonly called the 'Devil's Snuff-box') must be pulled before they are fully ripe. These must be thoroughly dried in an oven, and kept dry till wanted. A round box, made of thick tin, without any solder, must be provided. This box must be about two inches in diameter, and an inch and a-half deep, with a conical movable top, about an inch and a-half high, perforated with holes. The latter must also have three holes in it. With this box, and a piece of a fuzz-ball about the size of a hen's egg, in readiness, the operator commences by fixing an empty hive, of the same size as that from which he intends to take the bees, securely, in an inverted position, in a pail or some other convenient utensil. A sharp pointed stick having been stuck into the empty hive, so as to stand upright within it, the box is fixed thereupon, by inserting the stick into one of the holes in its bottom. The piece of fuzz-ball is then lighted and put in the box, over which the conical lid is placed. The hive from which the bees are to be taken is then placed over the empty hive and the burning fungus. To keep all close, a wet cloth is put round the place where the two hives join. In a minute or two the bees may be heard dropping heavily into the empty hive, where they lie stupified. After a short lapse of time, the full hive may be tapped, to cause the bees to fall faster. On removing the upper hive, the bees from it will all be found lying quiet at the bottom of the lower one. The queen may be taken from them and placed under a glass with a little honey on a small piece of comb. The stupified bees must then be sprinkled freely with a thick syrup made of sugar and ale boiled together. The hive containing the bees with which it is intended to unite the stupified bees must now be placed on the top of that containing the latter, just as the hive was from which they have dropped. A cloth must be closely fastened round the two hives, so as to prevent any of the bees from escaping. The hives in this position must be put aside, where they will not be likely to be thrown down or disturbed. The bees in the upper hive, attracted by the scent of the syrup, go down and begin to lick the sprinkled bees clean. The latter gradually revive, and all get mingled together, and ascend quietly in company to the upper hive, where they dwell as if they had always been one family. The two hives should be left undisturbed for twenty-four or thirty hours, at the end of which the upper hive is to be removed and placed immediately on the spot from whence it was taken. The object of taking the queen away is to avoid all risk of disagreement. It is, however, recommended to preserve her as long as she will live, lest any accident should happen to the sovereign of the other community.

Summer Management of Bees.

The feeding of bees at different seasons is an important point to the bee-keeper. In summer they feed themselves, and of course a good supply of the requisite material is then essential to their well-doing. The most highly-cultivated districts are not so favourable to bees as those in which wild heaths, commons, and woods prevail; or where white clover, saint-foin, buckwheat, mustard, and cole-seed, are produced in abundance. Bee-keepers, however, may do something to further the supply of summer food, by growing near their apiaries a selection of such plants as we have recommended under a previous section. But on the natural products of the country, generally speaking, bees must rely for summer food, if the weather be such as to permit of their gathering it. Should a succession of coarse bad weather occur, however, at the beginning of summer, and particularly after a swarm has entered a new hive, most apiarians think it essentially necessary to give honey, or a syrup of sugar and water, to the newly-hived stock. If no proper brook or fount be at hand, water should always form a part of the summer provision. The bees being at full work in this season, the door of the hive should be opened to its whole extent, and not closed, as is more or less requisite at other times. In the hives formed upon improved plans, ventilators constitute a part of the apparatus, and thermometers are introduced to regulate their use. Though these are valuable adjuncts certainly, they are not indispensable; seeing that the bees, as already mentioned, contrive to ventilate to some extent for themselves. Where artificial ventilation can be effected, it is recommended that the temperature should be maintained at from

65 to 80 degrees of Fahrenheit. It is recommended, on evenings when the moths are numerous, to place a small grating before the hive; and it will also be advisable to destroy any wasps, spiders, earwigs, or other insects which may settle near the hives.

Autumnal Management.

The autumnal period has long been the most calamitous for bees, not through the injuries of enemies or weather, but from the improper management of bee-keepers. After the carcasses of the drones, strewn in multitudes before the hive, have indicated that, with the beginning of August, has come the close of the rich honey season, the bee-keeper deems it time to take from the hive the reward of his care and attention. The use of storeyed hives or extra boxes renders it easy to take away a portion of honey early in the season, and this is called *virgin honey*. Even with a common straw hive, it has been found possible to take away the honey, and retain the bees in the hive. Wildman, the famous experimenter on bees, recommended that the hive should be taken into a dark room, and there struck repeatedly till the bees are forced to ascend into an empty hive. The combs are then cut out with a thin knife, and the bees finally returned to the old hive. But this plan is seldom pursued, being at once dangerous and destructive to the brood combs.

It is generally reckoned advantageous to change the pasturage for a week or two before taking the honey-harvest. About mid-autumn, the ordinary food of bees begins to fail, and their stock of honey to decrease daily. By a removal of three weeks to a heathy district, a hive not only loses nothing, but frequently gains as much as ten or twelve pounds of honey in ordinarily favourable circumstances. So well is this known by bee-keepers near Edinburgh, that one shepherd on the heathy Pentland hills receives in charge several scores of hives annually, for the heath-feeding.

Honey-Harvest.

After the autumnal accession of honey has been obtained, and the bees have been brought home again, the question comes to be, in what manner the harvest should be reaped. By partially depriving each of a portion of comb, and leaving some for food? By suffocating one-half the communities, taking their entire honey, and leaving the other hives with their honey untouched, to serve as stock? Or, finally, by removing the bees from one-half the hives to the other half, forming united stocks, and acquiring all the honey of the evacuated ones? These three plans are known by the several names of *partial deprivation* (commonly and most easily practised with improved hives, as already described), *suffocation*, and *union of stocks*. 'Partial deprivation,' says the Naturalist's Library, 'consists in appropriating early in the season a portion of the stores. In preparing prospectively for thus sharing in the products of the hive, the cultivator who pursues the storifying system, immediately after the swarming season is over, adds another storey or box to the two of which his hive consists, placing it undermost, or, as it is called by some bee masters, *nadiring*. The brood combs contained in the uppermost storey will, as the young bees are hatched, be quickly filled with honey, and may be removed about the beginning of August. The top cover is then replaced on the next storey in position, which was originally the lower, and is *now* the upper. In ordinary seasons, the bees will have ample time to lay in sufficient food for winter and spring use, after the abstraction of this portion of their stores. As the combs of the upper box are frequently found adhering by their lower extremities to the bars of the next, it will be necessary before removal to separate them by means of a very thin long-bladed knife, or a fine wire drawn through the hive at the point of junction. The operator will next expel the bees from this box or storey, by lifting the top cover, and blowing in a little smoke, which will cause the inhabitants to retreat quickly to the lower regions. The box may be then taken away, without the operator running the risk of the slightest annoyance. The honey found in this removed box will not be all honey of the current season, and consequently is not so delicately fine. It is also sometimes found mixed with, or rather deposited above a layer of farina. Should it be wished, therefore, to obtain a supply free from these impurities, the empty storey which is added may be placed *above*, instead of *below*, the original stock, and the honey will thus be of a superior kind. This mode of operating is called *super-ing*, in contradistinction to *nadir-ing*; and we understand that Dr Bevan practises the latter only with young swarms, and the former with those of preceding years.

Partial deprivation has never yet become general, because it is liable to frequent failure, even in improved hives, and because the full benefit is not derived from it at the very commencement of the system. The liability to failure, the first of the objections stated, is owing in most instances not to the *mode*, but to the *period* of the operation. According to the too common practice of those who are friendly to deprivation, a portion of honey is abstracted from the hives about the beginning or middle of September; and the owner compliments himself on his moderation in being content with a part instead of the whole, and on his humanity in saving the lives of his industrious favourites; while in nine instances out of ten he finds, on the arrival of March, that his moderation and humanity have been altogether unavailing, and that he has saved them from a violent death by suffocation, only to expose them to the more tardy, but not less cruel, death by starvation. Whereas if deprivation take place soon after the swarming season, as already recommended, and is managed with discretion, the issue will be very different, and ultimately more profitable to the owner, than the almost universally practised mode by suffocation, which is too well known to need description. The latter system may yield a greater return in proportion to the hives operated upon; but in the former there is a much greater number of hives available. For example, suppose two apiaries, each containing five stock hives at the end of July, exclusive of as many swarms recently thrown. The owner of the one, practising the depriving system, takes from each of his stocks 10 lbs. of honey, making an amount of 50 lbs. as his honey-harvest. The owner of the other, an abettor of suffocation, proceeds in September to smoke his five old hives, and receives from each 25 lbs. of honey, making an amount of 125 lbs. as his honey-harvest—between two and three times the quantity of the other. In the following year, the depriver has his five old stock hives, and the five swarms now become stocks also; from the whole ten he now takes 100 lbs. of honey, while at the same time his apiary is augmented by the addition of ten new swarms, making twenty for the following year; while his rival possesses only his former number of five, yielding 125 lbs. In the next year—that is, two years from the commencement of the comparative trial—the depriver has twenty stock hives, yielding 200 lbs., and so on by a geometrical ratio; while the other remains at his original 125 lbs. This calculation is made on the supposition that each owner takes but one swarm from each stock, and without making any allowance for losses and failures which will affect the produce of both in honey and bees, but to which both are liable.'

The writer of the treatise now quoted from, proceeds to point out the advantages of the humane principle of sparing the lives of these useful insects. 'It is pitiable to reflect, that the small degree of additional trouble required in uniting them, should prove so effectual an obstacle to this conservative practice. Yet the operation with each hive so treated need not occupy more than fifteen or twenty minutes. In the evening, when all are quiet, turn up the hive which is to be operated upon, fixing it in a chair from which the stuffed bottom has been removed; place an empty hive above it, wrap a cloth round the point of junction, to prevent the bees from coming out and annoying the operator; then, with a short stick or stone in each hand, beat round the sides, but *gently*, for fear of loosening the combs. In five minutes, the panic-struck insects will hastily mount into the empty hive, with a loud humming noise, expressive of their trepidation. The hives are then separated—that containing the bees is placed on its usual pedestal, and the other containing the honey is carried off. The union is next to be effected. Turn up the stock hive, which is to receive the addition to its population; with a bunch of feathers, or a small watering-pan, such as is used for watering flower-beds, drench them with a solution of ale and sugar, or water and sugar, made a little warm. Do the same to the expelled bees; and then, placing these last over the stock, mouth to mouth, a smart rap on the top of the hive will drive them down among the bees and combs of the undermost hive. Place this last on its pedestal, and the operation is completed. The strong flavour of the solution will prevent them from distinguishing between friend and stranger; and their first movement, after recovering from their panic, will be to lick the liquid from one another's bodies. This mode of operating is applicable to all kinds of hives.' (See previous section on the Union of Swarms.) With regard to the two queens, one would assuredly kill the other in a very short time; but the best way is to remove one of them before union.

One argument employed by advocates of the plan of suffocation by introducing the fumes of brimstone or other noxious effluvia is, that by the union of stocks you have an immense number of mouths to feed, of which the killing plan relieves you. Only inexperienced bee-keepers, however, could use this reasoning, De Gelieu having discovered the remarkable fact, that the increase of numbers in the winter hives is far from producing a proportionate increase of consumption. From fifteen to twenty pounds of honey, or from three to four pots, are requisite for the winter maintenance of a single hive of ordinary strength, with which the plan of union has not been practised. De Gelieu placed such a hive, with such a store, beside one into which three full communities had been introduced; and he found, on weighing the latter in the spring, that its inhabitants had scarcely used one pound of honey more than those of the single-stocked hive. The experimenter even went further. To a hive already amply stocked, he added the swarms of *four* other hives, and found, on weighing it in the spring, that 'the total diminution of honey did not exceed three pounds more than took place in ordinary single hives.' Had they not been thus united, he says, each of these stocks would have cost him much more honey than they were worth, and indeed the most of them 'would to a certainty have perished.' The cause of this strange fact, by which nature seems to point to the plan of autumnal unions as the best possible for both bees and bee-keepers, is yet unknown.

The combs, by whatever process procured, should be deprived of the honey at once, while a natural warmth remains in them. Various kinds of drainers have been used for separating the honey, and keeping it as much as possible from the external air. The honey which runs off naturally without breaking down the combs, and passes through muslin, is held to be the finest. A second kind is procured by cutting the combs in pieces, and letting the honey pass through a drainer, under exposure to a gentle heat. A third quality is procured by subsequently putting the combs in a vessel placed on a fire; the product, strained through canvas, is used in feeding bees. The separated wax of the combs is introduced into a woollen bag, firmly tied at the mouth, and put into boiling water. The pure wax oozes through, and is skimmed off the surface, where it floats. It is then to be allowed to cool slowly. The best honey is supposed to be that formed from heath. The famous bees of Hymettus were nourished by that plant.

Honey is used as a condiment at the table, and is also employed in medicine. In Britain alone, about £120,000 is annually spent for foreign supply; and if we add to this a large home production, and consider that in other countries the article is even more liberally made use of, we shall arrive at some conception of the economical value of the bee. But it is not the honey alone; we import 10,000 hundredweights of wax each year; and when we state that the price varies from £5 to £10, 10s. a hundredweight, it will be seen that its value is all but equivalent to that of honey.

In ancient times, honey formed the basis of a beverage called *Mead*, and from the practice of drinking it for a month after a wedding, came the expression *honeymoon*. In course of time mead was superseded by beer, wine, and other liquors, but is still allowed by writers on diet to be wholesome as a drink, and certainly less pernicious than the ordinary kinds of intoxicating fluids. As some bee-keepers, to whom our sheets are addressed, may wish to attempt the manufacture of mead for domestic use, we offer the following as one of the best methods for its preparation, from the Encyclopædia Britannica:—'Into twelve gallons of water put the albumen [or white] of six eggs, mixing these well together, and to the mixture adding twenty pounds of honey. Let the liquor boil an hour; and when boiled, add cinnamon, ginger, cloves, mace, and rosemary. As soon as it is cold, put a spoonful of yeast to it, and barrel it, keeping the vessel filled as it works; when it has done working, stop it up close; and when fine, bottle it off for use.'

Winter and Spring Management.

In winter and early spring, bees require to be tended with great care. In the case of those hives which have been entirely deprived of their honey, systematic feeding is of course indispensable in winter; but few bee-keepers of any experience ever willingly follow any other plan than that of leaving to bees a winter supply of their own produce. Some bee-keepers remove their hives into the house in winter; but this seems an unwise practice, as the bees must then be kept continually in confinement. Though the door of the hive should be carefully narrowed or shut up in very cold weather, at which time every bee that issues perishes, yet advantage should be taken of every fine day to let them abroad. On this point, however, great difference of opinion exists: many contending that the bee naturally becomes torpid in winter, object to their exposure to sunshine altogether, and for that purpose recommend screens and coverings. One thing is certain, that a moderate degree of warmth is necessary, and that this warmth should be as equable as possible; while at the same time there should be the most thorough precautions against damp. It is damp more than cold which kills our hives in winter; and he who protects them from cold and wet by a thorough covering of straw, fern, flax refuse, or the like, plastered over with Roman cement, is sure to have the healthiest apiary.

Proceeding on the 'dormancy' theory, a singular device for winter preservation has been recently resorted to by some bee-masters—namely, *burying the hives*. When this is to be attempted, the hive should be buried in a cool, dry, shady place, among leaves about a foot deep, and the interment should be performed during the first or second week of November. Mr Briggs, who first made public this device, records the following experiments:—'A friend in the vicinity of Hitchin buried a hive of bees in the first week of November, about a foot deep among dry leaves, &c. and disinterred it in the last week of February, when it was just *two pounds lighter than it was in November, and the bees in a lively and healthy state*. Another person, residing in Leicester, immured a hive of bees in the earth, four feet deep, in the second week in November, and at the end of January it was removed, and weighed *only three ounces less than it did before it was buried*. The above experiments,' adds Mr Briggs, 'are worthy of further attention; and I would recommend that a shed, having a northern aspect, and which is as dry as possible, would be a suitable place for further trials. The principal points by which there might be cause for fear of failure, would, as in other cases, be from dampness, disease for want of fresh air, and attacks from vermin. To prevent the former, I would recommend that the hives be placed on a long frame of wood, covered by a web of closely-worked wire, and raised a few inches from the ground, the ends of which should communicate with, and be occasionally opened to, the fresh air. A long tube should also be placed from the hole at the top of each hive to the open air of the shed, from the upper end of which any dampness might be condensed by bell-glasses, and conveyed away, as already directed. The materials with which the hives are covered and surrounded should consist of dry leaves pressed closely together, or dry and powdered charcoal or cinders, and may be several feet in thickness, to preserve the bees in a cool and torpid state, and at a regular temperature, in which state they should be kept as *dry*, *dark*, and *quiet* as circumstances will permit. As the spring approaches, the winter coverings should be gradually removed, and the hives placed in their summer situations. Small quantities of food should then be supplied as occasion requires, until the gooseberry and currant bushes are in bloom, at which time it may in general be considered that their winter is past.'

Where feeding is necessary, the following rules have been laid down for the management of common hives in winter and early spring:—Bees must be fed only when the weather is fine and warm, to prevent the temperature of the hive from being injured; and a large quantity should never be given at once; for the bees are so greedy of food, that they will rather fill the broad cells with it than relinquish their treasure. The quantity of food which ought to be given to a hive may be calculated in the proportion of two pounds a month; but if the weather be very cold, a less quantity will suffice. When a hive is fed in the spring, it should always be after sunset, when the bees have returned from the fields; otherwise the most disastrous consequences may ensue, from the robberies committed by the bees of other hives. If fed in the morning, it must be before sunrise, and the entrance instantly stopped, to keep out depredators; for as bees leave the hive on the very first appearance of daylight, a later period would prevent the return of those which had left the hive previous to the entrance being secured.

Relative to the substances which are proper for the feeding of bees, many different opinions exist; but the following may be considered among the most beneficial as well as economical articles of diet:—To two quarts of good ale put one pound of moist sugar; boil them until the sugar is wholly dissolved, carefully skimming it; when it is cold, it will be found of the consistency of honey, and it may be given to the bees in the following manner:—If the bees are in the plain cottage hive, an eek of the same diameter as the hive must be provided, and from three to four hands in height. When the sun is set, and the bees have retired, let the hive be gently raised, and the eek placed on the stool; then, having filled a soup-plate with the food, place it on the eek, and put down the hive. To prevent the bees being drowned in the liquid, it is necessary to place some straws over the plate, and over the straws a piece of paper, either thickly perforated or cut into nicks; these nicks, however, must not run parallel with the straws, but either across or diagonally; the entrance must then be closed, and the plate removed on the following morning, when the whole of the liquid will have been transferred to the combs.

Diseases and Enemies of Bees.

Bees, according to the conclusions of De Gelieu, after sixty-four years' experience, have 'no real disease; they are always in good health as long as they are at liberty, and when they are warm enough, and have plenty of food.' In early spring, however, they are found liable to an affection called dysentery, which is known by the marks on the board of dark-coloured evacuations, by the offensive smell, and by the frequent deaths. This disease certainly results, in most cases, from long confinement in a damp and impure air. By lifting the hive to expel the vitiated air, scraping, washing, and drying the board, and removing the dead bodies, the complaint, says Mr Taylor, may soon be remedied even in the most extreme cases. Rosemary, mixed with honey and water, has been recommended as a cure; but the experienced apiarian mentioned conceives all dietetic remedies to do more harm than good. A little chloride of lime, he suggests, may be used beneficially in washing the board. One point should be noticed here, that exposure to the sun is held decidedly injurious to the hives in winter. This caution is necessary, as bee-keepers, when they suspect dampness, might fall into an error on this score. While on this subject we may also mention a new remedy, which is said to have been adopted on the continent with success. When dysentery begins to show itself in the apiary, the bee-keeper prepares a syrup composed of an equal quantity of good wine and sugar, which is administered to the bees in every hive, either by pouring it into the cells, or placing it within the hive in a saucer, or any other shallow vessel.

About the end of spring another disorder sometimes makes its appearance, which Du Carne de Blangy calls vertigo. This is supposed to be occasioned by the poisonous properties of certain plants on which they feed. The symptoms are manifested by a dizzy manner of flight, by their involuntary startings, falls and other gestures in attempting to perform their usual operations, or in approaching the hive, and by the lassitude that succeeds these symptoms. This distemper has been hitherto found incurable. Bees, according to the same authority, are liable to a third distemper, the symptoms of which are swelling at the extremities of the antennæ, which becomes also much inflamed, and of a yellow colour; the head assuming shortly after the same tint, the bees lose their vivacity, and languish till they die, unless a proper remedy be applied. In France, they give them Spanish wine for this disorder. There is still another distemper which sometimes makes its appearance among bees, for which the continental agriculturalists administer Spanish wine, as in the former case. This is a kind of pestilence by which many of the insects are cut off. It happens when the queen bee has placed the eggs carelessly in the comb so that the larvæ perish in the cells, or that they are killed by the cold or otherwise, when numbers die and infect the rest. The only attention requisite in this case is to remove the infected combs, perfume the hive with aromatic plants, and give them the wine to sip, as already mentioned, in order to strengthen and restore them from their sickness.

A few hints from Gelieu and others, respecting the chief foes of the bee-tribe, may be useful to bee-keepers:—The former authority after observing that the possessors of bees, often from an ignorant excess of care, are among their greatest enemies, says—'Ants are their least dangerous enemies; true, the bees cannot sting them to death, because they are small and well defended with armour, but they seize hold of them with their teeth, and carry them to a distance. Had they not this means of getting rid of them, their colonies could not exist in the vast forests full of ants' nests, and where they thrive so well, in spite of the horrible massacres that annually take place.

Moths are little known, and never injurious, in the high valleys, nor on the mountains; but they attack and destroy a vast number of hives in the plains or in the vineyards, where they are a great scourge. Huber discovered that the *Sphinx atropos* or Death's-head moth was one of the most destructive of this tribe. As soon as a moth has penetrated a weak hive, it establishes itself in a comb, envelopes itself in a silken web, multiplies rapidly, consuming the wax, and spreading its destructive galleries from side to side, until, arriving at a certain point, the evil has scarcely a remedy. The only means of saving the colony is to imitate the surgeon, who cuts off a diseased limb to save the other

—every bit of infected comb must be cut out, leaving only those occupied by the bees. The bees must then be liberally fed, by giving them every evening as much honey as will maintain them, until such time as the field-flowers shall again yield a sufficient quantity. Thus, concludes Gelieu, I have preserved hives whose circumstances seemed to be desperate.

Spiders annoy the hive much. The bees get entangled in their webs, and are not able to extricate themselves. Here cleanliness is the best protection; therefore care should be taken to sweep the webs away from the hive and its avenues as fast as they appear.

Birds, such as the sparrow, house-lark, and swallow, eat a prodigious quantity of bees, especially in spring, when the trees are in blossom. Poultry, also, that roam about or near the water where the bees go to quench their thirst, gobble up a great many. Fowls should never be permitted in any apiary.

Mice, especially the red mouse, or *Sorex araneus*, sometimes penetrate a hive in the winter-time, either from the entrance being left too wide, or by gnawing a hole for themselves in the straw. They eat the honey, and even the bees, when clustered together on the side of the hive, in which position they are unable to defend themselves, and scarcely even see the enemy. The most effectual preventive against rats and mice is to place the hive on stands with projecting ledges, and in such a position that they cannot reach it.

Wasps are also reckoned among the numerous enemies of bees. I have, however, seldom seen a hive destroyed by wasps; although they are larger, stronger, and armed with a formidable sting, and an impenetrable cuirass, they seldom dare enter a well-stocked hive. Once attacked, they soon fall beneath the united efforts of these brave citizens, who sacrifice themselves to defend the place of their nativity. Wasps only appear in great numbers when the fruit is ripening, and then they range unceasingly round the hives, and enter the weak ones, or those of which the too spacious lodging bears no proportion to the number of its inhabitants. There are three ways of providing against the attacks of wasps. The first is, to unite weak hives by doubling or tripling the population, thereby enabling them to defend themselves. The second is, to contract the entrances, as soon as swarming time is over, after the massacre of the drones; and the third is, to destroy with assiduity all the nests of wasps that can be discovered in the neighbourhood.

Bees are subject also to a peculiar species of *pediculus*, called the bee-louse. Hives that have swarmed more than once, and such as contain but little honey, are most exposed to these troublesome vermin. The hives in this case should be cleared at the farthest once every week, and the stools on which they stand every morning; for the latter are likely to harbour the larvæ and moths, or other insects, as well as the hive. But these obnoxious creatures cannot be entirely extirpated without taking away the infected hive, removing the bees, and cleaning it, before it is restored to the former station. The lice are of a slender shape, or filiform, and of a ferruginous colour, and may be destroyed by strewing tobacco over the bees.

The bees are continually fighting between themselves, and robbing each other; avarice, not necessity, leads them to do so, it being almost always the strongest and best-provisioned hives that pillage the weak ones. When once a bee has been able to introduce itself into a hive, and carry away a load of honey without being arrested, it will return a hundred times the same day; and, making it known to its companions, they will then come in hordes, nor cease their pillage until there is nothing left to take. In one day the whole of the honey will be carried off, and with a determination which one can scarcely have an idea of without seeing it. This kind of pillage is most frequent in the spring and autumn, and it is easier to prevent than to stop it; and, for this purpose, the entrance of the hives ought to be straitened in proportion to the population.'

BRITISH WILD BEES.

Besides the garden or hive-bee, as already mentioned, there are various species of bees, which have never been domesticated by man, though many of them construct hives and produce honey. Of such of these wanderers of the wilds as are indigenous to Britain, the most common is the *humble* bee (*bombus*), an insect at least double the size of the hive-bee, with a black head and body, having yellow rings crossing the latter anteriorly and superiorly, and white and black rings alternating at the posterior extremity.

Both on account of their peculiar habits and selected places of residence, this and the other wild species are unfitted for domestication. Few of them survive the rigours of winter; but one, a female, that does escape, manages for a season the resuscitation of the breed. Abroad, it flies in early, and, alone and unaided, sets laboriously to work in constructing its nest, piercing the earth or moss, as its instinct may be, and excavating a small chamber wherein to lay its eggs. It does not make wax and cells for the young. These come to maturity in the cocoons which they spin for themselves in the larva state; and when they emerge, these cocoons form stores for food. The solitary bee feeds alone its earliest progeny, but these soon multiply around it, enlarge the cells, gather honey, and feed the increasing young. The wants of the young go on increasing for a great part of the summer, and the quantity of honey they consume is very large; towards the middle or latter part of September, however, the energies of the bees begin to wax fainter, and little further progress is made in adding to the colony, or in collecting honey. Cold and showery days begin, even by this time, to thin the number of the insect population, who are now seen creeping slowly, with damp and heavy wings, upon the stalks and petals of flowers, where they were formerly seen actively buzzing about in search of honey. The stores of the honey-cups have not outlasted the wants of the young unfledged bees, of which they were the proper food; and if the nests be examined now, these cups are found quite empty. The bees which survive the accidents of rain, cold, and frost, by degrees forsake the nest and its furniture, leaving the latter as a prey to mice, beetles, or other animals. To shelter themselves for the winter, they seek out some dry bank, where they penetrate to the depth of eighteen inches or two feet, pushing up the soil behind them, and leaving no visible track by which they have descended. In these situations they are often found by labourers and others while digging; and such people are often greatly puzzled to imagine how the insect can have reached such a depth. Those who have attended to the habits of wild bees, can readily fix on the spots where they take refuge.

The experiment of domesticating wild bees has been tried; and it was found that, by removing their nest cautiously in an evening, and placing it in a quiet situation, in a garden or other place where they could be observed, they went on with their works without apparent alarm or interruption. During the whole summer, they continued to prosecute their occupations with the same industry as other bees; but about September, as we have mentioned, the hive began to turn languid, and the numbers which appeared going and coming about the entrance became daily smaller. It was imagined they had taken refuge within the hive; but when this was opened, after all seemed to have ceased their labours, everything was found empty and deserted; there were neither bees nor honey; the stronger and younger insects, no doubt, having gone to make burrows for themselves in the earth, and the older ones having gradually fallen victims to the accidents of approaching winter. Our wild bees, therefore, appear to possess their brief lives but for self-enjoyment, or rather to form one of that order of beings created by the great Author of all as if for the purpose of leaving no corner of the universe without its utmost allotment of sentient and enjoying existence.

THE DOG—FIELD-SPORTS.

THE dog is an animal which seems to have been destined by the Creator to be the friend and assistant of man. Throughout the dangers and difficulties which beset the human being, particularly in an inartificial state of society, the dog has ever proved himself the kindly defender of his life and property, as well as a powerful and essential auxiliary in subduing other animals to his purpose. Without such assistance, man would not even yet have obtained a beneficial dominion over the various races of wild animals, or been able to watch with sufficient care those creatures which he domesticates for his sustenance and comfort.

According to naturalists, the dog belongs to the family *Canidæ* (from *canis*, Latin for dog), in the order *Carnivora*, class Mammalia. In the same family are united the wolf, fox, and jackal, and these so nearly approach the dog in physical construction, and certain habits and qualities, that some authorities are inclined to consider them of the same species. Be this as it may, the resemblance in some respects, and great dissimilarity in others, between dogs, wolves, foxes, and jackals, is not more remarkable than the general similarity of dogs to each other, as far as an apparent unity of species is concerned; while at the same time there is a striking difference of form and character between opposite breeds. One dog is large, another small; one is smooth in the skin, another rough; one has a long head, in another the head is short; one has an exquisite sense of smell, another has comparatively little of that power; and so on. We have an animal which watches our flocks; another which tracks and hunts down noxious wild beasts; another which destroys and digs out vermin from the earth; another which guards our houses and lives while we are asleep; another which seeks out for game in our field-sports; another which will plunge into the deepest waters, and save us from being drowned; besides many other varieties, all less or more distinct in character. The difference is so very remarkable, that the *varieties* would be entitled to be classed as of different *species* of animals, unless for the fact that they all breed together, and perpetuate mixed or mongrel crosses. This circumstance led Buffon and other naturalists to infer that all dogs whatsoever are but of one species; the physiological theory being, that no two different species can produce fertile descendants. Buffon further concluded, from a course of observations, that the numerous varieties have sprung from one common root—the shepherd's dog; and that climate, food, and peculiar training, have been the causes of the departure from the primeval stock.

The line of argument adopted in support of this theory is, that in the animal, as in the vegetable kingdom (see Nos. 3 and 35), improved or very remarkable varieties can be produced by selecting kinds, and breeding from them alone; as, for example, taking the two largest dogs of a breed, and breeding from them; then taking the two largest which this pair produces, and breeding from them also; and so on, till a large variety of dogs is ultimately formed. And further, that if each generation be trained in a particular way, the variety will come to possess properties agreeable to the kind of cultivation bestowed upon it. Such, there is reason to believe, is the true explanation of the extraordinary differences of size and character in the canine species. We must view these dissimilarities as a result of a course of treatment from the earliest period of civilisation till modern times. The ancient Egyptians, and after them the Greeks, are recorded to have paid considerable attention to the training of dogs, and, as is well known, this formed a favourite study in connection with the field-sports of later ages. Doubts may very naturally be entertained respecting the power of transmitting acquired qualities from one generation to another of any species of animals; but investigations into the subject afford some remarkable proofs of what can be accomplished by means of careful training or teaching.

EFFECTS OF TRAINING.

The ordinary training conferred on horses, dogs, and other domesticated animals, seems to be sufficient to establish the general fact of animal educability. We have no more forcible illustrations of the principle than in the uses which are now made of certain of the canine species in rural sports. The pointer, setter, springing spaniel, and all that section of dogs, are understood to be descended from one stock—the Spanish pointer—with a slight crossing from the foxhound, for the sake of improving the speed. The original animal may be considered as a record of the primary powers, to which everything else must be regarded as an addition made by human training. Now the original animal is only gifted by nature with a fine scent for game, and a disposition to make a momentary pause on seeing it, for the purpose of springing upon it. Man has converted this inclination to a temporary pause into a habit of making a full stop, or point as it is termed; and the animal, instead of gratifying his destructive tendency by springing upon the game, has been trained to be contented with witnessing a vicarious execution by the gun of his master.

It is a mistake to suppose that only the spaniel tribe is capable of serving sportsmen in the capacity of pointers and setters. There are other classes of dogs which perseverance would enable, to a certain extent, to act in the same way. Gervase Markham, who wrote on sports in the sixteenth century, speaks of having seen dogs of the bastard tumbler kind adapted to act as setters, though not so well as those of the spaniel kind. Mr Blaine ('Encyclopædia of Rural Sports') is of opinion that this power can be cultivated in most dogs. It has even been elicited in another and very different class of animals—the hog. Some years ago Mr Toomer, gamekeeper to Sir Henry Mildmay, bethought him of teaching a pig to act as a pointer, having been struck by the scenting powers of the animal in its search for palatable roots under ground. He began by allowing a young female pig to accompany his pointers, in their breaking lessons, to the field. Within a fortnight, to his own surprise, she was able to hunt and point partridges and rabbits. There being an abundance of these creatures near the keeper's lodge, her education advanced rapidly by frequent exercise, and in a few weeks she was able to retrieve game as well as the best pointer. *Slut*, as this extraordinary animal was called, was considered to have a more acute scent than any pointer in the charge of the keeper; and it was a kennel of the highest character. They hunted her principally on moors and heaths; and it often happened, that when left behind, she would come of her own accord and join the pointers. 'She has often stood,' says Daniel, 'a jack snipe when all the pointers had passed it: she would back the dogs when they pointed, but the dogs refused to back her until spoke to—Toomer's dogs being all trained to make a general halt when the word was given, whether any dog pointed or not, so that she has been frequently standing in the midst of a field of pointers. In consequence of the dogs being not much inclined to hunt when she was with them (for they dropped their sterns, and showed symptoms of jealousy), she did not very often accompany them, except for the novelty. Her pace was mostly a trot; she was seldom known to gallop, except when called to go out shooting;

she would then come home off the forest at full stretch, and be as much elated as a dog at being shown the gun. She always expressed great pleasure when game, either dead or living, was placed before her. She has frequently stood a single partridge at forty yards' distance, her nose in a direct line to the bird; after standing some considerable time, she would drop like a setter, still keeping her nose in the right direction, and would continue in that position until the game moved: if it took wing, she would come up to the place, and draw slowly after it; and when the bird dropped, she would stand it as before.'

These facts, together with what common observation presents to us in domesticated parrots, blackbirds, ravens, magpies, monkeys, &c. place the educability of animals upon a basis, in our opinion, not to be shaken. But the most wonderful thing, and the most convincing part of the proof, remains in the fact of the transmission of *acquired qualities* by animals to progeny. The habit which education has conferred upon the pointer appears in his puppy, which may be seen earnestly standing at swallows and pigeons in a farmyard, before he has ever once seen such a thing done by his seniors, or received the least instruction. Here only the object is amiss; the act itself is perfect. As may be readily supposed, the puppy of a race of English pointers can be trained to the whole business of the field in one-tenth of the time which the most experienced breaker would require to effect any improvement upon the simple instinct of *the pause* in an original Spanish spaniel. On the subject of the hereditary transmission of acquired qualities by animals, we have some curious information from the venerable naturalist, Mr T. A. Knight, in a communication to the Royal Society in 1807:—'In all animals,' he says, 'this is observable; but in the dog it exists to a wonderful extent; and the offspring appears to inherit not only the passions and propensities, but even the resentments of the family from which it springs. I ascertained that a terrier, whose parents had been in the habit of fighting with polecats, will instantly show every mark of anger when he first perceives the scent of that animal, though the animal itself be wholly concealed from his sight. A young spaniel brought up with the terriers showed no marks of emotion at the scent of the polecat, but it pursued a woodcock, the first time it saw one, with clamour and exultation: and a young pointer, which I am certain had never seen a partridge, stood trembling with anxiety, its eyes fixed and its muscles rigid when conducted into the midst of a covey of these birds. Yet each of these dogs are mere varieties of the same species, and to that species none of these habits are given by nature. The peculiarities of character can therefore be traced to no other source than the acquired habits of the parents, which are inherited by the offspring, and become what I call *instinctive hereditary propensities*.'

It appears from another communication made by Mr Knight to the same society in 1837, that he had then been pursuing investigations on this subject for nearly sixty years. He proceeds in that communication to give a general account of his investigations:—'At the period,' he says, 'at which my experiments commenced, well-bred and well-taught springing spaniels were abundant, and I readily obtained possession of as many as I wanted. I had at first no other object than that of obtaining dogs of great excellence; but within a very short time, some facts came under my observation which very strongly arrested my attention. In several instances, young and wholly inexperienced dogs appeared very nearly as expert in finding woodcocks as their experienced parents. The woods in which I was accustomed to shoot did not contain pheasants, nor much game of any other kind, and I therefore resolved never to shoot at anything except woodcocks, conceiving that by so doing the hereditary propensities above-mentioned would become more obvious and decided in the young and untaught animals; and I had the satisfaction, in more than one instance, to see some of these find as many woodcocks, and give tongue as correctly, as the best of my older dogs.

Woodcocks are driven in frosty weather, as is well known, to seek their food in springs and rills of unfrozen water, and I found that my old dogs knew about as well as I did the degree of frost which would drive the woodcocks to such places; and this knowledge proved very troublesome to me, for I could not sufficiently restrain them. I therefore left the old experienced dogs at home, and took only the wholly inexperienced young dogs; but, to my astonishment, some of these, in several instances, confined themselves as closely to the unfrozen grounds as their parents would have done. When I first observed this, I suspected that woodcocks might have been upon the unfrozen ground during the preceding night; but I could not discover (as I think I should have done had this been the case) any traces of their having been there; and as I could not do so, I was led to conclude that the young dogs were guided by feelings and propensities similar to those of their parents.

The subjects of my observation in these cases were all the offspring of well-instructed parents, of five or six years old or more; and I thought it not improbable that instinctive hereditary propensities might be stronger in these than in the offspring of very young and inexperienced parents. Experience proved this opinion to be well-founded, and led me to believe that these propensities might be made to cease to exist, and others to be given; and that the same breed of dogs which displayed so strongly an hereditary disposition to hunt after woodcocks, might be made ultimately to display a similar propensity to hunt after truffles; and it may, I think, be reasonably doubted whether any dog, having the habits and propensities of the springing spaniel, would ever have been known, if the art of shooting birds on the wing had not been acquired.

I possessed one young spaniel, of which the male parent, apparently a well-bred springing spaniel, had been taught to do a great number of extraordinary tricks, and of which the female parent was a well-bred springing spaniel; the puppy had been taught, before it came into my possession, a part of the accomplishments of its male parent. In one instance I had walked out with my gun and a servant, without any dog; and having seen a woodcock, I sent for the dog above-mentioned, which the servant brought to me. A month afterwards I sent my servant for it again, under similar circumstances, when it acted as if it had inferred that the track by which the servant had come from me would lead it to me. It left my servant within twenty yards of my house, and was with me in a very few minutes, though the distance which it had to run exceeded a mile. I repeated this experiment at different times, and after considerable intervals, and uniformly with the same results, the dog always coming to me without the servant. I could mention several other instances, nearly as singular, of the sagacity of this animal, which I imagined to have derived its extraordinary powers in some degree from the highly-cultivated intellect of its male parent.'

To conclude these preliminary observations on dogs. A gentleman of our acquaintance, and of scientific acquirements, obtained some years ago a pup which had been produced in London by a female of the celebrated St Bernard's breed. The young animal was brought to Scotland, where it was never observed to give any particular tokens of a power of tracking footsteps until winter, when the ground became covered with snow. It *then* showed the most active inclination to follow footsteps; and so great was its power of doing so under these circumstances, that when its master had crossed a field in the most curvilinear way, and caused other persons to cross his path in all directions, it nevertheless followed his course with the greatest precision. Here was a perfect revival of the habit of its Alpine fathers, with a degree of specialty as to external conditions at which, it seems to us, we cannot sufficiently wonder. We thus see that not only does what meta-physicians call the *law of habit* exercise a sway in the intellects of animals, but that modification which takes place in human communities, and passes under the comprehensive name of civilisation, also affects the lower tribes of creation. A race of animals, like a race of men, is civilisable; and we cannot doubt that the same softening influences which have produced the advanced nations of Europe, have operated upon the animals existing in the same countries, and made them very different from what they were in early times. It cannot escape remark, that the whole principle of civilisation acquires strength from having its basis thus widened. We become the more confident in the improvability of our own species, when we find that even the lower animals are capable of being improved, through a succession of generations, by the constant presence of a meliorating agency.

GENERAL CHARACTERISTICS OF THE DOG.

The general form and aspect of the dog is too well known to require any description. He has six incisory or cutting teeth in both jaws; beyond which there are, on each side, both above and below, a canine tooth; and still further into the mouth are six cheek-teeth, or molars, in each side of the upper jaw. The three first are sharp and cutting, which Cuvier calls false molars. The next tooth on each side is a carnivorous tooth, furnished with two cutting lobes, beyond which the other two teeth on each side are flat. There are seven cheek teeth, on both sides, in the under jaw; four of these are false molars, a carnivorous tooth, with the posterior part flat, and behind it two tuberculous teeth. The muzzle is elongated, subject to great variety of length in different varieties. The tongue is smooth and soft; the ears erect in the wild varieties, and in some of the tame ones, but, in the latter kinds, for the most part pendulous. The fore-feet are provided with five toes, and the hind-feet with four toes, furnished with rather longish nails, obtuse at their points, and not retractile. Occasionally a fifth toe occurs on the hind-feet, termed the *dew claw;* this is generally removed by the sportsman when the animal is young, as its presence is calculated to impede the animal's movements. The dew claw is regarded as a sign of degeneracy. The females are provided with both inguinal and ventral teats. The pupils of the eyes are circular.

The female goes with young sixty-three days, and generally produces from three to five at a birth, and sometimes even twelve, which are at first blind, in which state they continue for from nine days to a fortnight. About the end of two months their faculties begin to develop themselves. They shed their first teeth at the end of six months, which are replaced by others that do not exfoliate. At twenty months, or two years, dogs arrive at their full vigour. The males continue to propagate for nearly their whole lives, while the female discontinues having young ones at about the age of eight or nine years.

The average age to which dogs live is about fourteen years; they frequently, however, live to sixteen, and even have been known to attain the age of twenty years. In their latter days, dogs frequently suffer greatly from decay, and various diseases. They are extremely subject to rheumatism, from their liability to exposure to rain and damp beds. Until dogs have attained seven or eight years, their teeth are white, smooth, and acutely pointed; but after this age they become yellow-spotted, and their points assume an uneven and jagged appearance. At this time, also, the hair of the muzzle and around the eyes assumes a hoary appearance, and becomes whiter as they increase in years.

The dog is naturally carnivorous, but when domesticated, he does not refuse farinaceous food. He uses grass as a vomit; and drinks by lapping with his long flexible tongue. He does not sensibly perspire by the skin; the superfluous moisture of the body escapes at the mouth by panting, when heated, and by the extraordinary diuretic habits of the animal. The sense of smell is different in different varieties, but in all is sufficiently strong and refined to enable the dog to seek out and follow his master even among a crowd. His sense of hearing is also quick. He expresses anger by growling or barking, but also barks when joyful; and shows delight by the wagging of his tail. He exhibits fear by crouching and whining; howls when pained; and droops his tail under reproof. He sleeps very lightly, so as to be awakened by the slightest noise; and during his slumbers he is apt to dream, as is indicated by starting, whining, and short barks.

The most remarkable feature in the character of the dog is his attachment to man. In wild unpeopled countries, dogs are known to live in hordes, and seek their prey like other untamed animals; but brought into connection with human society, the dog leaves his own species without regret, and is only happy when belonging to a master to whom he can be faithful as a friend, servant, or companion. In this condition of domestication his ambition seems to be the desire to please; he is seen to come crouching along, to lay his force, his courage, and all his useful talents, at the feet of his master: he waits his orders, to which he pays implicit obedience: he consults his looks, and a single glance is sufficient to put him in motion: he is more faithful than even the most boasted among men: he is constant in his affections, friendly without interest, and grateful for the slightest favours: much more mindful of benefits received than injuries offered, he is not driven off by unkindness: he still continues humble, submissive, and imploring; his only hope to be serviceable, his only terror to displease: he licks the hand that has just been lifted to strike him, and at last disarms resentment by submissive perseverance.

More docile than man, as Buffon observes, more obedient than any other animal, he is not only instructed in a short time, but he also conforms to the dispositions and manners of those who command him. He takes his tone from the house he inhabits: like the rest of the domestics, he is disdainful among the great, and churlish among clowns. He knows a beggar by his clothes, by his voice, or his gestures, and forbids his approach. When at night the protection of the house is committed to his care, he seems proud of his charge; he continues a watchful sentinel; he goes his rounds, scents strangers at a distance, and gives them a warning of his being upon duty. If they attempt to break in upon his territories, he becomes more fierce, flies at them, threatens, fights, and either conquers alone, or alarms those who have most interest in coming to his assistance; however, when he has conquered, he quietly reposes upon his spoil, and abstains from abusing—thus giving at once a lesson of courage, temperance, and fidelity.

CLASSIFICATION OF VARIETIES.

Cuvier, the eminent French naturalist, formed a classification of dogs, founded on the shape of the head, and length of the jaws and muzzle. These he has separated into three great groups, as follows:—

I. Matins.—These have a head more or less elongated; the parietal bones insensibly approaching each other, and the condyles of the lower jaw placed in a horizontal line with the upper cheek teeth.

II. Spaniels.—The head moderately elongated; the parietal bones do not approach each other above the temples, but diverge and swell out, so as to enlarge the forehead and cavity of the brain. In this group are included all the varieties of dogs which are of the greatest utility to man, and also the most intelligent.

III. Dogues.—The muzzle more or less shortened; the skull high; the frontal sinuses considerable; the condyle of the lower jaw extending above the line of the upper cheek teeth. The cranium is smaller in this group than in the two previous, owing to the peculiar formation of the head.

These three groups have, for convenience, been further subdivided into nine sections, which we shall now treat *seriatim*—noticing the different breeds or varieties which have been ranked under each:—

I.—Dogs with Lengthened Heads.

SECTION 1. Half-reclaimed dogs, which hunt in packs.

The *Dingo*, or *Australian Dog*.—The head of this dog is not unlike that of a wolf, on which account Bewick calls it the New South Wales wolf. The muzzle is long and pointed, with short erect ears. He is two feet six inches in length, and about two feet in height. His fur is composed of a mixture of silky and woolly hairs, and is of a deep yellowish-brown colour; and his tail is long and bushy, resembling that of a fox, but generally carried curled over his haunch, and not pendent. The dingo, though naturally ferocious, is easily rendered tolerably tame; and in this state many specimens are now brought to this country. They are not to be trusted, however; and the moment they escape from confinement, all their natural bloodthirsty propensities return. We knew one which, after two years domestication, happened to slip the chain, and in less than a week, upwards of a score of sheep were destroyed by him in the neighbourhood.

The *Dhole* is the native wild dog of India, and bears a strong resemblance to the dingo, but without the bushy tail of that species; he is of a uniform bright-red colour. Differently from other dogs which hunt in packs, according to the account given by Captain Williamson, this species always hunts mute, and only utters a soft whispering sound when in high chase, and near his prey. The dhole is exceedingly swift of foot, and soon overtakes most animals which are the objects of his pursuit. It is said they are exceedingly fond of the flesh of the tiger, and that, in consequence, this animal is prevented from propagating to that extent which would soon overrun and lay waste all the countries which it inhabits. This predilection is confirmed by Bishop Heber, who states, upon the authority of the peasants of Khayra, which borders the frontiers of China, that a tiger is often killed and torn to pieces by the wild dogs, which give tongue like foxhounds or harriers. It is in the unfrequented wilds of the western frontiers of India that the dhole takes up his abode, lurking amongst the extensive jungles which cover mighty tracts of that territory.

The *Pariah* is the common village dog of India. He has a small sharp head, with short pricked ears, a slender body, and particularly drawn up about the abdominal region; his chest is deep, his limbs light, and his colour is of a reddish-brown. The native Indians use the pariahs in hunting the tiger and wild boar. They are very fierce, and follow their game with much avidity and determination.

The *Ekia* is the native dog of Africa, and in all likelihood sprung from the same stock as the dhole. They are said to be of various colours—as black, brown, white, and yellowish. They are eaten by the negroes, who relish them greatly. The African wild dogs, like those of India, hunt in packs.

The *South American Dog* is not unlike the dingo, and is about the size of the springer, with short and pricked ears, like most other wild dogs. The hair on his tail is long and bristly; he is of a brownish-gray colour on the back, with sandy-coloured spots on the legs and flanks. In general aspect he greatly resembles the wolf, but is much smaller in size. There is another South American dog called the Alco, of which there are two varieties. The head of the alco is very small, and the ears pendulous, thus differing from almost all other wild dogs. The back is somewhat curved, and the tail rather short. It is said that the Spaniards found this dog among the natives on the first discovery of America. Herrere says that Columbus found in America many dogs which did not bark. But there is reason to suppose that whatever may have been the original types of the South American dogs, they have been greatly altered by intermixture with the descendants of those introduced at the conquest by the Spaniards.

The *North American Dog*.—We have no very distinct account of this variety, but it is said to resemble the dingo in its pricked ears and general conformation. It is remarkable for the acuteness of its scent, and very expert in the detection of its prey, or animals which it may be trained to pursue.

SECTION 2. Domesticated dogs, which hunt in packs or singly, principally by the eye, although sometimes by the scent.

The *Irish Greyhound* ranks among the noblest of the canine race; his mien is striking, full of dignity, and his conformation beautiful. In his general shape he bears a strong resemblance to the common greyhound, but is much taller, and more robust. His use in early times was to free the country of wolves and wild boars, which abounded in England and Ireland; hence he is sometimes termed the 'Irish wolf-dog.' The hair is rough and shaggy, and the colour of these dogs is fawn or pale cinnamon. The Marquis of Sligo is said to have had some of this breed (!), which were of various colours: some were brown and white, and others black and white. The ordinary height of the Irish greyhound is about three feet, although they have been known to reach four feet. Goldsmith, who had seen several of this breed, says they were about four feet high, and as tall as a calf of a year old. The *true* Irish wolf-dog is now extremely rare, if not altogether extinct.

The *Albanian Dog* is about the size of a full-sized mastiff. His hair is very fine and close set, and of a silky texture, variously clouded with brown; his tail is long and bushy, and carried like that of a Newfoundland dog; his muzzle is pointed, and rather long; his legs are strong and muscular, which fit him well for hunting the wild boar, in which sport he was much used in ancient times; he was also used in hunting wolves, and in protecting sheepfolds from thieves.

The *French Matin* has an elongated head, and flat above; his ears are erect, and slightly pendulous towards the tips; the hair of a yellowish fawn-colour, with darker, oblique, and, parallel indistinct rays traversing the whole of his fur. His height is about two feet, and his length three feet. He is strong, muscular, and active, and very courageous. He evinces great eagerness in hunting the wild boar and wolf, in which sport he is frequently employed. Pennant thinks this variety is a descendant of the Irish greyhound.

The *Scottish Highland Greyhound* will either hunt in packs or singly. He is an animal of great size and strength, and at the same time very swift of foot. In size he equals, if not excels, the Irish greyhound. His head is long, and the nose sharp; his ears short, somewhat pendulous at the tips; his eyes are brilliant and very penetrating, and half concealed by the long crisped hairs which cover his face and whole body. He is remarkable for the depth of his chest, and tapers gradually towards the loins, which are of great strength, and very muscular; his back is slightly arched; his hind-quarters are powerfully formed, and his limbs strong and straight. The possession of these combined qualities particularly fit him for long endurance in the chase. His usual colour is a reddish sand-colour, mixed with white; his tail is long and shaggy, which he carries high, like the staghound, although not quite so erect. It is this noble dog which was used by the Scottish Highland chieftains in their great hunting parties, and is supposed to have descended in regular succession from the dogs of Ossian.

The *Russian Greyhound* is nearly as large as the Irish greyhound, resembling him in shape as nearly as possible, but covered with long bushy hair. His general colour is a dark reddish-brown. He is sometimes hunted in small packs, and as frequently single, in which case he not unfrequently will kill a wolf, deer, or wild boar, without any aid whatever. When used in coursing, he is taken to the field in slips, in the same manner as is practised with greyhounds.

SECTION 3. Domesticated dogs, which hunt singly, and always by the eye.

The *Gazehound* is a dog, the breed of which is now lost. It was hunted in the same manner as the greyhound, and took foxes and hares by running them down. It is said by Bewick that it was employed in stag-hunting, which we think is rather doubtful, as although the stag is an animal of great speed, yet the contest between it and a dog possessing the swiftness of a greyhound would be but very unequal.

The *Greyhound* is the fleetest of all dogs, which is in consequence of his peculiar conformation. His head is long, tapered, and shaped like that of a snake; his neck long and slender; his ears somewhat erect and pricked, slightly pendulous at their tips: the tail ought to be very fine, pointed, and the hair on it very short; the chest should be wide and deep; the belly drawn up, with strong loins, and with large and prominent hip-muscles. This dog is by no means so intelligent as many other varieties, and he is, in consequence, much less susceptible of education. He has, however, very fine feelings, and seems to be much alive to caresses, which excite him to such a degree, as to produce a quick pulsation of the heart. This may be felt beating against his side with much vigour. He is one of the most elegantly-formed of all the canine species.

The *Scotch Greyhound* is formed exactly like the common greyhound, and differs from it merely by being of a larger size, and in the hair being longer and wiry. The general colour is reddish-brown or sandy.

Shepherd's Dog—Scotch and Irish Greyhounds.

The *Italian Greyhound* is merely a miniature of the common greyhound, being only about half the size of that dog. It has a very fine coat of a silky texture, and is so tender, as to be easily injured by cold or wet. It is used only as a *pet*, being altogether valueless in other respects.

The *Turkish Greyhound* is still smaller than the Italian greyhound, being little more than half its bulk, and is entirely divested of hair, except on the tail, where it is few and scattered. Its usual colour is a blackish lead colour. It abounds in Turkish towns, where it forms a dreadful nuisance to travellers.

II.—Head less elongated than former division.

SECTION 4. Pastoral dogs, or such as are employed in domestic purposes.

The *Shepherd's Dog* is covered with long flowing, and somewhat woolly, hair; his muzzle is long and pointed, and his ears erect, and slightly bent downwards at the tips; his tail is long and bushy; and the usual colour of his fur black and white, or varied with black and gray; the backs of his fore-legs have also long hairs. The peculiar and highly useful qualities of this dog seem to be rather intuitive than acquired; indeed nothing can hardly exceed the quickness with which he can be taught any lesson; and certainly no other dog has the same patient perseverance and courageous fidelity, and at the same time possessed of the greatest discrimination. The labour of a shepherd, with the assistance of this faithful and intelligent animal, is comparatively an easy task; and it is hardly possible to fancy a more arduous employment than it would be, if divested of the services of the dog: for without him, how could he collect extensive flocks scattered over high and widely-spread mountain ranges! The shepherd's dog is possessed of great sagacity, gratitude, and self-denial, as is well known from innumerable anecdotes.

The *Cur*, or *Watch-Dog*, differs from the shepherd's dog in being nearly smooth; he is stronger in his make, and has half-pricked ears, and his tail is rather short, and slightly feathered beneath. He is a trusty and useful servant to the farmer and grazier, and is chiefly employed in driving cattle; and being larger and stronger than the shepherd's dog, from which he is sprung, he is better qualified for the grazier and farmer. He bites with great keenness, and always makes his attack at the heels. His sagacity is very great, and he soon knows his master's fields, and watches with great assiduity the cattle which are in them. A cross between this and the true shepherd's dog has been found to be extremely useful on the sheep-runs of Australia.

The *German Dog* is a small-sized animal, with bushy turned-up tail, bushy neck, small muzzle, and is generally of a cream colour, but also sometimes black. His manner is brisk, and his character that of great fidelity. He is seen all over central Germany, where he appears to be employed chiefly as a merry companion to man, and also for watching. A few specimens are beginning to be seen in England.

SECTION 5. Water-dogs, which delight in swimming, having their feet in general semi-webbed.

The *Pomeranian*, or *Wolf-Dog* has the hair on the head short, as is also that on the feet and ears; but it is long and silky on the body and tail, which last is curled up in a spiral form. His colour is white, black, gray, or sometimes yellowish; his head is long, and his muzzle pointed; his ears are short and pricked. He is possessed of intelligence nearly equal to that of the shepherd's dog, but is much less to be trusted.

The *Siberian Dog* has much the appearance of the Pomeranian dog, and is very nearly allied to him, except that he is covered with long hair, even on the head and paws. In their native country, four of these dogs are attached by pairs to a sledge, and in front of them is placed a leader, on the proper training of which much of the useful services of the others depend. These sledges are just large enough to contain one person, who directs them with his voice, and in which he is partially assisted by a stick. The reins are fastened to the dogs' necks by a collar. These dogs, thus yoked, have been known to drag a sledge from seventy to eighty miles in a day; and so powerful is their scent, that they contrive to keep on the beaten track by that means alone, even although it be obliterated by showers of snow.

The *Greenland Dog* is of a large size, strong in the bone, and its fur consists of long, thick-set, wool-like hair; his muzzle is sharp, and his ears short and pricked; his tail is thick, bushy, and spirally twisted. He is closely allied to the preceding variety.

The *Iceland Dog* is shorter in the hair than the above variety; his ears are pricked, but slightly bent downwards on the tips. His general colour is white, with patches of black differently disposed.

The *Esquimaux Dog.*—This highly useful variety is described by M. Desmarest as having the head shaped like that of the wolf-dog; the tail is spreading and curved, and the ears erect. The hair is thinly scattered, and consists of two sorts, the one silky, the other thick and fine, and somewhat curled, and so detached from the other that it may be pulled off in flakes from the animal. The dogs of the Esquimaux are very good-tempered and intelligent; active, swift, and enduring. (For their utility as beasts of draught, see INLAND CONVEYANCE, p. 103.)

The *Hare-Indian Dog* has a narrow, elongated, and pointed muzzle; his ears are broad at the base, and pointed towards the tips, and perfectly erect; his legs are long and slender, and his tail thick, bushy, and curved slightly upwards, but by no means so decidedly curved as that of the Esquimaux dog. His body is covered with long straight hairs, the ground colour of which is white, marked with large irregular patches of grayish-black, intermingled with various shades of brown. Dr Richardson says it has neither courage nor strength for pulling down any of the larger animals. The feet of this variety are unusually large, spread, and thickly clothed with fur, in consequence of which he can run upon the snow with rapidity and ease without sinking.

The *Newfoundland Dog*.—This beautiful and intelligent dog is remarkable for the symmetry of his form and the acuteness of his understanding. He measures, from the tip of the nose to the point of the tail, six feet and a-half, the length of the tail itself being two feet; from the one fore-foot to the other, over the shoulders, five feet eight inches; the girth behind the shoulders three feet four inches; the length of his head is fourteen inches. He has webbed feet, in consequence of which he is a dexterous swimmer. His hair is long, flowing, and slightly curled, and his tail very bushy, particularly in the lower side, and he carries it in a very graceful manner. The docility of the Newfoundland dog is very great; there are innumerable most striking anecdotes of his sagacity and benevolence of disposition, particularly with reference to his saving persons from drowning. During the gale on Thursday, June 11, 1829, a vessel was driven on the beach at Lydd; no boats could get off to the assistance of the crew, who were, however, all saved and brought ashore through the activity of a fine Newfoundland dog. The surf was rolling furiously, and eight poor fellows were crying for aid, which the spectators could not afford them, when one man directed the attention of his dog to the vessel, and the intelligent animal at once swam towards it, and the crew joyfully made fast a rope to a piece of wood, which the dog seized and swam with to his master on shore; a line of communication was thus formed, and the eight mariners rescued from a watery grave. Intelligent and sagacious as the Newfoundland dog undoubtedly is, there are certain occasions on which he is not to be trusted; and if sharply reproved or punished, is apt to resist the lash even of his master.

The *Russian Dog* is somewhat larger and stronger than the Newfoundland dog; he is a cross between that variety and the Siberian dog, and has now become a distinct race. His head is large, with his ears pendulous and rather full-sized; his tail is curled over his back; his hair is very long and shaggy, consisting of black and white patches.

The *Great Rough Water-Dog* is web-footed, swims with great ease, and dives with much courage and dexterity; his hair is long and curly, and he is of various colours; his legs and feet are also thickly covered with thick and bushy hair.

The *Large Water-Spaniel* is about the size of the English setter, but of a stronger make. His face is smooth, as also the front of his legs; while the rest of his body is covered with small crisped curls, usually of a dark liver-brown colour. This dog is very valuable in the sport of shooting wild-fowl.

The *Small Water-Spaniel*, or *Poodle*, is a breed between the large water-dog and the springer; he is thickly covered with fine hair, all of which is in distinct small curls, more like an effort of art than of nature. It is one of the most active of dogs. Its general colour is white, and sometimes it has various black patches. It dives with much dexterity, and will leap from a very great height into the water; we have seen one leap over Old Tyne Bridge at Newcastle—a height of nearly fifty feet.

The *Shock Dog* is the smallest of the water-dog varieties, and is probably bred between the smaller spaniel or King Charles's dog and the poodle. Its hair is extremely long and flowing, so much so, that its ears and eyes are nearly concealed from view by it. It is kept only as a lapdog.

SECTION 6. Fowlers, or dogs whose inclination is to chase and point birds, and hunt singly by the scent.

The *Springer* is shaped much like the English setter, but shorter in the body and legs in proportion to his size, being about two-fifths less than that dog; the hair is long and shaggy, and the ears very long and pendulous, and covered with long waved hairs. He is usually of a white colour, with patches of liver-colour or chestnut. He is, however, sometimes black, and at other times entirely of a liver-coloured brown.

The *Cocker* is about a third less than the springer, and like it in all respects. It is used as well as that variety for raising woodcocks and snipes, in which exercise they are both very expert and hardy.

The *King Charles's Spaniel* is still less than the cocker, and distinguished by the very great length of his ears. Its hair is silky; and this, with its gentleness and small size, has rendered it a favourite pet of ladies of fashion. It is fashionable for ladies to carry these little creatures in their arms while walking in the streets—an exhibition so absurd that it is even beneath reprobation. They are sold at a high price.

The *Comforter* is another diminutive variety of this race, chiefly used as a lapdog. It is supposed to be a cross between the Maltese and King Charles's dog.

The *Maltese* and *Lion Dogs* are descendants from nearly the same stock. They are also favourites with the ladies; and are rare, but useless.

The *Alpine Spaniel*, or *Great St Bernard Dog*, exceeds other varieties of the spaniel for size and beauty. Its usual height is two feet at the shoulders; and he is six feet in length from the nose to the tip of the tail. Two of these dogs are sent out from the monastery of the Great St Bernard, situated among the Alps of Switzerland, to scour the mountains during snow-storms, in search of lost or wearied travellers—the one with a warm cloak fastened to his back, and the other with a basket tied round his neck, containing a bottle with some cordial, and bread. In this employment they manifest great judgment, and seem to understand perfectly the import of their mission. They are frequently of the greatest use in meeting the travellers, who in those stormy and dangerous regions often fall victims to the inclemency of the weather. It is said that if they meet with a traveller who has sunk under the fatigue and inclemency of the blast, that they will lie close to him, until by their warmth they restore heat and energy to the animation which is nearly suspended, and thus frequently will save the life of the sufferer. Should they discover a traveller to have fallen into some deep pit or fissure, whence he is unable to ascend, and if they are unable to render him any assistance, they will return to the convent and give the alarm to the monks, and then conduct them to the place where the unfortunate traveller is immured.

The *Old English Setter* is supposed to have been produced between the large water-spaniel and the Spanish pointer. They were much more curled than the present breed of setters, and were very steady in the field, but not so rapid in their movements.

The *English Setter* is a mixed breed between the water-spaniel, Spanish pointer, and the springer, which has attained a very high degree of perfection as a sporting dog. He is one of the most beautiful, lively, active, and hardy of dogs.

The *Spanish Pointer* is the stock from which the English pointer has sprung. He is one of the most stanch of all dogs used in the sports of the field, although he is considered too heavy for the present improved mode of sporting, and has now nearly become extinct in Great Britain.

The *English Pointer* was obtained by a cross of the Spanish pointer and foxhound, and is unrivalled for the rapidity of his movements in the field, and the beauty and symmetry of his form. Since his first production, he has been improved by being re-crossed with the harrier. He is subject to considerable variety in point of size as well as of colour. When well trained, and of a pure breed, he is exceedingly staunch—instances having been known where he has remained above an hour in the act of pointing.

Newfoundland—Scotch Terrier—English Pointer—Cocker.

The *Small Pointer* is a diminutive breed, being only about two feet from the point of the nose to the tip of the tail, and scarcely a foot in height, and is a complete and beautiful miniature of the large pointer. They have proved themselves excellent sporting dogs, but their small size renders them unfit for use in rough land.

The Russian Pointer is much like the Spanish pointer in shape, but his hair is long and wiry. He is valuable if well trained; but is rather obstinate and unyielding in temper.

The *Dalmatian* is a handsome animal, beautifully spotted black on a white skin. In his native country he is employed as a pointer; but imported into England, he has there lost all qualities for sporting, and is kept merely as an attendant on carriages—hence the common term 'coach-dog.' While most other dogs attach themselves to man, this one seems to care for nothing but horses. He lives by choice in the stable, and is happiest when running at the heels of the horses; even his own species he abandons in following this prevailing taste. He barks little, and is docile.

SECTION 7. Hounds which hunt in packs by the scent.

The *English Terrier* is too well known to require any description. He is possessed of great courage, and is famous for killing all kinds of vermin, and at one time formed a useful attendant upon a pack of foxhounds, for getting into the earth when the fox has taken to his hole, and driving him out. His hair is smooth. His general colour is black, with tanned cheeks, and the insides of his legs are of the same colour. They are now to be met with of a brown, and even white colour, but these have unquestionably an admixture of some other breed in them.

The *Scotch Terrier* has short wiry hair, very rough, and is much shorter in the legs than the English terrier. His usual colour is sandy, but he is to be found black, and also gray. He bites with great keenness, and is a bold and determined dog. He will attack dogs of any size; and when he fixes on an animal, he maintains his hold with great pertinacity. He was at one time much used as an attendant upon packs of foxhounds, and forms an excellent killer of vermin. The *Skye terriers*, or terriers of the Western Isles, are longer in the body, lower in the legs, and decidedly rougher and shaggier than those of the Lowlands. Indeed they form altogether a distinct variety.

The *Talbot* is one of the primitive breeds of British dogs, and is the same which was used by the ancient Britons in the chase of the deer and other wild animals. It is now, we believe, extinct, or at least not in common use. He had a broad mouth, very deep chops, large pendulous ears, was fine-coated, and usually of a white colour. He was formerly known as 'St Hubert's breed,' and was distinct from the bloodhound, though by some confounded with that dog.

The *Bloodhound* is a powerful and sagacious animal, generally of a dark colour, with brown markings, and is endowed with a keen scent. On being led upon the footsteps of any animal or man, he will follow them up with unerring precision. This has led to the breed being employed for tracking criminals, or the unhappy victims of oppression. By the Spaniards a breed was taken to Cuba to track the natives, and this race of animals still exists in that island. A correspondent in a newspaper thus speaks of them:—'At a period not very remote, the unfortunate negroes in the Spanish settlements were frequently torn to pieces by the Cuba bloodhounds. In fact, under the title of Chasseurs, the Spaniards maintained regular regiments of these dogs and their attendants. In pursuing or hunting the runaway negroes, the chasseur is generally accompanied by two dogs, and armed with a *couteau de chasse*, or straight sword; and we are informed that these bloodhounds, when well and properly trained, on coming up with the object of pursuit, will not kill him unless resistance is offered, but bark at and terrify him till he stops, when they crouch near him, and, by barking, give their keepers notice, who approach accordingly, and secure their prisoner.

Dallas, in his account of the Maroon War in Jamaica, mentions an importation of these Cuba bloodhounds, in order to assist the regular troops in reducing the refractory Maroons. It may seem strange that dogs were called to the assistance of well-disciplined soldiers; but in order to elucidate the subject, it must be observed that the armed Maroons, under the conduct of various cunning leaders, particularly of Cudjoe, Smith, and Johnson, aware of their own inferiority in point of that organisation which constitutes the strength and essence of a regular army, cautiously avoided meeting their opponents on the plain; on the contrary, they retired to the impenetrable fastnesses of the woods and mountains, and by means of ambuscades, contrived so to harass the troops, that the governor of Jamaica ultimately procured a company of these dogs and their attendants from Cuba, which arrived at Jamaica under the command of Don Manuel de Sejas; and a tolerable idea of these dogs may be formed from a review which took place immediately after their arrival. General Walpole, who conducted the war against the Maroons, being anxious to review these chasseurs, left headquarters the morning after they landed, accompanied by Colonel Skinner, and arrived in a postchaise at Seven Rivers. Notice of the general's approach having been given, the chasseurs were taken to a distance from the house, in order to advance when he arrived. The Spaniards were drawn up in a line at the end of a gentle declivity, and consisted of upwards of forty men, with their dogs in front unmuzzled, and held by cotton ropes, as it was intended to ascertain what effect would be produced on the dogs if actually engaged under a fire of the Maroons. The Spaniards, upon the word being given, fired their fusees, when the dogs pressed forward with almost ungovernable fury, amidst the shouts of their keepers, whom they dragged along with irresistible impetuosity. Some of these ferocious animals, maddened by the shout of attack, and held in check by the ropes, actually seized upon the gun-stocks in the hands of the chasseurs, and tore pieces out of them. The unfortunate Maroons, who had successfully opposed all the efforts of regular troops, were panic-struck on the arrival of the bloodhounds, and surrendered without once daring to come in contact with animals which at best could oppose but a feeble resistance to firearms.'

The *Staghound* is the largest of all the British dogs of the chase; he has a noble and dignified aspect, and possesses great sagacity and endurance in the chase; this dog is also supposed to be a direct descendant of one of our original British dogs.

The *Foxhound* has a much larger muzzle than the staghound, and his head is small in proportion to the size of his body; his ears are very long and pendulous, although less so than those of the staghound and bloodhound. Though a determined enemy of the fox, this active hound is by no means destitute of warm affections. A foxhound bitch, belonging to the Kivington Hunt, near Bolton, on the 8th November 1792, during the chase, pupped four whelps, which she carefully covered in a rush aisle, and immediately afterwards joined the pack. In a short time after, she pupped another, which she carried in her mouth during the remainder of a hard chase of several miles, to the great astonishment of a number of spectators, after which she returned to the place where she had originally dropped the four.

The *Harrier* is used in hare-hunting, and was originally obtained by a double cross between the small beagle and southern hound. He is very eager in the pursuit of the hare. There are few instances of any of the deer tribe being hunted with success by dogs of so small a description as harriers.

The *Beagle* is the smallest of the dogs of the chase. He is possessed of a very acute sense of smelling, and pursues the hare with unwearied steadiness; and what he wants in speed and strength he makes up by his perseverance.

The *Otter-Hound* is a cross between the large southern hound and the large rough terrier. He has a large head, with pendulous ears, and his whole fur is of a wiry texture, and rather long; his colour is either sandy or black. Otter-hunting was a favourite sport in ancient times, but is now seldom pursued.

The *Bull-Terrier* is a cross between the bull-dog and the terrier, as its name implies, and has now assumed the character of a distinct breed. It is much used by gentlemen of the fancy as a fighting dog; it forms likewise a first-rate animal for the chain.

SECTION 8. Mongrel hounds, which hunt singly either by the scent or by the eye.

The *Lurcher* is a cross between the greyhound and harrier, and re-crossed with the terrier. His limbs are strong; his head less sharp than that of a greyhound; his ears are short, erect, and half pricked; and his hair coarse and wiry. He is much used by poachers, and is famous for killing rabbits, as he has a fine scent, and runs his game without giving tongue.

The *Leyemer* and the *Tumbler* are imperfectly known dogs, which are now nearly if not entirely extinct. They hunted both by the scent and eye.

The *Turnspit* is a small dog with a long body and short crooked limbs, and was much used in turning the spit before the invention of jacks. Breeds between this now useless variety of dogs and mongrel terriers and hounds, appear to form the nondescript and ugly races of animals which haunt the streets of our large towns, but whose numbers are now diminishing by the proper interference of the police.

III.—With Short Heads.

SECTION 9. Watch-dogs, which have no propensity for hunting.

The *Mastiff* has a large flat head, and a short and blunted muzzle; his lips are full, and hanging considerably over the lower jaw; his ears, although rather small, are pendulous. He has a sullen and grave aspect, and is excellent as a watch-dog; his voice is loud and deep-toned. He is a dog of large size, and is supposed to have been produced betwixt the Irish greyhound and English bull-dog. Like the dog next mentioned, he is ferocious in disposition, and of little use when out of the chain.

The *Bull-Dog* is remarkable for the depth of his chest and the strength of the whole muscles of his body. His head is large, flattened above, and his muzzle much blunted, with the under jaw projecting considerably beyond the upper one; his eyes are set far apart, and project considerably from his head; his power of smelling is less acute than any other of the canine race, on which account he is a dangerous dog, for he has frequently been known to lay hold of his master without discriminating the difference between him and a stranger. He is the boldest and most obstinate of all dogs, and has been known to hold his adversary so determinedly that his legs have been cut off without making him desist.

Many instances have been recorded of the invincible courage of the English bull-dog, but we scarcely recollect one in which so much unconquerable spirit and tenacity of life have ever been displayed as on the following occasion:—A short time since, a large dog of this species, from some cause that was not observed, suddenly flew at a fine cart-horse that was standing at the end of the Salthouse Dock, Liverpool, and fixing his lacerating teeth in his shoulder, defied every effort to get him off. At first he was beaten with cartwhips and sticks, with such fury as seemed to break his bones; but this being unavailing, a carpenter with an adze in his hand came up and beat him with the blunt iron head of the instrument, till it was thought he had pounded him to a jelly; but the dog never moved a tooth. A man then took out a large pointed clasp-knife, with which he stabbed him repeatedly in the back, loins, and ribs, but with no better success. At length one of the spectators, who appeared to have more strength of sinew and arm than the rest, squeezed the ferocious beast so tightly about the throat, that at length he turned up the white of his eyes and relaxed his jaws. The man threw him off to a distance, but the dog immediately went round the crowd, got behind the horse, and again seized him by the under part of the thigh. As no terms could now be kept with this untameable brute, he was again loosened, and thrown into the dock to drown. He instantly, however, rose to the surface, when a sailor struck him a supposed deadly blow on the head with a handspike, which again sent him to the bottom. He arose once more, and was again sent down in the same manner, and this process was repeated five or six times. At length one of the bystanders, who either possessed or assumed some right of property in the dog, overcome by his amazing tenacity of life, and weary of persecution, got him out, and walked off with this prodigy of English courage, to all appearance very little the worse for the horrible punishment he had undergone. Since the very proper disuse of bull-baiting, this ferocious variety of the dog has fortunately diminished in number.

The *Pug Dog* is descended from the bull-dog, by a cross with the small Danish dog, and resembles the former so much in appearance that he may be considered as a miniature of that variety. He is a useless dog, and with generally a bad temper, has no good quality to recommend him.

GENERAL MANAGEMENT.

As formerly mentioned, dogs are very susceptible of education, and will fall into such habits as are impressed upon them by a course of training. Whatever be the peculiar variety kept in or about a dwelling-house, it is important that he be at least taught good manners; as, for example, to be silent and lie down when bidden, to refrain from leaping on the knees of persons visiting the family, and not to sit staring at meals, watching every bit that is put in the mouth. To make a dog behave properly in these and other points, he must be carefully taught when young, and for this purpose his master requires to employ a judicious mixture of severity and gentleness. He must be made fully aware that he must do as he is bid; that if he do not he will be punished, but that if he obey he will be rewarded. As all dogs are very tractable in such matters, they will soon learn to comprehend the meaning of a look, a sign, or a word, and will act accordingly. As very few persons take the trouble to teach domestic dogs either one line of conduct or another, we see on all occasions instances of the natural consequences of such neglect.

Breeding.

The best dogs are produced from parents not less than two years old, to which period a valuable bitch should be reserved. During her heats before this time she should be locked up, and be treated with a little cooling medicine. All who are interested in preserving the breed of their dogs should on no account suffer a cross. In every instance let the male and female be of the true breed designed, not mixed or deteriorated. If a slight alteration of character be desirable, breed from the nearest varieties. Breed always from the healthiest and best-shaped animals. Mongrel breeds are good for nothing.

Breeders of sporting dogs require to pay marked attention to these principles. According to the author of the 'Oakleigh Shooting Guide,' the theory respecting pointers is, 'that the farther any dog is removed from the original Spanish pointer, the worse the dog is; and consequently that all attempts to cross the pointer with any other blood must necessarily deteriorate the breed. The greyhound is seldom or never crossed to give him additional fleetness, nor the hound to improve his nose; why, then, should the pointer be crossed with dogs which, in so far as the sports of the field are concerned, scarcely inherit one quality in common with him! Attempts, however, are constantly made to improve the pointer by a cross with the bloodhound, fox-hound, Newfoundland dog, or mastiff, sometimes with a view of improving his appearance, and bringing him to some fancied standard of perfection, but in reality inducing a deformity. The best pointer is the offspring of a pointer-bitch by a pointer-dog; such a one is nearly broken or trained by nature. The Spanish [or true] pointer seldom requires the whip; the hound-pointer has never enough of it.' The same writer continues—'Dogs should be constantly shot over during the season by a successful shot, and exercised during the shooting recess by some person who understands well the management of them, otherwise they will fall off in value—the half-bred ones will become unmanageable, and even the thorough-bred ones will acquire disorderly habits.'

It appears that the females, before or during a state of heat, are liable to receive mental impressions of the appearance of the males with which they have been in company, and that these remembrances will affect their progeny even for years afterwards. We beg to refer to 'Blaine's Encyclopædia of Rural Sports,' p. 412, for some interesting information on this subject.

Whelps, at a month old, are generally deprived of their dew-claws. With some varieties it is also the custom to shorten the ears and tail, with a view of improving their appearance; but it is questionable if any breed can be improved in aspect by such treatment, and certainly no pure and well-formed variety can benefit by such mutilations. It is not customary to emasculate males, except those which are intended for pets; the operation renders the animal a much more docile and agreeable companion. There is a prejudice of very old standing, that dogs have a worm beneath their tongue, and that the removal of this, called *worming*, deprives the animal of the power of biting should it become rabid. No worm exists; and it is doubtful if the process is of any use. That which is called a worm is merely a minute ligament or fibrous cord in the bridle beneath the tongue; and when the bridle is cut, the ligament may be drawn forward and separated at both extremities; the contraction of the ligament, on extraction, resembles the movement of a worm, and hence the origin of the term.

Feeding.

Some of the most troublesome traits in the dog's behaviour arise from mismanagement in feeding. If a dog be half-hungered, he cannot be blamed for watching the breakfast or dinner table. We advise all who indulge themselves with keeping dogs, not to leave their feeding to the chance scraps of either the kitchen or the parlour. Give the dog his own regular meals, and with food suitable to his wants or the duty he has to perform. The food should be chiefly flesh of some kind, boiled and cold; if given raw, it has a tendency to foster ferocity of disposition, and will cause the animal to be offensive in smell. No pet-dog, especially, should ever be allowed to eat raw meat. Any common pieces of flesh or tripe will answer for dog's meat. Some persons give liver, which is decidedly bad; it relaxes the bowels, and is otherwise objectionable. Besides the piece of boiled meat considered necessary, give dogs a few bones from the dinner table; they are fond of these, and they are useful in cleaning and preserving their teeth, and keeping their bowels in order. If the dogs will take it, they should also be given a little farinaceous food, as morsels of bread or a little oatmeal porridge with milk.

The nature of the dog leads him to feed well when food is offered to his appetite, and to feed seldom. Once a day, therefore, is, in ordinary circumstances, sufficiently frequent for his meals. Present him with his allowance in the morning or forenoon, and give him no more till next day. He, however, requires to drink frequently; and it is a leading rule in keeping a dog, to have at all times a pan of clean cold water ready for his use. Change the water daily, or oftener.

For the feeding of hounds, Daniel recommends that flesh meat should be alternated with a diet of oatmeal porridge, made with broth in which meat has been boiled. Greens boiled in their meat is also proper. 'A horse killed and given to the hounds whilst warm, after a very hard day, is an excellent meal; but they should not hunt till the third day after it. The bones broken are good for poor hounds, as there is great proof in them. Sheep trotters are very sweet food; and bullock's paunches may also be of service in a scarcity of horse flesh. Hounds should be sharp-set before hunting; they run the better for it.' The same excellent authority continues to observe that hounds should be fed once when returned from the fatigues of the chase, and again some time afterwards. 'It is the best plan to feed twice the hounds that have been out. Some hounds will feed better the second time than the first; besides, turning them out from the lodging-house refreshes them; they stretch their limbs, and the litter being shaken up, and the kennel cleaned out, they settle themselves better on the benches afterwards. At all times, after being fed, the hounds should be turned into the grass court to empty themselves; it will not a little contribute to the cleanliness and health of the kennel.'

Lodging—Kennel Treatment.

Dogs require to be lodged in a dry situation, at a moderate temperature. The practice of keeping dogs out all night during frosty weather, or of putting them into cold coach-houses, is most inhumane and disgraceful. Those kept for watching the outside of premises should be provided with a comfortable house of wood, bedded with clean straw, and sheltered from cutting winds. A dog kept in a dwelling-house should have an appointed place, as in a lobby, for sleeping; its berth should consist of a basket, open box, or small house, according to the taste of the animal. A spaniel will not go into a dog-house; a terrier prefers it. In any case, the berth should be laid with a mat or carpet, which must be frequently washed.

Damp is seriously injurious to dogs. It produces rheumatisms, which show themselves by lameness in the shoulders, and other disorders detrimental to their usefulness. It is therefore of great importance to build kennels in airy situations, and to keep them dry and airy. The best kennels are paved with tiles or stone, but on the floors there are raised benches, littered with straw in winter, on which the dogs repose. The straw should be daily changed, nothing being of so much consequence as cleanliness, both for the sake of general health, and preserving the powers of scent of the animals. For this latter purpose some keepers of packs of hounds have a change of rooms, one being used while the others are becoming sweet after cleaning. On this subject Daniel observes—'The excellent sense of smelling, so peculiar to the hound, is what our sport entirely depends on; care therefore must be taken to preserve it, and the utmost cleanliness is the surest method: to keep the kennel sweet cannot be too much recommended, and is on no account to be neglected. The exactness of the master in this particular will insure that of the feeder.

Hounds that come home lame should not be taken out the next hunting day, since they may appear sound without being so. At the beginning of a season, the eyes of hounds are frequently injured; such hounds should not be hunted; and if their eyes continue weak, should lose a little blood. Such as have sore feet should have them well washed out with brine or pot-liquor. Hounds unable to work should be permitted to run about the house; it will be of great use to them; and such as are ill or lame ought to be turned into a kennel by themselves; there it will be more easy to give that attention both to their medicine and food which is requisite.'

Hounds which are properly disciplined are obedient in a very extraordinary degree to the orders of the huntsman. 'To see,' says the writer of the article *Hunting*, in the Encyclopedia Britannica, 'sixty couples of hounds, animals all hungry as tigers, standing aloof in their yard, and without even hearing, much less feeling, the whip, not daring to move until the order is given to them. And what is the order given? Why, at the words "Come over, bitches," or "Come over, dogs," every hound of each individual sex comes forward, as the sex it belongs to may be called for, leaving those of the other sex in their places. Then the act of drawing them to the feeding-troughs is an exceedingly interesting sight—often, with the door wide open, having nothing to do but to call each hound by his name, which of course he answers readily to. The expression of countenance, too, at this time is well worthy of notice; and that of earnest solicitation, of intreaty, we might almost say of importunity, cannot be more forcibly displayed than in the face of a hungry hound awaiting his turn to draw. He appears absolutely to watch the lips of the huntsman, anticipating his own name.'

Health—Disease.

All dogs whatsoever, but those designed for field-sports in particular, require to be kept in what is called 'condition;' that is, neither too fat nor too lean, but the body in that hardy and active state that will enable the animal to perform its duties. If loaded with flesh or fat, it will not possess wind, or a due power of quick breathing, for any length of time in the chase. Colonel Cook observes, on what constitutes a proper condition—'The ribs should be visible, and the flank moderately hollow, but the loins must be well filled up in a dog in perfect condition. When dogs exhibit general fulness and too much flesh, commence by physic and a regular course of exercise, which should be mild at first, but increased until it is severe. Avoid too great a privation of food, otherwise the conditioning process will be retarded.'

To keep a dog in a state of good health, he must not only be regularly fed and admitted freely to water, but be allowed plenty exercise daily in the open air, and kept in a cleanly condition. If his bowels appear relaxed, he is not in sound health; and as a preventive of this, let his food, as already said, be substantial, and consist partly of bones; let him also have access to grass; every proper kennel has a grass-yard to which the dogs can resort. In the pan of water used by house-dogs put a piece of brimstone; it slightly affects the water by lying in it, and helps to keep the animals cool.

All dogs are liable to be troubled with fleas, which they get from the ground; the skin also contracts dirt, and from that or other causes becomes offensive in smell. The remedy is cleanliness. Every lap or house-dog should be washed at least once a week with soap and water. Some dogs have a great dislike to washing, but it must nevertheless be performed. After washing thoroughly, rub the animal dry with a hard cloth, and comb and brush it. If there be fleas, a small-toothed comb will remove them, and they should be killed as they appear. Wash and dry delicate dogs before the fire.

On the subject of physicking as a preventive of disease, or when there are symptoms of diseased skin, a little sulphur and antimony is recommended, mixed with the meat, or done up as a bolus or pill, and in this latter form pushed over the throat. 'Once a week or fortnight,' says Daniel, 'during the hunting season, hounds should have one pound of sulphur given them in their meat; and when the season is over, half a pound of antimony should be added to the sulphur, and well mixed with the meat. This cools, and is doubtless of service to them.'

The *Mange* is a cutaneous disease in dogs, very closely resembling itch in the human species, but more inveterate, and is hereditary as well as contagious. Mr Blaine, in his 'Encyclopedia of Rural Sports,' thus speaks of this nauseous complaint:—'Of all the causes which beget mange, and they are not few, the acrid effluvium from their own secretions is the most common; when it is generated by numbers, particularly when it is confined within a limited space, it is sure to appear. Close confinement of any dog will commonly produce it, and most certainly so if it be at the same time fed on salt provisions; thus there are few dogs on shipboard that do not contract it, except such as are allowed full liberty of the deck. Food too nutritive in quality, and too considerable in quantity, is productive of mange; and, on the contrary, food in a great measure withheld, or being very poor in quality, is equally a parent of the disease.' The same authority gives several receipts of medicine to be employed; the leading are—powdered sulphur, four ounces; muriate of ammonia (sal-ammoniac) powdered, half an ounce: aloes powdered, one drachm; Venice turpentine, half an ounce; lard or other fatty matter, six ounces: the whole to be mixed and administered in boluses. In all bad cases, however, we should recommend no one to attempt doctoring his dog, but to apply to a regular practitioner.

Distemper.—This disease is most common among dogs which are much kept in the house and subjected to artificial treatment. The disorder is epidemical, affects the constitution, and is very difficult of removal. W. H. Scott, in his work on 'British Field-Sports,' thus describes the symptoms of distemper in a young dog:—'Sudden loss of usual spirit, activity, and appetite; drowsiness, dulness of the eyes, and lying at length with the nose to the ground; coldness of the extremities, ears, and legs, and heat of the head and body; sudden emaciation, and excessive weakness, particularly in the hinder quarters, which begin to sink and drag after the animal; an apparent tendency to evacuate from the bowels, a little at a time; sometimes vomiting; eyes and nose often, but not always, affected with a catarrhal discharge. In an advanced stage of the distemper, such symptoms will occur as spasmodic and convulsive twitchings, the nervous and muscular systems being materially affected; giddiness and turning round, foaming at the mouth, and fits. The disease is then often taken for incipient madness, into which it might not improbably degenerate.' The same authority adds—'I have found daily mild doses of from two to three grains of calomel alone, lapped by the animal in milk, continued for four or five days, with intermissions when necessary, fully sufficient to carry it safely through the disease, even when the fever has been very high. James's powder has, however, always proved the most certain remedy.' To aid recovery, nourishing diet should be given. In cases of severity consult the veterinary surgeon.

Canine madness, rabies, or hydrophobia, is the most fatal malady to which dogs are subject, and for which, as far as we have heard, there is no certain cure. Blaine considers that rabies is never produced spontaneously in dogs or any other animals, but is invariably the effect of inoculation by a bite from a dog already mad. But as the disease must have commenced spontaneously in some dog at first, we do not understand why it may not do so again; in short, the doctrine, in the exclusive form in which it is put, seems untenable. Rabies is little known in hot or cold countries; it is common chiefly in temperate regions, but shows itself principally in summer, when it may be supposed to be excited by a feverish condition of body.

The leading symptom of the rabid state is an apparent discomfort and unsettledness of purpose, with a desire to gnaw and eat anything within reach, as straw, wood, coal, or any other rubbish; as the disease advances, the animal snaps and bites at everybody, or any animal near it. This is, however, no effect of bad temper; the dog has no wish to go out of his way to bite; he is under the influence of a derangement which makes him catch only at what is near. Like the unnatural appetite he possesses, the snapping propensity may also partly arise from the irritated state of the stomach and intestines, both of which are greatly inflamed. The throat is likewise livid; and by a constriction of parts, soon prevents the animal from swallowing. That the rabid dog has a terror of water (hence the origin of the name *hydrophobia*) is now beginning to be doubted; and at all events it is not an invariable symptom, for mad dogs have been known to lap water the day before their death. In the later stages of the disease paralysis comes, and from the fourth to the seventh day the dog expires. It is humanity to shoot the animal before this final catastrophe.

With respect to the production of rabies in the human species, there have latterly been some very grave doubts. An idea has been started, and supported with considerable plausibility of argument by certain medical practitioners, that hydrophobia in the human being is merely a nervous affection, very much, if not almost altogether, arising from the influence of the imagination; the person bit fancies he is going mad, and mad he becomes. It is very desirable that the medical world should investigate and arrive at some determinate conclusion respecting this remarkable doctrine; meanwhile, till the matter is settled one way or other, we must speak of rabies in the human subject as a real disease, against which every reasonable precaution should be adopted. On being bit, it is always safe to wash the wound immediately, and have the parts burnt with a hot iron, or cut out. In every case let a skilled surgeon be immediately consulted—one who will not hesitate to act with promptitude and decision.

Many cures have been mentioned for the bite of a mad dog. We shall notice a few. The following, according to Blaine, is the famous Herefordshire cure, commonly called *Webb's drink*:—'Take the fresh leaves of the box-tree, two ounces; of the fresh leaves of rue, two ounces; of sage, half an ounce; chop these finely, and after boiling them in a pint of water to half a pint, strain and press out the liquor; beat them in a mortar, or otherwise bruise them thoroughly, and boil them again in a pint of new milk, until the quantity decreases to half a pint, which press out as before. After this mix both the boiled liquors, which will make three doses for a human subject. Double this quantity will form three doses for a horse or cow; two-thirds of it is sufficient for a large dog, calf, sheep, or hog; half the quantity is required for a middle-sized dog; and one-third for a smaller one. These three doses are said to be sufficient; and one of them is directed to be given every morning fasting.' Blaine has not much confidence in this remedy, but allows it is worth trying. Mr Murray, known as a lecturer on chemistry, mentions, in a letter to a newspaper, the following remedy:—'Let a mixture of two parts of nitric and one part of muriatic acid, both by measure (evolving chlorine in a concentrated form) be applied to the wound as soon as possible, and more than once.' He adds that he has found this a preventive. M. Buisson, a Parisian physician, declares that madness from the bite of a rabid dog may be thoroughly cured by fumigating the patient in a hot vapour bath, and afterwards keeping up the copious perspiration in bed; this he recommends to be done for several successive nights.*

FIELD-SPORTS.

Conducted on principles of moderation, humanity, and fair-play, the sports of the field may be said to be those exhilarating and healthful pursuits by which the tribes of wild animals are made subservient to man's use, or removed from a sphere in which they are inconvenient and unsuitable. In taking amusement from such sports, it is the glory of the true English gentleman to avoid every proceeding which can give unnecessary pain to the animals over which he claims dominion, and to discountenance by every means in his power such odious abuses of sport as baiting, worrying at the stake, or any other method of protracting the death of the creatures who have the misfortune to be objects of the chase. Our limited space will permit us to notice only the leading field-sports of Britain in past and present times.

FALCONRY.

Falconry was the favourite field-sport of the middle ages, as shooting with the gun is the predominant one of the present day. It appears, in this country, to have declined and gone out of use in the seventeenth century, in consequence of the gun having then become, by the addition of the lock and flint, a much more ready means of bringing down game than the use of hawks had ever been. Falconry, while it existed, was the peculiar sport of kings, and princes, and nobles, many of whom were painted in life with their hawks seated on their wrist, and were sculptured on their tombs after death with the same creature placed at their feet; thus marking the special regard in which they held the animal which was the means of giving them so much amusement.

The sport, we need scarcely remark, was founded on the natural instinct of the rapacious order of the feathered creation, as the chase may be said to be founded on the instinct of the dog to pursue the hare, fox, and other animals. The rapacious order of birds—of which the eagle, falcon, and owl are the three principal types—are formed in such a way as evidently fits them for pursuing, seizing, and destroying the smaller birds; a part in creation which at first sight appears to involve much cruelty, but which has been clearly shown to be intended to save rather than to produce pain, and to be indispensable to a system of things in which one leading feature is, that there shall always be as many living creatures as can possibly be supported. The falcon family were alone employed for purposes of sport, as alone possessing the required docility; and of this family two or three species were more frequently used than any other. Of those possessing long wings, the falcon proper and the ger-falcon; and of the short-winged, the goshawk and sparrow-hawk, seem to have been the favourite kinds. Species called the hobby, the kestral, the merlin, and buzzard, were the next in request. The female, which is in all the varieties of this tribe considerably larger than the male, was alone employed in sport, and the common names of all the species apply to that sex, the male having usually some distinctive appellation: thus the male of the ger-falcon was called the *jerkin*; of the falcon proper, the *tierce gentle*; of the goshawk, the *tiercel*; and of the sparrow-hawk, the *musket*.

These birds naturally choose retired habitations. The falcon, in particular, builds her nest amongst cliffs in wild and unpeopled regions. In order to fit birds

* See an account of Buisson's proceedings in 'Chambers's Edinburgh Journal,' No. 257, old series.

for the sport of *falconry*, it was necessary to take them from the nest at a very early stage of their existence (then technically called *eyasses*), or to ensnare them in their more mature age, and then train them for the purpose. A falcon in its natural state was said to be a *haggard*; hence, apparently, the term by which we still express a wild or agitated aspect. The first step in training the falcon was to *man* it, or accustom it to the presence of human beings. Feeding was the grand source of the power which its keeper acquired over it. When it did as required, it was fed, and thus taught to know that it had done right, and not otherwise. If extremely refractory, a stream of cold water was directed at its head, as an admonition that nothing was to be gained by such conduct. From the very first, the animal was accoutred with certain paraphernalia, the names of which at least must be familiar to most readers. First, its head was covered by a leathern *hood*, fitting close all round, so as to shut up its eyes, and calculated, by a slit behind, to be readily slipped on and off. On the top of the hood there was a tuft of feathers, which usually has a graceful effect in the old pictures representing ladies or gentlemen travelling with their hawks upon their wrist. Leathern straps, called *jesses*, a few inches in length, were fitted to the legs of the bird by a button slipping through a slit or loop. Close beside the end attached to each leg was a small spherical *bell*, like that of a child's rattle, and composed of silver, for clearness of sound, the one being in some nice instances made a semitone higher than the other. The other ends of the jesses were furnished each with a ring, which could be readily fitted upon the swivel designed to connect them both with the *leash*, a long slender strap, sometimes prolonged by a *creance*, or common cord, and designed as a tether by which to restrain the animal, at the same time that it should be allowed considerable room for free motion. Two great objects in training were to teach the bird to fly at its proper game, and to habituate it to come back to the hand of its master, after on any occasion having been let free in pursuit of its prey. For the first of these ends, in the case of long-winged birds, an implement termed the *lure* was used. It consisted either of a stick or of a cord, on the end of which were fixed pieces of flesh, with a bunch of the feathers of the prey which it was designed that the bird should fly at, or perhaps an actual resemblance of the prey in its entire form. The falcon being set loose by one man, another stood at a distance waving the lure around his head, thus tempting the animal to advance and strike at it. A whistle was the implement used to *reclaim* or bring back the hawk. When a hawk was to be kept on the hand, strong gloves were worn for protection from its talons. It may here be remarked that the training of falcons was altogether a most laborious business, and that trained birds were accordingly to be only purchased at a high price. At the beginning of the seventeenth century, a trained goshawk and tiercel brought one hundred marks, and it was considered a favour to part with them. The extreme labour attending the training of the animals must have been sufficient in early times to confine the sport to persons of birth and fortune, if there were no other cause; and it must also have conduced to the rapid decline and extinction of the sport, after a ready means of killing wild-fowl by the gun became attainable.

The sport, after being long given up, was revived in England some years ago by Colonel Thornton, the Duke of St Albans, and a few other gentlemen, chiefly through the influence of a taste for whatever is elegant and romantic in the usages of our forefathers. It is said to be a gallant and goodly sight, when a train of well-mounted English ladies and gentlemen rides forth on a clear sunshiny day to pursue this sport, attended by their falconers, each with his hawk on his wrist. In the present day, as of yore, various kinds of feathered game are flown at. Heron-hawking is, we believe, in greatest esteem. The heron, as must be generally known, is a large bird in appearance, with a long neck, long legs, and a long sharp bill, being designed to haunt marshes and pools, and feed upon whatever fish it can find therein. It is, however, a light unsubstantial bird, with nothing to protect it from enemies but its sharp bill. Herons are gregarious, and the lonely places where they live are called heronries. These explanations will introduce the following account of heron-hawking, from Blaine's 'Encyclopædia of Rural Sports:'—

'The daily visitations of the heron to its feeding-places are watched by the falconers, who station themselves to the leeward or down wind of the heronry, so that the heron, on its return, must fly against the breeze, which gives a great advantage to its enemy. As soon as one is discovered on the return, a cast of falcons is let loose, who, catching sight of the quarry, rise in pursuit. The heron, instinctively aware that its life is at stake, prepares for the fray by disgorging the contents of its stomach to lighten the weight of the body. The coursing falcons ascend the airy vault in spiral gyrations, by which the atmospheric resistance to their flight is lessened. These circlings, it has been observed, have frequently the curious effect of presenting the three birds as flying in different directions; whereas the real intentions of the two hawks are steadily directed to one point, which is that of contact with the heron, whose entire efforts are as steadily engaged in avoiding it. To effect this, the affrighted heron strenuously endeavours to rise above the hawks, who, however, by the superior power of wing, commonly succeed in getting the upper station, from which one presently makes its stoop; and happy it is for the poor heron if he can evade the blow, which he occasionally does, either by shifting his station, or by receiving the falcon on his sharp bill, which instantly transfixes it. This danger is, however, denied on authority, but we feel assured that it does occur. The second hawk, if the first fails, stoops in his turn; but the meditated blow of this also is frequently evaded like the former. The trio then still rising higher and higher, the sight becomes interesting in the extreme, and the spectators are scarcely less agitated than the feathered warriors above. At length another stoop takes place, and the fatal seizure is made by one hawk, while the other *binds* to his fellow, and all three quickly descend together, but not with a dangerous rapidity, as their powers of inflation and the action of their wings break the fall. It is now that the mounted horsemen make the best of their way to the assistance of their falcons, and their first efforts must be directed to secure the head of the heron, that the sharp beak may not take effect on one or both of them.'

Pheasants are objects of this sport, but not to a great extent, on account of the inconvenience presented by the sylvan ground in which the sport must be practised. Partridge-hawking is found to be a more convenient sport. To quote the same authority—'The scene of practice is commonly on large fields or open tracts of country, where the horsemen and company generally can beat in line, and the attendant falconer or master, being well-mounted, can ride forward, and be ready to receive the quarry. Either pointers or spaniels are necessary, or both. The partridge being flushed, the hawk will stoop with astonishing rapidity, and seize on it; at which time neither horses, dogs, nor company should press forward; on the contrary, they should permit the falconer only to advance, who, approaching the hawk with caution, must walk quietly round her, when, gently kneeling down with his arm extended, as though in the act of feeding the hawk, he should lay hold of the partridge, and at the same time place the hawk on his fist. This done, restore the hood, and reward the hawk with the head of the quarry; and if she be not intended to be flown again, let her be fed immediately.

A somewhat different method of partridge-hawking is practised in the latter part of the season, when the country is very bare, and when the partridges are often very wild, and lie indifferently even to the dog. In such cases it is recommended that the company "draw up in line at fifty or sixty yards' distance from each other, and gallop across the plain with a hawk upon wing," the falconer being in the centre of the line, that he may regulate the pace by the situation of the hawk. Sir John Sebright informs us that this method of partridge-hawking has afforded him more sport than any other, and that when the face of the country was so bare, and the birds so wild, as to make it impossible to approach them in the usual way.

Brook-hawking, as it is often termed, was much in vogue formerly. The practice was not, however, confined to brooks, but extended to rivers, sea-shores, moors, and ponds. It engaged, according to Blome, "the jer-falcon, the haggard-falcon, the jerkin, and the tassel gentle." Waterfowl of every description were made prey of; but some particular objects, according with the training of the falcons, were particularly sought for. Dogs were employed to rouse the fowl, being led on by men who traversed the water's edge; while horsemen, with the hawks on their fists, were at hand to *cast off* one or more, according to the nature of the game. A heron or mallard would require two, while a widgeon or a teal (being small) would probably engage only one.'

DEER-HUNTING.

Deer-hunting was another principal amusement of past times, but has now been abandoned in the form in which it used to be conducted. The species of animals chiefly hunted in England was the fallow-deer, a beautiful creature with stately horns and antlers, and of great speed in running. Fallow-deer are now closed up in parks, at least in Britain. The stag, red deer, or hart, whose female is called the hind, differs in size and in horns from the fallow-deer. He is much larger, and his horns are round, whereas in the fallow species they are broad and palmated. Red deer are now, we believe, the only objects of field-sport in this country, and principally in the Highlands of Scotland, where they still exist in considerable numbers. Hounds, however, as in the chase in former ages, are now seldom or never employed—the hunter depending on his gun and his skill in approaching the animal noiselessly. This, which is called *deer-stalking*, is a sport requiring a vast deal of tact, knowledge of the animal's habits, and patience, as whole days are occasionally taken up in stealthily watching an opportunity for a shot. Such is the power of sight, scent, and hearing, that to approach unperceived on a plain is impossible. They must be approached down the wind, and from behind thickets or hillocks. A telescope is required in these difficult manœuvres. When it is impracticable to reach them in this artful manner, attendants drive them into gorges among the mountains, and the sportsman singles out an object for his gun as it passes his concealed station. A lively work on deer-stalking has lately been written by Mr Scrope, to which we beg to refer those who are interested in the subject; and some very graphic pictures may also be found in Mr St John's attractive volume on 'The Wild Sports and Natural History of the Highlands.'

FOX-HUNTING.

The variety of fox most common in Britain is called the *cur fox*, which is of a brown colour, with generally some white on the breast and belly, and a light tip to the long bushy tail. Foxes go to *clicket* in winter, and cubs are produced in the latter end of March; they breed but once a year, and have from three to six young ones at a time. In his nature the fox is playful, but rapacious in his appetite, and his predominating characteristic is great craftiness. He usually fixes his abode on the border of a wood, at no great distance from a farmhouse or village; he listens to the crowing of the cocks and the cries of the poultry; he scents them, and chooses the time of his attack with judgment; he conceals his road as well as his design; he slips forward with caution, sometimes even trailing his body, and seldom makes a fruitless expedition. He plans similar encroachments on the nests of birds, rabbit warrens, &c.; and, in a word, is so destructive to poultry, game, and even young lambs, that it is absolutely necessary to take and kill him.

Fox-hunting on a proper scale requires to be conducted with the class of active horses termed hunters, a pack of foxhounds to scent and run down the prey, and terriers to turn the animal from his hole, should he take to earth. A pack of hounds varies from twenty to thirty couples; but besides these, some hounds are always left undrafted into the field. The cost of a well-bred pack is reckoned at from £1000 to £1200, and the annual expense of its keep and management about as much. The huntsman, as the grand leader of the chase, is a functionary of no small importance; he is assisted by two whippers-in, who bring up and take charge of the hounds.

The fox being an early riser, and his scent lying best on the damp grass, he is hunted in early morning; and the first business on taking the field is to ride to and draw cover—that is, bring out the fox from his retreat. At the first sight, the view halloo is given by the huntsman, and all follow the sweeping track of the hounds. It is a rule in hunting never to get before the dogs, or to throw them out any way by a false signal; on the contrary, the great art is to keep them to the scent, and to aid their search. The run is considered the exhilarating part of the sport, and consists of a rapid chase through a broken or rough country, with the hounds in full cry. Then is the ardour of the chase shown; and it continues till the fox, by some clever manœuvre—such as tracking up a brook—throws the hounds off the scent, and the party is brought to check. The scent and track of the animal being again found, off all go once more in pursuit, but with generally frequent doubts of the result. 'See,' says Beckford, in his enthusiastic style, 'where the hounds bend towards yonder furze brake! I wish he may have stopped there. Mind that old hound; how he dashes o'er the furze! I think he winds him! Hark! they halloo! Ay, there he goes! It is nearly over with him! Had the hounds caught view he must have died!' He will hardly reach the cover. See how they gain upon him at every stroke! It is an admirable race; yet the cover saves him. Now be quiet, and he cannot escape us; we have the wind of the hounds, and cannot be better placed. How short he runs! He is now in the strongest part of the cover! What a crash! Every hound is in, and every hound is running for him! That was a quick turn! Again, another! He's put to his last shifts! Now mischief is at his heels, and death is not far off! Ha! they stop all at once; all silent, and yet no earth is open! Listen! Now they are at him again! Did you hear that hound catch him!—they overran the scent, and the fox had lain down behind him. Now, Reynard, look to yourself! How quick they all give their tongues! The terriers, too, are now yelping at him. How close *Vengeance* pursues!—how terribly she presses!—it is just up with him! What a crash they make; the whole wood resounds! That turn was very short! There!—now!—ay, now they have him! Who-hoop!' The chase is over: Reynard is no more; and his *brush* or tail being cut off as a trophy by the huntsman, his unfortunate carcass is thrown to the hounds, and in a few moments destroyed, leaving scarcely a wreck behind.

HARE-HUNTING—COURSING.

Hares are hunted in much the same manner as foxes, the chief difference being, that harriers are employed instead of hounds: both hunt by the scent. Of this branch of field-sports, the writer of the excellent article on *Hunting*, in the 'Encyclopædia Britannica,' makes the following mention:—

'Hare-hunting claims precedence of fox-hunting in the sporting chronology of Great Britain, and we believe of all other countries, inasmuch as a hare has always been esteemed excellent eating, and a fox the rankest of carrion. We gather from Xenophon that it was practised before his day, and he wrote fully three centuries before the Christian era, both hounds and nets being then used in the pursuit. Neither can we marvel at hare-hunting being the favourite diversion in all nations given to sporting, where the use of the horse in the field had not become common. But we will go a point farther than this, and assert, that how inferior soever may be the estimation in which hunting the hare is held in comparison with hunting the fox, no animal of the chase affords so much true hunting as she does, which was the opinion of the renowned Mr Beckford.

The difficulty of finding a hare by the eye is well known. It is an art greatly facilitated by experience, although not one person in ten who attempts it succeeds. But here we recognise the hand that furnished her with such means for her security; as, from the delicacy of her flesh, she is the prey of every carnivorous animal, and her means of defence are confined only to flight. In going to her form she consults the weather, especially the wind, lying always, when she can, with her head to face it. After harvest, hares are found in all situations; in stubble fields, hedgerows, woods, and brakes: but when the leaves fall, they prefer lying upon open ground, and particularly on a stale fallow; that is, one which has been some time ploughed; as likewise after frost, and towards the spring of the year. In furze or gorse, they lie so close, as to allow themselves nearly to be trodden upon, rather than quit their form. The down or uplandbred hare shows best sport; that bred in a wet marshy district the worst, although the scent from the latter may be the strongest. If a hare, when not viewed away, runs slowly at first, it is generally a sign that she is an old one, and likely to afford sport; but hares never run so well as when they do not know where they are. Thus trapped hares, turned out before hounds, almost invariably run straight on end, and generally till they can run no longer; and they generally go straight in a fog. The chase of the hare has been altered, and rendered less difficult in some degree by the improvement of the hound used in it.

The difference in the terms used in hare-hunting and fox-hunting is comprised in a few words:—Harriers are cast off in the morning; foxhounds throw off: the hare is found by the quest or trail; the fox by the drag: the hare is on her form or seat; the fox in his kennel: the young hare is a leveret; a fox a year old is a cub: the view hollo of the hare is "Gone away;" of a fox "Tallyho:" the hare doubles in chase; the fox heads back, or is headed: the harrier is at fault; the foxhound at check: the hare is pricked by the foot; the fox is balled or padded: the hare squats; the fox lies down, stops, or hangs in cover: the "who-whoop" signifies the death of each.'

Hares are hunted with packs of generally twenty couples of harriers; but whatever number is employed, it is the established rule not to run in upon the hares as soon as discovered in their forms, but to allow them a little space before the dogs are set on. The hares also must not be pressed upon in the chase by the company; neither are the dogs, in losing scent, to be called on the right path; for this leads them to depend on the sight of the huntsman instead of their own nose. Leave the harriers pretty much to themselves.

Coursing is the chasing and taking of the hare by means of greyhounds, which hunt by the sight only. Among fox-hunters it is considered an inferior kind of sport, but many country gentlemen find in it an exhilarating recreation, and it is patronised by numerous coursing clubs. 'There is,' says Blaine, 'even a philanthropic character about coursing almost unknown to other huntings. It may be said to offer a kind of refuge for the sporting destitute, for it holds out innocent recreation to those whose means or whose prudence will not allow them to risk either their neck after a fox, or their wealth after a racer. Here the octogenarian, at once labouring under his increased years and his decreased energies, may solace himself with an epitome of former huntings; and farther, that the joys of this chase are within the reach of every state or stage of life.'

The greyhound, whose form so eminently adapts him for competing with the hare in a race, requires to be well trained in the art of turning suddenly, and determinedly pursuing his game on a new line of pursuit. His eye should be clear and quick, and his wind good, to enable him to hold out to the last. Greyhounds are delicate in their nature, and require very careful treatment; their lodging must be dry and comfortable; and when taken out in a cold morning, they must be held in leash, with jackets on, ready to let slip. In any case, they are not uncoupled or let go till the hare has been seen and started. A single pair of dogs is generally sufficient for the sport; and betting often ensues as to the *points* in the course. There are numerous rules of ancient and modern date on the subject of coursing. The following, established by the Duke of Norfolk in Queen Elizabeth's reign, are yet held applicable:—

'The feuterer, or person who lets loose the greyhounds, was to receive those that were matched to run together into his leash, as soon as he came into the field, and to follow next to the hare finder, or him that was to start the hare, until he came to the form, and no horse or footmen were to go before, or on either side, but directly behind, for the space of about forty yards.

A hare was not to be coursed with more than a brace of greyhounds.

The hare finder was to give the hare three "sohos" before he put her from her form, to give notice to the dogs that they may attend her starting.

The hare was to have twelve score yards law before the dogs were loosed, unless the small distance from the cover would not admit it without danger of immediately losing her.

The dog that gave the first turn, and during the course, if there was neither cote, slip, nor wrench, won.

A cote is when the greyhound goes endways by his fellow, and gives the hare a turn.

A cote served for two terms, and two trippings or jerkins for a cote; if the hare did not turn quite about, she only wrenched; and two wrenches stand for a turn.

If there were no cotes given between a brace of greyhounds, but that one of them served the other at turning, then he that gave the hare most turns won; and if one gave as many turns as the other, then he that bore the hare won. A "go-by," or bearing the hare, was equivalent to two turns.

If neither dog turns the hare, he that led last to the cover won. If one dog turned the hare, served himself, and turned her again, it was as much as a cote, for a cote was esteemed two turns.

If all the course were equal, the dog that bore the hare won; if the hare was not borne, the cause was adjudged dead. If a dog fell in a course, and yet performed his part, he might challenge the advantage of a turn more than he gave.

If a dog turned the hare, served himself, and gave divers cotes, and yet in the end stood still in the field, the other dog, if he ran home to the cover, although he gave no turn, was adjudged the winner.

If by accident a dog was run over in his course, the course was void, and he that did the mischief was to make reparation for the damage. If a dog gave the first and last turn, and there was no other advantage betwixt them, he that gave the odd turn won.

He that came in first at the death, took up the hare, saved her from being torn, cherished the dogs, and cleansed their mouths from the wool, was adjudged to have the hare for his trouble.

Those that were judges of the course were to give their decision before they departed out of the field.'

SHOOTING—GROUSE—PARTRIDGES, &c.

The leading sports with dog and gun are the shooting of grouse, partridges, and pheasants, which differ in some respects from each other. The first thing to be attended to in either case is having a good fowling-piece or gun; and the second is, to know how to use and clean it. Next, the sportsman must be provided with a dog trained to point the kind of game for which he is taken to the field: to take a dog accustomed to point partridges on a grouse-shooting excursion would be improper. The gunpowder employed should be kept very dry in a metal flask, and of proper strength and purity. Patent shot is now commonly used; it is of eight sorts, each numbered, and rises from 83 pellets to 620 pellets in the ounce. The more tender the birds, the smaller may be the pellets or drops. For grouse, shooters begin with No. 7, or 400 to the ounce; ducks require shot No. 4, or 105 to the ounce.

The following hints to a beginner in shooting are by Hawker and others:—'In raising the gun, let him remember that the moment it is brought up to the centre of the object the trigger should be pulled, as the first sight is always unquestionably the best. Then send him out to practise at a card with powder till he has got steady; and afterwards load his gun occasionally with shot, but never let the time of your making this addition be known to him; and the idea of it being perhaps impossible to strike his object will remove all anxiety, and he will soon become perfectly firm and collected.

The intermediate lesson of a few shots at small birds may be given; but this plan throughout must be adopted at game, and continued, in the first instance, till the pupil has quite divested himself of all tremor at the springing of a covey, and observed in the last, till most of his charges of shot have proved fatal to the birds. If he begins with both eyes open he will save himself the trouble of learning to shoot so afterwards. An aim thus, from the right shoulder, comes to the same point as one taken with the left eye shut, and it is the most ready method of shooting quick. Be careful to remind him (as a beginner) to keep his gun moving, as follows:—before an object, crossing; full high for a bird rising up or flying away very low; and between the ears of hares and rabbits running straight away. All this of course in proportion to the distance; and if we consider the velocity with which a bird flies, we shall rarely err by firing, when at forty yards, at least five or six inches before it. Till the pupil is *au fait* in all this he will find great assistance from the sight, which he should have precisely on the intended point when he fires. He will thus, by degrees, attain the art of killing his game in good style, which is to fix his eyes on the object, and fire the moment he has brought up the gun. He may then ultimately acquire the knack of killing snap shots, and bring down a November bird the moment it tops the stubble, or a rabbit popping into a furze-brake, with more certainty than he once used to shoot a young grouse in August or a partridge in September.

Many begin with very quick shooting, and kill admirably well, but are often apt not to let their birds fly before they put up their gun, and therefore dreadfully mangle them; and, I have already observed, are not such every-day shots as those who attain their rapid execution on a slow and good principle.

If a rival shooter (some stranger) races to get before you, push him hard for a long time, always letting him have rather the advantage, and then give him the double without his seeing you. Having done this, go quietly round (supposing you have been beating up wind); and on reaching the place where you began, work closely and steadily the whole of the ground or covert that you have both been racing over, and you will be sure to kill more game than he will, who is beating and shooting in haste, through fear of your getting up to him, and (if the wind should rise) driving the dispersed, and consequently closest-lying birds, to your beat as fast as he finds them.

Beware of the muzzle of the gun being kept hanging downwards; when so carried, the shot is apt to force its way from the powder, especially in clean barrels. If it happens that a space of sixteen or eighteen inches is thus obtained, and the gun fired with its point below the horizon, it is ten to one but the barrel bursts. There are other perilous consequences besides those that generally accompany the disruption of a barrel; for the men, horses, and dogs, are in perpetual danger of being shot when a gun is carried in the before-mentioned pendent manner.

When a gun begins to exhibit symptoms of having done its work, the sooner a man discards it the better. An injured barrel or enfeebled lock may prove fatal to the owner or his associates. Accidents occur every day, and very lamentable consequences proceed, from a culpable neglect in retaining arms which should be declared unserviceable and disused.'

Grouse Shooting.—This favourite field-sport, as is well known, commences annually on the 12th of August, when thousands of persons adjourn to remote parts of the country to follow it, with all its toils and privations. Among the varieties of this game are numbered the cock of the wood or capercailzie; the black cock, heath-cock, black game, or black grouse; the red grouse, moor-fowl, or gorcock; and the white grouse or ptarmigan. Moor-fowl are the most common, and seem to be peculiar to Britain. They are very plentiful in the Highlands of Scotland, and by no means scarce in any of the wild, heathy, and mountainous tracts in the northern counties of England and Wales. Red grouse pair early in spring, and lay from six to ten eggs; the young brood follow the hen during the whole summer; and in winter they unite in flocks of forty or fifty. They are never seen in the valleys, but always keep on the summits of the hills, where they feed on mountain berries and the like; and are exceedingly shy and wild. Being generally hatched in April, if the summer has been dry, the young birds will be pretty strong on the wing and ready for the sportsman on the legal 12th of August.

The best weather for shooting is that which is dry, clear, and warm; wet makes them lie still on the ground. No one must attempt grouse shooting who is of delicate health, or not well trained by previous feeding and exercise. The labour of walking over heather is most toilsome, and the danger of colds from rain or wet feet considerable. The dress ought to be very strong, without any regard to fineness; stout shoes or quarter-boots are indispensable.

The times of day best suited for grouse shooting are the morning and evening, when the birds are in quest of food; but few are able to reach their haunts till eight o'clock, when the sport commences. 'To find the birds,' says the author of Wild Sports of the West, 'when, satisfied with food, they leave the moor to bask in some favourite haunt, requires both patience and experience; and here the mountain-bred sportsman proves his superiority over the less practised shooter. The packs then lie closely, and occupy a small surface on some sunny brow or sheltered hollow. The best nosed dogs will pass within a few yards and not acknowledge them; and patient hunting, with every advantage of the wind, must be employed to enable the sportsman to find grouse at this dull hour. But if close and judicious hunting be necessary, the places to be beaten are comparatively few, and the sportsman's eye readily detects the spot where the pack is sure to be discovered. He leaves the open feeding-grounds for heathery knowes and sheltered valleys; and while the uninitiated wearies his dogs in vain over the hill-side, where the birds, hours before, might have been expected, the older sportsman profits by his experience, and seldom fails in discovering the dell or hillock where, in fancied security, the indolent pack is reposing.'

Our most practical authority on this exciting topic is the Oakleigh Shooting Guide:—'Grouse shooters should separate and range singly; they should have no noisy attendants. In wet weather one dog is sufficient; we advise rest from eleven till two. The flight of grouse is generally about half a mile. Their favourite haunts, when undisturbed, are those patches of ground where the young heather is most luxuriant. They avoid rocks and bare places where the heather has been recently burnt; at anyrate they are not to be approached in such localities. It is in young heather that grouse most frequently feed. They are seldom found in the very long thick heather that clothes some part of the hills, until driven there for shelter by shooters or others. It is early in the morning and towards evening that grouse are to be found in young heather. During the middle of the day the shooter should range the sunny side of the hill, and avoid plains.

No species of shooting requires the aid of good dogs more than grouse shooting, and in no sport does so much annoyance result from the use of bad ones. The best dog perhaps for the moors is a well-bred pointer, not more than five years old, which has been well tutored—young in years, but a veteran in experience. The setter is occasionally used with success, but we prefer the pointer. The latter has unquestionably the advantage when the moors are dry, as it not unfrequently happens that they are in August. If a setter cannot find water wherein to wet his feet every half-hour, he will not be able to undergo much fatigue. Some sportsmen will hunt a couple of mute spaniels for grouse shooting in preference to any other team of dogs. Of course when this method is pursued the birds are never pointed, and the shooter must ever be on the look-out, for the game is generally sprung very near to the gun.' Grouse shooting, we may add, legally terminates on the 9th of December.

Partridge Shooting.—Of partridges there are two kinds, the red and gray, the latter being that which is common in this country; the plumage is of a brown and ash colour, elegantly mixed with black; the tail is short, and the figure more plump than handsome. Partridges pair about the third week of February, and sometimes, after being paired, if the weather be severe, they all gather together and form a covey, and are then said to pack. They begin to lay in six weeks after pairing. The female lays her eggs (from twelve to twenty) on the ground, scraping together a few bents and decayed leaves into any small hollow. The young birds begin to appear about the first ten days in June, and the earliest will take the wing towards the latter end of that month. In dry seasons they are most numerous. So many are the enemies of the partridge, that it is believed never more than a half of those produced come to perfection; and yet there is in general abundance for the sportsman during the shooting season. The affection of both parents for their young is very remarkable; they lead them out in quest of food, shelter them with their wings, and resort to many tricks to lead supposed enemies away from their broods. Corn-fields are the places which partridges most delight in, especially while the corn is growing; for that is a safe retreat where they remain undisturbed. They frequent the same fields after the corn is cut down, and there feed on the dropped grains, finding a sufficient shelter under cover of the stubble. When the winter comes on, and the stubble-fields are either trodden down or ploughed up, they then retire to the upland meadows, where they lodge in the high grass; they also sometimes resort to the low coppice-woods, especially if they are contiguous to corn-fields.

Partridge shooting commences, by law, on the 1st of September, when the birds are strong, and terminates on the 1st of February. In the course of September, the short flights of the coveys, in tolerably well-preserved grounds, afford abundance of sport. In more open districts of country, where there is a wider range, partridge shooting requires more skill, and the aid of a steady pointer or setter. In shooting either at a flight of grouse or covey of partridges, select a bird on the outside, and fire at it alone; it is only over-hasty or ill-taught sportsmen who let fly indiscriminately at the centre of a group of birds.

Pheasant Shooting.—Pheasants are a species of birds allied to domestic fowls, and partake of some of their habits; no birds of the game kind possess such elegant plumage, and few are so large. They breed on the ground, and, like partridges, are fond of nestling in clover; but their chief resort is shrubberies or secluded spots in plantations. The pheasant and its brood, if undisturbed, remain in the stubbles and hedgerows some time after corn harvest; if molested, they seek the woods, and only issue thence to feed in the stubbles at morning and evening. Besides corn, the birds will live on wild berries, or any seeds they can pick up. As the cold weather comes on they begin to fly up at sunset into trees, where they roost during the night.

'For shooting pheasants it often becomes necessary to start very early in the morning, as they are apt to lie during the day in high covert, where it is almost impossible to shoot them till the leaf has fallen from the trees. We can never be at a loss in knowing where to go for pheasants, as we have only to send some one the previous evening, for the last hour before sunset, to watch the different barley or oat stubbles of a woodland country, and on these will be regularly displayed the whole contents of the neighbouring coverts. It then remains to be chosen which woods are the best calculated to shoot in; and when we begin beating them, it must be remembered to draw the springs, so as to intercept the birds from the old wood. If the coverts are wet, the hedgerows will be an excellent beginning, provided we here also attend well to getting between the birds and their places of security. If pheasants, when feeding, are approached by a man, they generally run into covert; but if they see a dog, they are apt to fly up.

There are very few old sportsmen but are aware that this is by far the most sure method of killing pheasants, or any other game, where they are tolerably plentiful in covert; and although, to explore and beat several hundred acres of coppice, it becomes necessary to have a party with spaniels, yet on such expeditions we rarely hear of any one getting much game to his own share, except some sly old fellow, who has shirked from his companions to the end of the wood, where the pheasants, and particularly the cock birds, on hearing the approach of a rabble, are all running like a retreating army, and perhaps flying in his face faster than he can load and fire.'

It is necessary in pheasant shooting to use a short double-barrelled gun of wide bore, and large shot. Fire at not a greater distance than thirty yards, and only when the bird has risen clear of the bushes; aim is to be taken at the head; but if the pheasant is crossing your path, fire a little before the head, the rapid flight of the animal bringing it in contact with the shot. Towards November, this field-sport—which commences on the 2d of October, and terminates on the 1st of February—may be united with woodcock shooting.

GAME.

Though, according to law, wild animals are no one's property, yet only certain kinds may be killed without a license. Those protected from indiscriminate slaughter are called *game*, and are deer of every species, hares, partridges, grouse, pheasants, woodcocks, snipes, &c. The wild animals not reckoned game are rabbits, rats, mice, crows, rooks, pigeons, sparrows, all kinds of sea-birds, &c.; any one may kill and appropriate these, provided it be in a highway, the sea-shore, or any other public ground. Game cannot be legally taken or killed in any form without a license procured from the competent officer of the crown, and a permission from the proprietor of the ground on which the game happens to be. To shoot or hunt without a license is called *poaching*; to shoot or hunt with a license, but without a permission, renders the person liable to an action for *trespass*. These game-laws are relics of ancient laws instituted by the Anglo-Saxon and Norman sovereigns for protection of the royal forests; and though some of these provisions are useful, they are, generally speaking, a disgrace to the statute book, and ought to be simplified and amended. Of late, some slight modifications have been sanctioned by the legislature, but these are not of a kind to affect in any sensible degree either the spirit or bearing of the general question.

ANGLING.

ANGLING is the art of alluring and capturing fish by means of a rod, line, and baited hook—the bait being made to resemble some object on which the animals naturally prey. The art is so termed, according to some, because an angle, as it were, is formed by the apparatus when held over the surface of the water; while others trace it to the angular shape of the hook, as originally fashioned of wood or bone, such being still the form and materials employed by savage nations. Whatever the origin of the term, the practice of taking fish in this excusably crafty manner, either for profit or for amusement, is of great antiquity, as we may learn from the mention made of it by the prophet Isaiah: 'The fishers also shall mourn, and all they that cast angle in the brooks' (chap. xix. verse 8). As well as fishing with nets, the practice has continued through all ages to the present time, and in almost all countries. In the British islands, it has long formed a favourite pastime among every class of society, lay and clerical, and to all presents many features of attraction. 'It is,' to use the words of Mr Blaine, 'far from dangerous or expensive, but on the contrary is productive of interest and amusement without an extraordinary sacrifice. Its *apparent* simplicity lures many into the practice; and as a trifling success elates the tyro, and leads him on by its fascinations, so he pursues it, although he soon discovers that extreme nicety and precision, great patience, caution, and perseverance, are essential requisites to the attainment of proficiency in the art. Nevertheless, he still continues the pursuit; difficulty after difficulty is overcome; each succeeding year adds interest to the practice, which he continues with undiminished ardour to the latest period of his life. It is asserted, and we believe with truth, that there is not one among the field-sports that takes so permanent a hold on the passions as this. It is no less remarkable for the variety it offers, for it presents itself under many forms, some of which are suited to the taste of every age, of every rank, and every variety of character and habit. The sedentary, the thoughtful, and the advanced in life, may watch the float as it slowly moves with the stream, without disturbance to the train of thought, or without any fatiguing exercise to their person. The active and volatile may throw afar the leaded bait for the pike, or may engage in the graceful evolutions of the fly-rod. Its seductions, therefore, prove universal, and it owns votaries of every age and station.' As the sport is pursued on the banks of rivers or lakes, in the midst of purely natural scenery, and in weather which invites to out-of-door recreation, everything conspires to render it in a peculiar manner exhilarating and healthful, when indulged in with judicious moderation.

No kind of amusement has been the object of such frequent description as angling. Hundreds of treatises have been written descriptive of the sport in all its departments, and with reference to all varieties of fish and the waters to which they resort. Indeed several of our rivers are the subjects of illustrated monographs, detailing not only what is peculiar to the angling of their waters, but whatever in the way of anecdote, tradition, or history, seems likely to render the practice of the 'gentle craft' inviting and agreeable. The first writer of note on the subject, and who has been acknowledged the great father of the angle, was Isaac Walton (born at Stafford 1593, died 1683), who in the year 1653 gave to the world his 'Complete Angler,' a work afterwards enriched with additions by his friend Charles Cotton, and which till this day is esteemed not more for the correctness of its details than the singularly happy humour of its apologues, poetical pieces, and disquisitions. According to old Isaac, all recreations sink into insignificance in comparison with angling, which in almost every page he lauds for its moral qualities, and the health and happiness it is calculated to yield. 'Will you hear,' says he, on one occasion, 'the wish of an angler, and the commendation of his happy life, which he sings in verse:—

"Let me live harmlessly, and near the brink
Of Trent or Avon have a dwelling-place,
Where I may see my quill or cork down sink
With eager bite of perch, or bleak, or dace;
And on the world and my Creator think,
Whilst some men strive ill-gotten goods to 'mbrace,
And others spend their time in base excess
Of wine—or worse, in war and wantonness.

Let them that list these pastimes still pursue,
And on such pleasing fancies feed their fill,
So I the fields and meadows green may view,
And daily by fresh rivers walk at will,
Among the daisies and the violets blue,
Red hyacinth and yellow daffodil,
Purple narcissus, like the morning rays,
Pale gander-grass, and azure culver-keys.

I count it higher pleasure to behold
The stately compass of the lofty sky,
And in the midst thereof, like burning gold,
The flaming chariot of the world's great eye;
The watery clouds that in the air up-rolled,
With sundry kinds of painted colours fly;
And fair Aurora, lifting up her head,
Still blushing, rise from old Tithonus' bed.

The hills and mountains raised from the plains,
The plains extended level with the ground;
The grounds divided into sundry veins,
The veins enclosed with rivers running round;
Those rivers, making way through nature's chains,
With headlong course into the sea profound;
The raging sea, beneath the valleys low,
Where lakes, and rills, and rivulets do flow.

The lofty woods, the forests wide and long,
Adorned with leaves and branches fresh and green,
In whose cool bowers the birds, with many a song,
Do welcome with their choir the summer's queen;
The meadows fair, where Flora's gifts among
Are intermixed with verdant grass between;
The silver-scaled fish, that softly swim
Within the sweet brook's crystal watery stream:

All these, and many more of His creation
That made the heavens, the angler oft doth see;
Taking therein no little delectation,
To think how strange, how wonderful they be,
Framing thereof an inward contemplation
To set his heart from other fancies free;
And whilst he looks on these with joyful eye,
His mind is rapt above the starry sky."'

So much for the *poetry* of the art; we shall now speak of its practice, beginning with a few remarks on the

GENERAL CHARACTERISTICS OF FISH.

The fish which are the object of attention to the angler are all confined to fresh water, and are chiefly found in rivers or small brooks; some are found in lakes and ponds. All, except eels, have a pretty uniform character (more fully detailed under the head ZOOLOGY), though differing in appearance and size. Their form is suitable in a remarkable way to give celerity and ease of motion—a small head swelling into a thick body, and tapering off towards the tail. Those designed for slower motion are more thick and lumpy in figure. The power of moving quickly, and of buoying themselves in the water, is very nicely provided for by their specific gravity, which is nearly the same as the water in which they move; in other words, they are about the same heaviness as the water which they displace, and consequently they are almost destitute of any feeling of weight. On this account they are not in the slightest degree encumbered in their movements, and are difficult to tire in their exertions.

The tail is the grand instrument of motion; it is a thin delicate membrane, whose smallest bending to and fro impels the body forward in any required course. The fins are principally required for balancing and regulating the movements of the fish; if any be cut off, the animal loses the power of keeping itself with the back fairly upwards; should it be deprived of the tail, the ability of moving forward is gone, and it lies a hulk at the mercy of its enemies. Not the least remarkable peculiarity in the economy of the fish is the existence of an air-bladder, by the dilatation or contraction of which it possesses the power of rising or sinking in the water, according as it feels inclined. It may be observed that fish, while in water, are constantly moving the gills, which is analogous to the art of breathing. The water sucked in by the mouth, and vented by the gills, contributes a minute portion of air, but enough to keep up the circulation of the blood and sustain life; if we were to tie up the gills, the fish would be immediately suffocated. The blood of fish is cold, being only about two degrees warmer than the water in which they live.

The senses of fish have engaged much attention from naturalists. Their quickest sense is that of sight; but they are destitute of the power of contracting the iris of the eye, so as to accommodate themselves to different degrees of light. In ordinary circumstances this is of no consequence, as the water diminishes the intensity of light, and the animal has the means of retiring to the bottom, or into holes, to escape the glare of the mid-day sun. It has been doubted if fish have any organs of hearing; but it is certain they do possess them, and hear to a limited extent. They are affected by any loud noise, though this may be partly ascribable to feeling the vibrations of the water. The taste of fish is allowed to be very blunt, if it exist at all; and so likewise is their smell. Whatever may be their deficiencies in these respects, they are provided with an appetite of boundless voracity.

'Every aquatic animal that has life,' observes Daniel, 'falls a victim to the indiscriminate voracity of one or other of the fishes. Insects, worms, or the spawn of other tenants of the waters, sustain the smaller tribes; which in their turn are pursued by millions larger and more rapacious. A few feed upon mud, aquatic plants, or grains of corn; but the far greater numbers subsist upon animal food alone; and of this they are so ravenous as not to spare those of their own kind. That there are vegetables in both fresh and salt waters admits no doubt, and these may furnish food to particular fishes; but these sorts are few, perhaps no one kind can be pointed out that subsists entirely upon them; and although most fishes eat flies and terrestrial worms when they come in their way, yet in the immeasurable waste of waters surrounding this globe, the swarms of fishes are so immense, that the subsistence to be derived from the above sources appears to be altogether disproportioned to their wants, and those of a smaller size seem to constitute the principal food of nearly all the fishes known to us. Charr kept in a pond, if scantily supplied, frequently devour their own young; other fish, that are larger, go in quest of more bulky prey—it matters not of what sort, whether of their own or of another species. If we turn our attention, in this argument, to sea-fish, those with the most capacious mouths pursue almost everything that exists, and often meet each other in fierce opposition, when the fish which has the widest throat comes off with victory, and devours his antagonist.

The voracious fishes differ widely from the predatory kinds of terrestrial animals; they are neither limited in their number nor solitary in their habits. Their rapacity is not confined to a few species, one region of the sea, or individual efforts. Almost the whole order is continually irritated by the cravings of an appetite which excites them to encounter every danger, and which, by its excess, often destroys that existence which it was intended to prolong. Innumerable shoals of one species pursue those of another through vast tracts of the ocean, from the vicinity of the pole to the equator. The cod pursues the whiting, which flies before it from the bank of Newfoundland to the southern coasts of Spain. The cachalot drives whole armies of herrings from the regions of the north, devouring at every instant thousands in the rear. Hence the life of every fish, from the smallest to the greatest, is but a continued scene of rapine; and every quarter of the immense deep presents one uniform picture of hostility, violence, and invasion.

In these conflicts, occasioned by the voracity of the different kinds of fishes, the smaller classes must have long since fallen victims to the avidity of the larger, had not nature skilfully proportioned the means of their escape, their numbers, and their productive powers, to the extent and variety of the dangers to which they are unceasingly exposed. To supply the constant waste occasioned by their destruction in the unequal combat, they are not only more numerous and prolific than the larger species, but, by a happy instinct, are directed to seek for food and protection near the shore, where, from the shallowness of the water, their foes are unable to pursue them. These, however, yielding to the irresistible impulse of hunger, become plunderers in their turn, and revenge the injuries committed on their kind by destroying the spawn of the greater fishes, which they find floating upon the surface of the water.

In what manner digestion, to such an amazing extent and rapidity, is carried on in the stomach of fishes, the inquiries of naturalists have at present been unable to ascertain. It so far exceeds everything that can be effected either by trituration, the operation of heat, or of a dissolving fluid, that a celebrated physiologist (Dr Hunter), after various experiments, was of opinion that none of these causes were equal to the effect, and that the digestive force in the cold maw of fishes is so great as to overturn the systems that have attempted to account for it on those principles; that by some power in the stomach yet unknown, which from all kinds of artificial maceration acts differently, the meat taken into the maw is often seen, although nearly digested, still to retain its original form; and whilst ready for a total dissolution, appears to the eye as yet untouched by the force of the stomach.' It may be added, however, that although generally voracious, fish have a remarkably accommodating appetite, and will endure hunger without injury a much longer period than most terrestrial animals.

Fishes are for the greater part oviparous—that is, produced by eggs or spawn, in the deposition of which a male and female fish are concerned. It is usual to call the male a *milt* or *milter*, and the female a *roe* or *roeman*. The process of spawning, which takes place in secluded parts in the beds of rivers, is involved in considerable obscurity. The salmon, of which most is known, seeks the higher parts of rivers for spawning, and there the deposit is made. Mr Halliday, in his communications to the House of Commons on this subject, describes the process as follows:—'When they proceed to the shallow waters, which is generally in the morning, or at twilight in the evening, they play round the ground, two of them together. When they begin to make the furrow, they work up the gravel rather against the stream, as a salmon cannot work with his head down the stream, for the water entering his gills in this manner would drown him. When they have made a furrow, they go to a little distance, the one to one side, and the other to the other side of the furrow, and throw themselves on their sides when they come together, and, rubbing against each other, they shed their spawn both into the furrow at once. They do not lay it all at once; on the contrary, it requires from about eight to twelve days for them to emit their stock of spawn, which being deposited, the bed is made and covered as they go along, both male and female assisting in the operation.'

Immediately after spawning, all fish are thin and poor, and not worth the trouble of catching. In about twenty days, if the circumstances be favourable, the eggs are hatched, and emit the young fry of fish. The number of young is in some cases enormous. Carp, perch, or roach, produce from 30,000 to 200,000 young; a herring from 20,000 to 36,000; a mackerel from 400,000 to 500,000; and a cod between three and four millions. Of the young of any fish, however, comparatively few reach maturity, the greater proportion being devoured by enemies shortly after hatching. As if for the sake of mutual protection, most fish of a kind, as may be observed in the case of minnows and parr, associate together and swim in flocks or shoals.

That fishes are liable to diseases, arising from variations of temperature and other causes, there is no reason to doubt; but few are ever seen dead in the water, there being too many scavengers of the deep to allow of this waste of food. In general, the weak fall a prey to the strong before the period of natural death. It is understood that fishes possess a blunted nervous energy, which renders them almost insensible to any ordinary infliction; and so mean are their reflective faculties, that after escaping from a hook which has lacerated their palate, they will in the next minute catch at a similar bait, and be hooked a second time and drawn from the water. A number of years ago, two young gentlemen, while fishing in a lake in Dumfriesshire, having expended their stock of worms, had recourse to the expedient of picking out the eyes of the dead perch they had taken, and attaching them to their hooks—a bait which this fish is known to take as readily as any other; one of the perch caught in this manner struggled so much when taken out of the water, that the hook had no sooner been loosened from its mouth than it came in contact with one of its eyes, and actually tore it out. In the struggle, the fish slipped through the holder's fingers, and again escaped to its native element. The disappointed fisher still retaining the eye of the aquatic fugitive, adjusted it on the hook, and again committed his line to the waters. After a short interval, on pulling up the line, he was astonished to find the identical perch that eluded his grasp a few minutes before, and which literally perished in swallowing its own eye.

Fishes are exposed not only to external foes, which it requires all their dexterity to elude, but to the torment of parasitical marauders in their own person. Besides creatures which make a lodgment in the intestines, various parasites fix themselves beneath the scales, in the mouth, and upon the gills. Salmon, perch, trout, and other fresh-water fish, are preyed upon in this manner by different species of lice; and as some of these parasites cannot live in salt water, it has been supposed that one of the reasons for the salmon migrating to the sea is to relieve itself from the lice (*Lernæa salmonia*) which have adhered to its gills. The trout louse, or *L. truttæ*, is not unknown to fishers.

FISHING-TACKLE.

The equipment of the angler consists mainly of his rods, lines, hooks, and baits, with the means of keeping them in order, or supplying their place in the event of an accident. To these dealers have added numerous accessories, more cumbrous than useful, and always more sought after by the holiday angler than the genuine disciple of Walton. As one-half the art depends on proper equipment, we shall describe the leading implements in detail.

The Rod.

This is the chief implement of the angler. It ought to be strong, but perfectly elastic, and bend, on being waved, through its upper half, but particularly at the small tapering point. The wood most suitable is hickory or ash, with yew for the upper part, to which a point of whalebone is attached. The size and strength must depend on the nature of the duty to which the rod is put. One for trout, perch, &c. ought to be from twelve to fifteen feet in length, and a salmon one from sixteen to twenty feet, besides being considerably stronger. Whatever be the length, it must be quite straight, and on all occasions bend back to its original straightness. If there be a single knot in the timber, reject it, for it will certainly snap at the first severe pull or jerk. It should be varnished, to protect it from the action of the water. The rod is not all of one piece. For the sake of convenience, it is divided into four, or perhaps six pieces in the length. These pieces are usually joined by means of screws and ferules; but if this be the plan of the rod offered to your choice, take care to see that these metal junctions do not impair the bending properties of the instrument, or render it too heavy. Rods of a plain kind made in the country are spliced with wax threads, and these are generally more serviceable than the fine-looking rods manufactured in cities. Listen to what John Younger of St Boswell's (a village on the Tweed) says on this subject:—'To those who reside near the water, I would recommend a rod all of glued and tied joints as best in point of real use, and not so liable to break in the moment of action. Or, indeed, even for travelling, I would prefer tied joints, as wherever a person has time to stop to fish, though only for a day or two, he has at least five minutes to spare for tying his rod in a sufficient manner. Rods are often breaking at brass joints; and those who use them, instead of bringing in a back-load of fish, are constantly arriving home from the water, telling you, "I've broke my rod!" Such sickening news may generally be prevented by tied joints.'

At the bottom of the rod, where it is grasped by the hand, a brass reel or *pirn* is attached, and on this the line is wound. It should be simple in its mechanism, so as to allow of expeditious winding or unwinding. The line is conducted from the reel to the upper termination through small wire-loops, in Scotland called *mylics*, which are fixed to the rod; these must be in an even line when the pieces of the rod are joined together, and be about a foot asunder. In *fashionable* rods, the mylics are small rings held by wires to the rod, and they conveniently fall flat when the rod is not in use. Good serviceable rods require no such elegance of design. The angler who is skilled in his art cares nothing for finery of apparatus, and will pull out dozens of fish in a day with an instrument which many would think not worth the carrying. Indeed, one of the best day's sport ever we enjoyed was with a sapling ash, lithe and green, from the banks of the river over which it was plied with such memorable success.

Lines.

These should be long, smooth, light, and flexible, and of a material which will not be easily injured by wet. These qualities are found in lines made of horse hair and gut, which we recommend in preference to any other. The part of the line which is wound on the reel, and goes along the rod, is called the *reel-line*; and being designed to be let out only on occasions when a fish darts off with a hook in its mouth, it need not be so thin and light as the bulk of the portion termed the *casting-line*. The reel-line, which may be about thirty yards in length for ordinary trout-fishing, is formed by spinning together horse hairs, so as to make a fine even cord. As it is troublesome to make, it should be purchased from a respectable dealer in fishing-tackle. It should be from twelve to fifteen hairs in thickness, the hairs being white, fresh, and well cleaned. The line for salmon should contain from eighteen to twenty-four hairs, and extend to at least sixty yards in length.

The casting-line, which is united by a loop to the reel-line, may be also of horse hair, but of a smaller texture and lighter in weight. It should be five lengths of hairs in extent, the uppermost length being eight hairs in thickness, and gradually diminishing the number to three or four in the lowest length. To the lower end of this casting-line is added the *gut-line*, which is the part that actually falls upon the water, and therefore requires to be very fine. It consists of a series of strong gut, and to it is attached the short lengths or casts of gut on which are the hooks. In some instances, the casting-line is altogether made of gut, on which more dependence can be placed than on hair; if of gut, three threads are sufficient for the thickness.

On the article gut, Mr Stoddart, in his 'Art of Angling,' has the following observations:—'This article, originally imported from the East, and now brought in considerable quantities from Spain and Italy, is, as far as we have been able to learn, fabricated from the male silk-worm in a state of decomposition. The operation is principally conducted by children, and consists in removing the external slough of the worm with the fingers, elongating at the same time the gluey substance which composes its entrails. To do this properly requires some care and attention. Should the worm be kept too long, a hard crust forms itself over it, in destroying which the application of the nail is necessary; hence the gut becomes flattened, and loses much of its value. The sinews of herons and other birds are also manufactured in Spain into a sort of gut, and are much used, although unwittingly, by our salmon fishers. Worm-gut varies in length from nearly two feet and downwards. We have seen, however, an article very closely resembling it from the Archipelago, which measures at least a yard and a-half. This is not to be confounded with sea-weed, although a vegetable fibre, and drawn out of a plant. It is much stronger and better suited for angling. The inhabitants of the Greek islands use it for catching mullet, and will often toss a fish some pounds weight over their heads by a thread or two. We ourselves have found it excellent for the larger sorts of tackle. Animal gut is, however, more generally used, and better adapted for trouting. It ought to be small, round, and transparent, without any flaw or roughness. When worn or disordered, the application of a piece of India-rubber will at once renovate it. In joining threads together for the purpose of making casts, the single knot properly drawn is quite sufficient. One should avoid clipping the useless extremities too closely in this operation, as in that case the knot is somewhat liable to give way. Gut, to keep well, should be moistened with fine oil (almond or olive), and stored in oiled paper.'

To these recommendations we may add, that lines of all kinds should be kept dry. On returning from a fishing excursion, draw out the line, and let it be thoroughly dried by waving in the air before being wound up or laid aside. When to be again used, look it over, giving it a gentle tug here and there to try its strength, and repair damaged parts. On coming to the water-side, and just before throwing, allow the casting line to be wetted in the water, and this will at once give it smoothness and elasticity.

Hooks.

These are small instruments made of tempered steel, and of whatever size, they require to possess the qualities of lightness and great strength. They have been always principally manufactured at two places—Kendal in Westmoreland, and Limerick in Ireland. The Kendal circular bends, as they are called, are reckoned the best hooks of a small size, while the Limerick hook is preferable for salmon. Many of the fish-hooks of ordinary English makers are worthless. Hooks range in size from about an inch and a-half in length down to a quarter of an inch, with a proportional diminution of thickness. Some makers number them from No. 10, the smallest, to No. 20, the largest, while others number from 1, the largest, to 14, the smallest. The Limerick hooks are denoted by letters, commencing with A, and so on. In purchasing hooks, see that the body is of equal thickness throughout, and that the barb is boldly yet firmly set. Try their power of resistance by forcing the bend with the fingers, and urging the point against the thumb-nail. Hooks for fly-fishing should be thinner in the shank than those designed for bait. An angler should keep a small stock of hooks of various sorts, to be ready on all emergencies; with the tackle to which they are attached, they require to be kept very dry.

Landing Net—Gaff—Drag-Hook.

The *landing net* is considered in England a necessary implement for an angler, but in our opinion they must be poor hands at fishing who cannot drag a trout or any similar small fish from the water after hooking it without resorting to such a cumbrous apparatus. Perhaps it is found to be essential, in consequence of the feebleness of the rods and tackle usually employed. It consists of a small bag net stretched on a hoop at the extremity of a pole four or five feet in length. Mr Blaine, in his 'Encyclopædia of Rural Sports,' seems to think a landing net of first importance; and for the use of tyros in the art, he gives the following directions:—'In fly-fishing, when the line is long, and there is not much space to step backward, or the reel clogged, it is necessary sometimes to lay hold of the line with one hand; but this should be done with great caution, and then only after the fish is well-nigh spent, or one struggle may carry away line, hook, and fish. In all other cases avoid touching the line if possible; but having sufficiently played the fish, whether taken by bottom or by fly-fishing, bring him within reach of the landing net, and then carefully conduct or slide the net obliquely under the foreparts of his body, which, if the fish be completely exhausted, will fall into it; but if he has still sufficient vigour, it will be prudent rather to slide him over the net than the net under him. It must have occurred to every angler to have supposed a trout or salmon to be completely spent, who, the moment he has been touched by the net, or has even caught sight of the fisher, has sprung off with most annoying violence. Against such an accident it is prudent to be ever prepared by keeping the rod in an upright position, acting on a tightened line, but yet so disposed that it can run at liberty if required. When the head and shoulders of the fish are once fairly within the net, a slight turn of it will take in the whole body, and the net being then kept horizontally, will insure his safety; for with the head downwards, he cannot disengage himself from the net: but if he be received tail foremost, as is sometimes done in deep waters, from overhanging banks, &c. beware of his plunges.'

The *gaff* is another aid to landing fish, and is employed in cases in which the landing net would be too small. It is used chiefly for landing salmon, and consists of a peculiarly-shaped hook at the end of a staff. When the salmon flounders about and incommodes the fisher, he is expected to secure the animal, and prevent it from breaking his line and rod by hooking it with the gaff at the gills, the tail, or any part he can conveniently lay hold of.

The *drag-hook* is an implement with three bent prongs or hooks, with a long cord line attached. It is used for casting into rivers to clear away any object at the bottom upon which the hook is caught. We pity the angler who attempts fishing in weedy puddles requiring such a clearer of hindrances.

Angler's Pocket-Book, &c.

The angler's equipment is completed by the addition of a basket for holding his fish, which is slung on the back by a shoulder-belt; also a pocket-book for holding hooks and other trifles; and a round flat tin box for his fly-casts. Many carry their supply of fly-casts wound round their hat, and some keep them within the leaves of their pocket-book. This pocket-book, which is the storehouse of all kinds of odds and ends—we have seen a good one made out of an old pocket almanac—should have two or three pockets for holding an assortment of hooks, silk thread, stuff for making flies, gut, wax, small cord, fly-nippers, scissors, &c.—all to be used in case of breakage of tackle or rod, or any other accident. In fishing for perch, gudgeons, bream, &c. a small float is often used. Floats are made of cork, quill, reed, and other materials; and a choice, according to circumstances, can be added to the contents of the pocket-book.

For an angling dress all finery is worse than useless. Fish are easily scared with the appearance of any light or showy object on the banks. Let the angler, therefore, dress himself in a plain dull-coloured suit, with a hat equally sober in its aspect; and let him use only strong shoes on boots, which will not be injured by water. A suit of gray-coloured Tweed, with a felt or flap hat, is at present reckoned orthodox; and to these we may safely suggest the addition of a pocket-flask, to be filled at the outset of the day's excursion according to the taste of the bearer.

Baits.

A bait is any substance put upon a hook to act as a lure to the fish; and when used, the baited hook is dropped into, and allowed to sink in, the water, instead of being kept near or upon the surface, as in the case of fishing with fly. The materials, living and dead, used for bait are very numerous; but the leading kinds are worms, maggots, minnows, insects, and salmon roe. The hook employed in either case is tied by the shank to the gut with waxed silk, and the preparation is therefore not at all difficult. When dressed to the gut, it is called bait or worm-tackle.

Worms used for bait are of various sorts; but that which is most commonly employed is the lob or garden-worm, a long reddish-coloured reptile found in abundance in many gardens, grass-plots, under old cow-droppings in fields, and in any rich old soil. They may be dug up with a spade, or caught while crawling from their holes at twilight, and particularly after heavy showers. 'He who seeks them,' says Daniel, 'must move cautiously without noise, or they will quickly retreat into the earth; draw them gently out of their holes without nipping; those that sever in taking must be thrown away, as they will soon become putrid, and infect the others; when as many are collected as are wanted, having plenty of good moss freed from dirt, dip it into clean water, and wring it nearly dry; put it into an earthen pot proportioned to the quantity of worms, laying it regular, and forcing it down with the hands; strew the worms on the surface, after dipping them in clear cold water to rid them of the soil that may adhere to them; such as are not injured will soon bury themselves in the moss, and those that do not must the next morning be picked off as useless; they must be inspected every three or four days, the dead ones removed, and have fresh moss, or that wherein they have been kept well washed and picked, and the water squeezed out at least once a week; they must be so placed summer and winter as to be safe from the extremity of the weather at both seasons. In a week's time they will be fit for use; and upon the angler coming home from fishing, he will return from his worm-bag into the pot those which he has not used. By observing the above carefully, they may be kept a month in summer, particularly by now and then giving them, drop by drop upon the moss, a small quantity of new milk and the yolk of an egg well beaten together, and warmed so as to thicken it; but when a stock of lob-worms is meant to be retained for a considerable length of time, a large vessel must be filled half or three-quarters full of good mould, in the middle of which is to be placed some moss or old coarse linen cloths, hopsack, or rags wetted; in hot dry weather, clean water must be sprinkled upon the earth with a watering-pot, so as to keep them moist, but not wet; they may thus be preserved as long as is requisite; and a week before angling, what are wanted may be drawn from the store, and put into moss to scour themselves.' Another worm, which is found in dunghills, called the *brandling*, from its striped appearance, forms a good bait, but it is seldom used.

Maggots, or the larvæ of insects, as is well known, are found on fly-blown meat or any putrid animal substances; very fine ones are procured from game in a *high* condition. Daniel calls these creatures *gentles*, and describes them as of great virtue in certain kinds of fishing:—'Gentles,' he observes, 'may be procured almost at any time at the tallow-chandlers, and should be kept in oatmeal and bran, as bran by itself is too dry. Those who live in or near London may buy them in proper condition for the day on which they wish to use them; but for the accommodation of those who reside in the country, remote from such convenience, the best modes of breeding them will be here mentioned, in order to prevent disappointments. Coarse fish, such as *chub* and *roach*, may be laid in an earthen pot, in the shade, and will soon be fly-blown; when the gentles are of the proper size (but not before), put some oatmeal and bran to them, and in two days they will be well scoured, and fit to fish with; in about four more they become hard, assume a pale red colour, and soon after change to flies: the red ones should not be thrown away, as frequently roach and dace take these with a white one, in preference to all other baits. Some have recommended a piece of liver suspended by a stick over a barrel of clay, into which the gentles fall and cleanse themselves; but clay will not scour them, and, besides, they fall from the liver before they have attained their full size. The before-mentioned is a less disgusting plan; for a short time after oatmeal and bran are put to the gentles, the fish in which they are bred will be found perfect skeletons, and may be thrown away; however, if they are to be bred from liver, it should be scarified deeply in many parts, and then hung up, and nearly covered over, as in that way the flies will blow it better than when wholly exposed. In two or three days the gentles will be seen alive; the liver is then to be put into an earthen pan, and there remain until the first brood are of full growth; a sufficient quantity of fine sand and bran (letting the liver remain) is then to be put into the pan, and in a few days they will come from the flesh, and scour themselves in it. The liver should then be hung across the pan, and the latter brood will soon drop out, and be fit for use; and by thus breeding them in October, and keeping them a little warmer than those bred in the summer, until they arrive at their full growth, and afterwards putting them in the same pan into a dampish vault, they may be preserved for winter fishing. Those bred in summer, but for the bran and sand, would soon sink into a dormant state. The skins take on a blackish-red, full of white matter, and shortly after become flies: those produced in autumn, from whatever substance, will continue in this state all the winter, provided they can shelter themselves under the surface of the earth in fields, gardens, &c.; and in the warm weather of the ensuing spring they change into flies, thus preserving their kind from year to year. Gentles are so universal and so alluring a bait, that the angler should never be unprovided with them. Trouts have been taken with them in clear water, when they have refused all kinds of worms and artificial flies.'

Caddis, or *cad-bait*, is another kind of larva, inhabiting pieces of straw, or little cylinders formed of bits of stick or sand at the sides of rivers. Daniel has some interesting observations on this species of bait:—'The several kinds of cadews in their nympha or maggot state thus house themselves: one sort in straw, thence called straw-worms; others in two or more parallel sticks, creeping at the bottom of brooks; a third in a small bundle of pieces of rushes, duck-weed, &c. glued together, therewith they float on the surface, and can row themselves about the water with the help of their feet: both these are called cad-bait. It is a curious faculty that these creatures possess of gathering such bodies as are fittest for their purpose, and then so glueing them together, some to be heavier than water, that the animal may remain at bottom where its food is, and others to be so buoyant as to float, and there collect its sustenance. These houses are coarse, and show no outward art, but are within well tunnelled, and have a tough hard paste, into which the hinder part of the maggot is so fixed, that its cell can be drawn after it without danger of leaving it behind; and it can also thrust out its body to reach the needful supplies, or withdraw into its covering for protection and safety. These insects inhabit pits, ponds, low running rivers, or ditches, in cases of different forms, and composed of various materials: some of them enclosed in a very rough shell, found among weeds in standing waters, are generally tinged green; others are bigger than a gentle, and of a yellowish hue, with a black head: they form an excellent bait, and are found most plentifully in gravelly and stony rivulets, and by the sides of streams, in large rivers among stones.

To collect them, turn up the stones, and the best will adhere to them; when the quantity wanted is obtained, put them into a linen bag for five or six days, dip them, together with the bag, into water once a day, and hang them up; they will then turn yellow, become tough, and fitter for angling than when first got from the brook. If meant to be kept long, they must be put into a thick woollen bag, with some of the moist gravel or sand from the same rivulet whence they are taken; they must be wetted twice a day, but oftener in very hot weather: when you carry them abroad, fill the bag with water, and holding the mouth of it close, let the water run from them; in this way they may be kept three weeks. Another way of preserving them is by placing them in an earthen pot full of river water, with some of the gravel they were bred in at the bottom; but the preceding method is preferable. Some use bait pans of different sizes for insects, the tops punched full of holes, not so large as to admit of their escaping when placed in the river, which not only keeps them cool, but supplies them with aliment in the fresh water; some keep them in moss in a woollen bag on a damp floor, taking care that the bag retains a proper moisture. A third mode of preserving caddis, and also grasshoppers, caterpillars, oak-worms, or natural flies, is to take the green withy bark from a bough six or seven inches round, and about a foot in length: turn both ends into the form of a hoop, and fasten them with a large needle and thread; stop up the bottom with cork, and bore the back full of holes with a red-hot wire; tie over it a colewort leaf, and lay it in the grass every night. In this manner caddis may be preserved until they turn to flies. When grasshoppers are to be preserved in the case, some grass must be put into it.

In angling with caddis, the line, when all out, should be as long as the rod, for three lengths next the hook, of single hairs, with the smallest float, and the least weight of lead that the swiftness of the stream will allow to sink; and that may be aided by avoiding the violence of the current, and angling in the returns of a stream, or in the eddies betwixt two; which are also the most likely places wherein to kill fish, either at the top or bottom. The caddis may be at times, with very good effect, joined to a worm, and sometimes to an artificial fly, to cover the point of a hook; and also two or three together may be put in upon the hook. It is always, however, to be angled with at the bottom, especially when by itself, with the finest tackle, and at all seasons forms a most holding bait for trout and grayling.'

Minnow bait.—Minnows are a small fish, from an inch to two inches in length. They swim in flocks, and may be captured by a hoop-net on the end of a staff, or more simply by a crooked pin baited with a small worm. Anglers generally hire a boy to catch a quantity of them. The tackles used for minnow bait are various in their formation; some are single hooks; others a pair of hooks dressed back to back; and a third kind are a series of pairs, one above another. We cannot do better than give Mr Stoddart's description of these deadly instruments, and the mode of baiting them. He alludes to Kendal hooks:—

'The most simple, and in some places the most deadly, is a common single bait-hook. This we insert through the back of the minnow, and drawing it out, run below the gill, allowing the barb to protrude from the mouth; we then tie up the tail along the gut, either with a piece of silk thread, or more expeditiously with the gut itself, hitched over the part. This is angled with in the same manner as the worm, allowing plenty of time for the fish to gorge. A tackle similar to it may be used in standing-pools or lochs. Here, however, the shank of the hook (a long one) is loaded, and the bait allowed to descend rapidly towards the bottom. Large cautious fish are sometimes taken by this method of angling. Of all minnow tackles, that with swivels is the commonest and most agreeable to employ. There are many ways of constructing it. Two of these we shall mention as preferable to all others. One is simply a large hook, No. 11, fastened to good round gut with two smaller ones, No. 7, tied back to back above, and looped in the dressing, so as to slide along, and shorten or lengthen the tackle to the dimensions of the bait. In using it, enter the lowermost hook through the mouth, and bring it out near the tail of the minnow; insert one of the hooks on the slider through its lips, noticing that the fish be slightly curved so as to spin properly. The other tackle is composed of six hooks, No. 7, dressed in pairs, and is angled with only when the trout are in a taking mood. Two or more swivels are required for both of these contrivances—the lowermost fastened about two feet or so above the bait. Leaden pellets may also be used, but many think them unnecessary. Some anglers attach behind the whole apparatus an extra hook, No. 12 or 13, dressed upon a hog's bristle, which, should the trout miss the minnow, is apt to catch him, when retiring, by the middle or other part of the body. This is a superfluity, and, like many superfluities, does more harm than good, alarming the fish without securing them. Tackle for trolling with par or small trout ought to be constructed on the same principles as the minnow-tackle; only the hooks should be larger and dressed upon gimp instead of gut. Snap-hooks, also, are in use for this kind of angling. Small silk cord oiled will be found the best trolling-line.'

The perfect insects used for baits are grasshoppers, crickets, day-flies, spring-flies, May-flies, humble bees, and various others. The ephemeræ, or those fragile creatures that live but for a day or even a few hours, and therefore called day-flies, are found sporting by the low banks of rivers in warm weather, and form a taking bait for trout and some other fish.

Salmon Roe.—The efficient use of this as a bait is a modern discovery, and has added largely to the angler's means of capturing the finny tribes. The roe is taken from a salmon a fortnight before spawning, at which time it is best for the purpose. Some prepare it for use by salting it a little, and drying it to a state in which it will keep; others cure it with sugar instead of salt. Blaine recommends the following as a method by which it may be kept good for two years in a cool situation:—'A pound of spawn is immersed in water as hot as the hands can bear it, and is then picked from membraneous films, &c. It is now to be rinsed with cold water, and hung up to drain for twenty-four hours, after which put to it two ounces of rock or bay-salt, and a quarter of an ounce of saltpetre, and again hang it up for twenty-four hours more. Now spread it on a dish, and gently dry it before the fire or in the sun, and when it becomes stiff pot it down. We should, however, recommend that the potting be not in one mass, but, like the shrimp-paste sold at the fish-sauce shops, that it be divided into small pots, pouring over each some melted suet, by which method a pot can be opened when wanted, instead of disturbing the general store. It forms an additional security to cover each over with a moistened skin or bladder. Trout roe is also said to make a good bait, but we have no personal experience of its efficacy—in fact, we never tried it; but it has been so strongly recommended, that it would be but fair to give credence to its value until numerous trials have proclaimed it as totally inert.

To bait with salmon roe, first put on the hook (which should be sized according to the fish intended to be tried for) a mass which shall fill up the hollow of the bend and hide the steel. On the point put two or more firm large grains of it, both to conceal the snare and tempt the fish. In this way it is said to be principally a winter and a spring bait, but we know no reason why it may not be advantageously used at other times, for spawn of some kind is almost always to be found.'

Pastes made of shrimps, of cheese, of bread crumbs mixed with honey, and of other materials, are also employed, according to the fancy of the angler, and the nature of waters and sport he intends to pursue; our limited space, however, obliges us to refer those who are curious in the subject of baits to the Encyclopædia of Blaine, where there is a vast body of highly interesting matter on angling. Those who are disinclined to prepare roe and pastes, or have not the means of doing so, may be supplied by the dealers in fishing-tackle.

Artificial Flies.

Hooks dressed up so as to bear something like a resemblance to actual live flies, are by far the most important lures employed by the angler. The principal materials employed in dressing are light portions of cock's hackle or other feathers, to form wings, the fur of a hare's ear or some other substance to make the body, and waxed silk thread, by which the whole is tied in an artful manner on the shank of the hook. A whole sheet might easily be filled with descriptions of artificial flies suitable to different fish, waters, and seasons; but the bulk of what has been written by Walton, Daniel, and many others, is now considered superfluous, experienced fishers having arrived at the conclusion that fishes in general are such eager and heedless fools as to be satisfied with a very limited choice of deceptions. The author of the article *Angling*, in the 'Encyclopædia Britannica,' has some clever remarks on this branch of the art:—

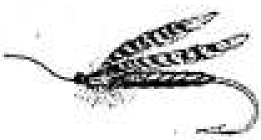
'As simulation,' says he, 'consists in the adoption or affectation of what is not, while dissimulation consists in the careful concealment of what really is—the one being a positive, the other a negative act—so the great object of the fly-fisher is to dissimulate in such a manner as to prevent his expected prey from detecting the artificial nature of his lure, without troubling himself by a vain effort to simulate or assume with his fly the appearance of any individual or specific form of insect life. There is, in truth, little or no connection between the art of angling and the science of entomology; and therefore the success of the angler, in by far the greater proportion of cases, does not depend on the resemblance which subsists between his artificial fly and the natural insect. This statement is no doubt greatly at variance with the expressed principles of all who have deemed fishing worthy of consideration, from the days of Isaiah and Theocritus, to those of Carrol and Bainbridge. But we are not the less decidedly of opinion, that in nine instances out of ten a fish seizes upon an artificial fly as upon an insect or moving creature *sui generis*, and not on account of its exact and successful resemblance to any accustomed and familiar object.

If it is not so, let us request to be informed upon what principle of imitative art the different varieties of salmon-fly can be supposed to bear the most distant resemblance to any species of dragon-fly, to imitate which we are frequently told they are intended? Certainly no perceptible similarity in form or aspect exists between them, all the species of dragon-fly, with the exception of one or two of the sub-genus Calepterix, being characterised by clear lace-like pellucid wings, entirely unadorned by those fantastic gaudy colours, borrowed from the peacock and other "birds of gayest plume," which are made to distinguish the supposed resemblance. Besides, the finest salmon-fishing is frequently in mild weather during the cooler seasons of the year, in autumn and early spring, several months either before or after any dragon-fly has become visible on the face of the waters, as it is a summer insect, and rarely makes its appearance in the perfect state until the month of June. If they bear no resemblance to each other in form or colour, how much more unlike must they seem when, instead of being swept like lightning down the current as a real one would be, the artificial fly is seen crossing and recrossing every stream and torrent with the agility of an otter and the strength of an alligator! Or darting with regular jerks, and often many inches under water, up smooth continuous flows, where all the dragon-flies on earth, with St George to boot, could not maintain their place a single second! Now, as it is demonstrable that the artificial fly generally used for salmon bears no resemblance except in size to any living one—that the only tribe which from their respective dimensions, it may be supposed to represent does not exist in the winged state during the period when the imitation is most generally and most successfully practised—and if they did, that their habits and natural powers totally disenable them from being at any time seen under such circumstances as would give a colour to the supposition of the one being ever mistaken for the other—may we not fairly conclude that, in this instance at least, the fish proceed upon other grounds, and are deceived by an appearance of life and motion, rather than by a specific resemblance to anything which they had previously been in the habit of capturing? What natural insect do the large flies, at which sea-trout rise so readily, resemble? These, as well as grilse and salmon, frequently take the lure far within the bounds of the salt-water mark; and yet naturalists know that no such thing as a salt-water fly exists, or at least has ever been discovered by their researches. Indeed, no true winged insect inhabits the sea. What species are imitated by the palmer, or by three-fourths of the dressed flies in common use? An artificial fly can, at the best, be considered only as the representative of a natural one which has been drowned, as it is impossible to imitate the dancing or hovering flight of the real insect over the surface of the stream; and even with that restricted idea of its resemblance to nature, the likeness must be scarcely perceptible, owing to the difference of motion and the great variety of directions in which the angler is obliged to drag his flies, according to the nature and special localities of the current, and the prevailing direction of the wind.

We are therefore of opinion that all or a great proportion of what has been so often and sometimes so well said about the great variety of flies necessary to an angler—about the necessity of changing his tackle according to each particular month throughout the season—about one fly being adapted solely to the morning, another to noonday, and a third to the evening—and about every river having its own particular flies, &c. is, if not altogether erroneous, at least greatly exaggerated and misconceived. That determinate relations exist between flies of a certain colour and particular conditions of a river, is, we doubt not, true; but these are rather connected with angling as an artificial science, and have but little to do with any analogous relations in nature. The great object, by whatever means to be accomplished, is to render the fly deceptive; and this, from the very nature of things, is continually effected by fishing with flies which differ in colour and appearance from those which prevail upon the water; because, in truth, as we shall afterwards have occasion to show, none else can be purchased or procured. Even admitting for a moment the theory of representation, when a particular fly prevails upon a river, an artificial one in imitation of it will never resemble it so closely as to appear the same to those below (that is, the fish); on the contrary, a certain degree of resemblance, without anything like an exact similitude, will only render the finny tribe the more cautious through suspicion, while a different shape and colour, by exciting no minute or invidious comparisons, might probably be swallowed without examination. Indeed it seems sufficiently plain that where means of comparison are allowed, and where exact imitation is at the same time impossible, it is much better to have recourse to a general idea, than to an awkward individual representation.'

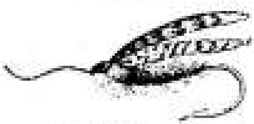
Mr Stoddart, one of our most experienced anglers, entertains a similar opinion:—'The colours of water and sky,' he observes, 'are the only indicators which can lead us to select the most killing hook, and even these are often deceptive. We have fished in one stream where dark, and, in the next, red flies took the lead. There is no trusting to the fancy in certain places. On Tweed, we have seen it veer about, like the wind, in one moment, without a note of preparation. Most rivers, however, are more steady; and when the water is of a moderate size, may be relied on with at most two sorts of flies all the year round. For ourselves, our maximum in every Scottish stream is reduced to only four descriptions of artificial flies, with one or other of which we engage to catch trout over all the kingdom. Knowledge and practice have convinced us of the needlessness of storing up endless and perplexing varieties, which some do, in order to appear knowing and scientific.'

The following, according to these and other trustworthy authorities, form a very serviceable set of lures for fly-fishing:—*First*, there is a fly which has been called *the professor*, after Professor Wilson of Edinburgh. The wings are formed of a mottled brown feather, taken from the mallard or wild-drake, the body being composed of yellow floss silk, rather long, and wound about close to the bend with a fine red or black hackle. This simulated fly has a tight clever aspect, and is reckoned a powerful killer.



The Professor.

Second, a fly which differs from the above only by being a little shorter, more thick, and with a body made of pale-green instead of yellow silk. Green worsted may be used.



Fly with Green body.

Third, a rough powerful hackle, with wings of white and black marked feather, a bristling body of dark-green wound about with gray or mottled hackle, to which is given a pointed tail.

Rough Hackle.

Fourth, a fly of a sombre cast, the wings formed of woodcock, snipe, or lark feather, and the body of hare's ear, darker or lighter, according to individual fancy.

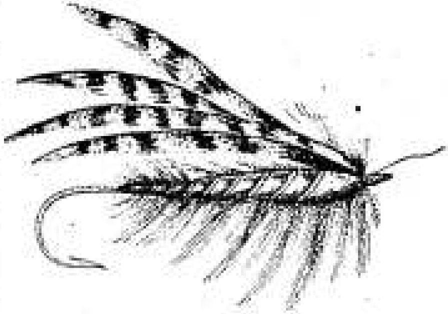
Fifth, a fly with wings of the starling or fieldfare, and having a body made of mouse or water-rat fur.

Sixth, a plain hackle, black or red, without wings, and commonly called *palmer*.

Seventh, a red hackle with wings of the starling, and a body formed of light-red mohair and a red cock's hackle.

To these may be added any other variety of fly that the fancy suggests as being suitable to the time or place of fishing. Flies for salmon-fishing must be of a much more large and powerful kind, as representing insects of larger proportions. In the adjoining figure, a specimen is given of a powerful spring lure, with wings of variegated turkey feather, a body of orange camlet, mixed with mohair, and a brown cock's hackle. A thread of gold may be wound round the body for summer fishing. We refer to the work the 'Rod and the Gun' for further information on salmon-flies, which in all cases require to be dressed on double gut.

From dealers in fishing-tackle all sorts of artificial flies may be obtained at a reasonable advance upon the raw material; persons, however, who intend to make themselves masters of the art of angling, should not be dependent on tradesmen for their supplies, but learn to dress hooks for themselves. Mr Stoddart offers the following explicit directions on fly-dressing:—



Salmon-Fly.

'Our materials for the making up of flies are as follow:—Hooks, and small round gut; a pair of brass nippers for twisting hackles; a point for dividing the wings; a pair of fine scissors; orange, yellow, and green silk thread of all sizes; good cobblers' wax enclosed in a piece of soft leather; a hare's ear; some brown wild-rake, teal, and pheasant feathers; the fur of a mouse, squirrel, and water-rat; a few wings of lark, snipe, landrail, and starling; and lastly, red and black hackles, taken from the neck and head of an old cock at Christmas; these should be fully formed, and free from softness. Plovers' herls, and those of the peacock, are used by some, yet we deem them superfluous, as also tinsel, except for large flies.

Commencing your operations, the first step is to lay out the intended wings and body before you; wax your silk, and applying one end of it to the gut and hook together, wrap them both round four or five times, commencing a little below the end of the shank, and proceeding downwards; you then fasten, by drawing the disengaged end of the thread through under the last turn of the wrapping. Work the silk upwards to where you commenced, then take your wings, which are still unseparated, and lay them along your hook, so that their extremity or tips shall reach its curve; twirl the thread twice round the upper part, which lies along the shank top; then taking it under, press firm, and clip off the unnecessary portion of the feather; divide with your point or penknife, so as to form the two wings; take up the silk betwixt them, and wrapping again round at the head, bring it back crosswise; then lift your hackle, and lay the root of it down along your hook; whip the thread over, as far as your first fastening; seize the top of the hackle with your nippers, and whirl it round in the same manner; fasten and lengthen the body to your liking with fresh floss silk; fasten once more, and your fly is made. This last fastening ought, in our opinion, to be the same as that used in arming bait-hooks, for which we quote Hawkins's directions:—"When you are in about four turns of the bend of the hook, take the shank between the fore-finger and thumb of the left hand, and place the silk close by it, holding them both tight, and leaving the end to hang down; then draw the other part of the silk into a large loop, and with your right hand turning backwards, continue the whipping for four turns, and draw the end of the silk (which has all this while hung down under the root of your left thumb) close, and twitch it off." When the body of your fly is required to be of hare's ear or mouse skin, pull out a small quantity of the fur, and lay it along the silk, after the wings are formed; twist together, and then wrap as if the thread were bare, and fasten as above. In making flies, keep all tight, guard against heavy wings and much dubbing; the fibres of your hackle ought to be short and lie near the head of the fly; they are intended to resemble legs, which in the real insect are always so placed. Such is our method of fly-dressing, commendable both for its simplicity and expedition. It differs, we find, somewhat from that generally practised, being in a manner self-taught, and not encumbered with any unnecessary display.'

Having now described the various parts of the angler's apparatus, and the lures which he generally employs, we proceed to show how he is to practise his craft when fully equipped for the purpose.

PRACTICE OF ANGLING.

There are two distinct kinds of angling—bait-fishing and fly-fishing, and these are variously practised according to the depth, current, and state of the water, or the nature of the fish sought to be caught.

Bait-Fishing.

This kind of angling is practised to a great extent in the Thames, the Lea, and other deep and somewhat dull rivers of England. The fish usually sought for in these waters are gudgeon, dace, roach, bream, chub, barbel, tench, carp, perch, and pike; all are sometimes taken by fly, but a bait of worms, gentles, roe, or some other material, is commonly employed. The angler in these rivers usually stands on the shore while fishing, but in some instances he fishes from a punt, or small flat-bottomed boat, in which his chief occupation is to sit watching his float, and pulling in his line when a fish appears to be hooked. Among the apparatus of this order of deep-water fishers, a plummet and line is carried, in order to sound the depth of the river, which having ascertained, the angler puts his float upon the line, at that point which will allow the bait to trail slightly on, or just free of the bottom, while the float swims on the surface.

The first thing the bait-fisher has to learn is the art of baiting his hooks. Taking the hook in his right hand and the bait between his fingers in the left, let him enter the hook at the head of the worm, and carry it through the animal to near the tail, covering the entire hook and its tying. The worm should be broken or mangled as little as possible; and the more life-like it appears, the greater the probability of its proving an effectual lure. There must not, however, be too much spare worm left dangling from the hook, otherwise the fish will keep nibbling it away without biting at the bait bodily, and taking it into its mouth, the thing which the angler desires.

In throwing the line with bait, take care not to splash the water, but throw somewhat horizontally forward, so as to let the bait fall gently on the surface, and sink slowly in the water to the required depth. After sinking, the rod and line should be very slowly moved in a direction against the stream, or in some other way to give motion to the bait, which the fish perceiving to glide through the water, will hasten to seize upon. As fishes, however, are always on the outlook for floating garbage, one-half the dragging and twittering which bait-fishers generally employ is altogether useless, often positively hurtful, as scaring rather than alluring the objects of their capture.

Occasionally the angler will *feel* a nibble, but he must not be in a hurry to *strike*—that is, to draw the fish from the water. Perhaps it is no more than a nibble, and it is well to allow the fish time to get the hook in his mouth. If drawn too quickly, you may actually pull away the hook after it is half gulped. Experience and dexterity are required in this ticklish part of the craft. As a general rule, do not strike till the line has been distinctly tugged; then strike by a slow side motion at first, then a more quick jerk, so as to cause the hook to catch in the jaws of the animal. Supposing the fish to be hooked, do not draw it violently out of the water, as if in a transport of delight, but wind up part of your loose line if necessary, and holding up your rod, retire gradually backward, by which the fish may be landed on the shore. A good angler does not lay aside his rod to take a fish from the hook, unless it be of great size, requiring two hands; if small, hold the rod in the right hand while you catch the fish with the left; unhook it without mangling, place it in the basket, put on a new bait, and once more proceed to your sport.

The *gudgeon*, a fine large fish of the trout shape, affords a favourite amusement to anglers in the Lea, a river near London, and also in the Thames. Blaine thus speaks of this branch of angling:—'Fishing for gudgeons in the Thames is usually practised by means of a punt, which is fixed across the stream part of the river just above a tolerably sharp scower, running over a fine gravelly bottom, free from weeds, at depths varying from five to eight or ten feet. As the eddy is greater generally, and the water deeper in these scowers than in those of the Lea, so the tackle used is commonly somewhat stronger, and a fine gut-line is more frequently met with there than one of single hair. Fine tackle, however, in a good hand, is to be always preferred; and we have seen many hundred dozens of gudgeons taken in the sharpest currents of this river also with a single hair only for the two bottom links. Punt-fishing for gudgeon in the Thames is a delightful amusement, particularly to the luxurious angler who is not inclined to take much trouble. The scenery, the quietude, and safety from interruption, the cleanliness of the practice, where the bait is put on the hook by the attendant fisherman, and where even the prize it gains is removed by the same hand, all tend to make it epicurean in the extreme. But the thorough-bred fisher is soon tired with it after this method, for the very reason that there is actually too much luxury in it to constitute true sporting, which must of necessity present some labour to keep up the attention, and some difficulty to enhance the value of the prey. In the Thames, so many as fifty dozen of gudgeons have been taken in a day; but in the Lea seldom half that number are caught. Yet the Lea angler has the best scope for his sport, for he can commence it in March, whereas in all that part of the Thames within the liberties of the city of London, it must not be attempted until the beginning of June, at which time the gudgeons have spawned, and continue for some time afterwards inferior in point of their gastronomic worth. Gudgeon-fishing seems to have varied little from the ancient practice, and the angler who has aught of the antiquarian about him, will be amused probably at the close parallel between the present method and the gudgeon-fishing of early times, as it is described by John Davers or John Dennys, Esq., for it is a disputed point to which of these worthies the "Secrets of Angling," in which it is contained, owes its birth. Walton ascribes it to Davers, and gives the name at full length in the fifth edition of "The Complete Angler:"—

"Loe, in a little boat where one doth stand,
That to a willow bough the while is tied,
And with a pole doth stir and raise the sand,
Whereat the gentle streame doth softly slide;
And then with slender line and rod in hand,
The eager bite not long he doth abide.
Well leaded is his line, his hooke but small,
A good big cork to bear the stream with all.

His bait the least red worme that may be found,
And at the bottome it doth alwayes lie;
Whereat the greedy gudgion bites so sound,
That hooke and all he swalloweth by and by.
See how he strikes, and pulls them up as round
As if new store the place did still supply:
And when the bit doth die, or bad doth prove,
Then to another place he doth remove."'

The roach is a thick fish, deep from the back to the belly; it inhabits the bottom of deep rivers or lakes, and is usually reckoned so incautious and silly as to be called the water sheep; nevertheless, it is not taken without some degree of skill. It is angled for by means of bait sunk to within a few inches of the bottom. The fish may be attracted by throwing in some crumbs of bread. It is caught in the Thames some time after the end of August. The baits used are gentles, red paste, and boiled malt or wheat; one grain of the latter is sufficient. Great attention is required to strike quick when the bait is taken. Dace and tench are angled for much in the same manner. Carp is angled for in stagnant waters from February to September, and the baits are worms, larvæ, grain, and pastes. The perch also inhabits dull waters, and is a short unshapely fish, soft in the flesh, and seldom worth cooking. It is so eager to bite that little skill is required in pulling out a whole fry; the baits employed for it are worms, insects, and minnows.

Pike-Fishing.

The pike is a voracious fish, and may very appropriately be termed the fresh-water shark; it does not confine itself to feed on worms, insects, fish, and frogs, but will devour water-rats and young ducks, and attack much larger animals. All small fish are terrified at the approach of this marauder, which, if permitted, would soon clear a pond of all its finny tribes. 'Pike,' says Daniel, 'love a still, shady, and unfrequented water, with a sandy, clayey, or chalky bottom (arriving at a larger size in pools than rivers); and from May to the beginning of October they usually place themselves amongst or near flags, bulrushes, and water-docks, and particularly under the *Ranunculus aquaticus* when in flower, and which floats on the surface; they will sometimes be found in the termination of sharp currents; from March to the end of May they resort to back waters that have direct communication with the main stream; as winter approaches they retire into the deeps, under clay-banks, bushes impending over the water, stumps and roots of trees, piles of bridges, and flood-gates. They spawn in March or April, according to the coldness or warmth of the weather, quitting the rivers for the creeks and ditches communicating with them, and there dropping their ova in the grass and reeds; in ponds they choose the weeds upon the shallows for depositing it; ducks and other wild-fowl eagerly devour the spawn, and by them it is transported to other waters. The appearance of the pike in ponds where none were ever put, has been deemed as extraordinary as its asserted longevity; it is, however, easily accounted for upon the well-known principles of the generation of fishes. If a heron has devoured their ova, and afterwards ejected them while feeding in one of these ponds, it is highly probable that they may be produced from this original, in the same way as the seeds of plants are known to be disseminated.

Pike are in season from May to February (the female fish are to be preferred), are bold biters, afford the angler good sport, and may be fished for all the year; but the best months (especially for trolling) are February, before the weeds shoot, and October, when they have rotted down; the latter is to be preferred, as the pike are fattened by their feed during the summer; and from the lowness of the waters, their harbours are easily discovered.'

The same author thus describes the method of trolling for pike:—'For trolling, the rod should be twelve or fourteen feet long; but a strong top for this fishing, with a ring at the end for the line to run through, may be fitted to a fly or general rod; there should be one ring upon each joint to conduct the line, which is better than a greater number (and these rings must be set on straight, that it may run freely, so that no sudden check after the bait is taken prevent the pike from gorging it): the line should be of silk, with a swivel at the end to receive the armed wire or gimp, and at least thirty yards long, wound upon a winch or reel fixed to the butt end of the rod. Hooks for trolling, called dead gorges, and other sorts for trolling, snap, and trimmer, and fishing-needles, are to be bought at every shop where fishing-tackle is sold. In the choice of the first, let them not be too large, nor their temper injured by the lead on the shanks, nor the points stand too proud; and although usually sold on wire, it is recommended to cut off the wire about an inch from the lead, and with double silk well waxed, fasten about a foot of good gimp to the wire, with a noose at the other end of the gimp large enough to admit the bait to pass through, to hang it upon the line. The best baits are gudgeons or dace of a middling size; put the baiting-needle in at the mouth, and out at the middle of the tail, drawing the gimp and hook after it, fixing the point of the hook near the eye of the fish; tie the tail to the gimp, which will not only keep it in a proper position, but prevent the tail from catching against weeds and roots in the water; thus baited, the hook is to be fastened to the line, and dropped gently in the water near the sides of the river, across the water, or where it is likely pike resort; keep the bait in constant motion, sometimes letting it sink near the bottom, and gradually raising it. The angler need not make more than two or three trials in a place, for if a pike be there, he will within that time bite if he means to do so. When the bait is taken, if at a depth too great to see, it will easily be ascertained by the line being drawn tight, and by some resistance; let the pike have what line he chooses, it will be soon known when he has reached his harbour by his not drawing more; allow from five to ten minutes for his gorging the bait; wind up the line gently until the pike is seen (which he will permit though he has not gorged); should the bait be across his mouth, give more time; but if he has swallowed, manage him with a gentle hand, keeping him, however, from roots and stumps, which he will try to fasten the line upon; in clear water veer out line until he is sufficiently tired, and a landing-net can be used; but by no means, however apparently exhausted, attempt to lift him out with the rod and line only; for the moment he quits the water he will open his mouth, and from his own weight, tear the hook from his stomach; and the fish will be lost to the angler, although it must inevitably perish. In trolling, the bait should never be thrown too far; in small rivers, the opposite bank may be fished with ease; and the violence of its fall upon the water, in extensive throws, soon spoils the bait by rubbing off its scales, and alarms the pike instead of enticing him. Pike are to be allured by a large bait, but a small one is more certain to take them; never suffer weeds to hang upon the hook or bait when recast into the water, and which cannot touch the surface too softly. Always prefer a rough wind, and when the stream is clear, for trolling; pike never bite in white water after rain or freshets. If a pike goes slowly up the stream after taking the bait, it is said to be a signal of a good fish.'

Mr Stoddart's methods of angling for pike here deserve notice:—'In rod angling for pike, we adopt three methods, employing the gorge tackle, the swivel tackle, and the fly. Our gorge-hook is double brazed, and armed upon brass wire. A par or small trout inverted is the usual bait. We insert the wire of our tackle through the fish, bringing the upper end of it out at the tail, and allowing the two barbs of the hook to protrude from its mouth. In angling, we both throw and drop the bait, as the nature of the water demands, moving it slowly towards the surface. When a pike seizes it, there is at first no perceptible tug; one feels as if he heard the shutting of a pair of jaws on the bait; and if you can manage to see your fish, you will observe him holding your trout by the middle, as if crushing the life out of it. Keep a tight line, but do not pull or strike. Too much resistance places your intended victim on his guard; a little, however, sharpens his appetite. After a few seconds, the pike will begin to move towards his den, still grasping your bait betwixt his teeth, and intending to bolt it immediately. Let out line with your hand from the reel; and now he is fixed, and darts off like a tiger, shaking his chain, and with open mouth tossing himself out of the water at thirty yards' distance—the worst is over, and he turns revengefully towards the shore; wind up—ha! he is out again, and again he makes for the shallows; but the monster is exhausted and moves heavily; lead him with caution to the edge, lay down your rod, and lift him upon the bank. In order to disengage your hook from the entrails of this formidable fish, the gills should be forced open, and a knife introduced for the purpose, taking care previously to thrust it through the spine-bone of your victim, and so prevent the possibility of your catching a Tartar. Unfasten your hook from the wire before drawing the latter through the mouth of the pike, as otherwise it is again apt to catch among the teeth, from which it may be somewhat difficult to extricate it, without incurring a few scratches.

Should a fish, after having bitten, abandon your gorge-hook, try him with a running bait upon swivels, and let this be a fresh trout of a smaller size than your other, and fixed upon a gimp tackle with the tail downwards, as in minnow-fishing. See that it spins judiciously; and when the pike rises, let him turn with the bait before you strike. River pike, it may be remarked, seldom play so well as those in lochs. They push generally below the banks instead of striking across, and look out for old stumps upon which to entangle and break your line. One ought, therefore, to make quick sport with such rascals—running them down upon level banks in a twinkling, and before they are able to get under weigh.

The third method of angling for pike is with the fly—a kind of fishing not much in use, but still on some waters very deadly. The pike-fly should be large and gaudy, fabricated of divers feathers and tinsels, to resemble the king-fisher, or a huge dragon-fly. Use it in a strong warm wind, upon water from six to two feet deep, and near weeds. You will kill with it fish of various sizes, from ten inches in length and upwards: very heavy ones, however, refuse to take it, on account, probably, of the exertion necessary in order to come to the surface. We have always noticed that the biggest pike are caught during close sultry weather with a ground bait, and at those times when trout refuse food altogether; also at night, with set lines, in the summer months, when they leave the weeds and bulrushes in quest of food.

Although the pike is often nice and suspicious in places where trout abound, still, when provoked, he becomes bold and unwary, treating your presence as no constraint upon his temper and appetites. He will follow the bait to your very feet, and should it escape him, will retire a yard or two, waiting eagerly for its reappearance. When angry, he erects his fins in a remarkable manner, as the lion doth his mane, or the porcupine his quills; moreover, the pike appears careless of pain, if indeed fishes in general feel it to any great degree. We have actually landed one of these fish, couped him alive in our creel, and when by some negligence of ours he made his escape into the water, have succeeded a second time in securing him. On another occasion, we remember having a part of our tackle, consisting of a large double gorge-hook dressed upon brass wire, carried off by a pike; and yet, upon renewing it, the aggressor returned to the charge, and was taken. The former hook we discovered gorged by him in such a manner as must, we thought, not only have suffocated any other animal, but done so by the medium of the most exquisite internal agony.

Great injury has of late years been done by the transference of the pike to many of our best trouting lochs, where a single individual has been known to consume nearly its own weight of fish daily. This was the case on Loch Turit, near Crieff, where the trout, formerly abundant, are now greatly reduced by the hostile and merciless depredations of their natural enemy. The pike at table is reckoned by some a coarse dry fish, and so in general they are; yet to our knowledge, in certain lochs, for instance that of the Lowes in Selkirkshire, they almost rival the turbot, and should be cooked somewhat in a similar manner. They are none the worse for being kept a few days, especially if of any size. A good eating pike ought to weigh at least from five to twelve pounds—the smaller ones being without exception bad.'

Trout-Fishing.

The trout is of different species and varieties, as the common trout, the gillaroo or gizzard trout of Ireland, the bull trout, and the salmon trout. The shape is handsome; the flesh firm and sweet, and coloured pink or white, according to species and feeding-ground; and the weight varies from half a pound to four or five pounds. In one or other of its varieties, the trout is a universally-known fish in temperate climates; its favourite haunts are clear running rivers; and there, both in England and Scotland, it affords a favourite object of sport to the skilful angler. Sometimes bait is employed, but the fly is more common. In some cases the bait and fly must be tried alternately in one day, as the fish is capricious, and requires to be tempted in all kinds of ways. The season most favourable for trout-fishing is spring and early summer.

Fishing with bait.—'Trout,' says Blaine, 'begin to take a bait on or near the ground early in the year, and before March, will readily take most bottom baits all day long in favourable weather; but as the summer advances, it is only very early or very late in the day that they will take a bait near the ground, they being at the intermediate hours more disposed to rise to the surface for winged insects. In March and April, use the worm in the forenoon, and a fly or minnow, according to the state of the water, the rest of the day, in the swiftest and sharpest currents, provided the day be warm and bright, and in the deeps early and late; but if the water be discoloured, or very thick, try the gravelly shallows near the sides and tails of streams with a worm only, to run on the bottom with one large shot a foot at least from it. When there is a small *fresh*, or the water is clearing off, and is of a dark-brownish colour, first use the worm, which should be a well-scoured brandling, cast in as a fly at the head of the stream, and move it gently towards you, still letting it go down with the current, so as to keep it a little under water: the line should be rather short, with no lead upon it, and the hook fine; then try the minnow, and as the water clears, the artificial flies should be tried. In fishing for trout with the worm, use running-tackle, and employ a strong line, but let its strength consist in the excellence of its material rather than its bulk, to which end the hook should be small, the gut fine, the shotting fine also, and let the whippings be well concealed, for in bright water trout are singularly wary and suspicious. In some instances a float is indispensable; and when such is the case, let that likewise be as light and fine as the water will allow.'

A short line and quick striking are recommended by Mr Stoddart, who says the line 'ought always to be kept at its full stretch, and moved in a half circle with the angler. It requires some degree of perception to know the exact instant when the fish first seizes your bait; it does so with such softness, and with no likeness of a tug, as one is apt to imagine; nay, it merely closes its jaws upon the hook, as a gaping oyster would do upon one's finger. Then is your opportunity for striking; if you neglect it, you allow the trout its more leisurely process of nibbling, and its chances of escape. In striking with the short line, do it sharply, and never against the current, but rather with it, in a diagonal direction, and not too high. The reason of this advice is obvious, for all fish feed with their heads pointing up the stream—kindly giving you the choice of pulling the hook into or out of their mouths; the latter of which purposes you accomplish, to a dead certainty, by striking against the current. This whip-jack manner of bait-fishing is very deadly with an experienced hand. The long-line anglers make nothing of their method comparatively; and yet, among clear waters, and where fish are few, or bite shyly, patience and a long line will carry the day. Remarkably fine gut ought to be used by all ground anglers, whatever be the practice. Trout are a suspicious, distrustful set, and three in general slink off for one that nibbles, terrified no doubt by those singular accompaniments of your worm, a line and hook.

To all bait-fishers Scotland affords excellent sport; her rivers run so strongly, and are maintained by so many sources in the shape of mountain burns. These romantic streamlets abound in trout; every stone shelters its inhabitant, and the meanest pool is peopled with numbers. Burn fish, however, are generally of a small size; they seldom exceed a pound in weight, except in the spawning season, when larger ones ascend from broader streams, or lochs at a distance. Still, the taking of them is a pleasant pastime, especially when they bite eagerly at your worm, as they do during rain and in discoloured water. At such times, you have only to drop your bait without art, and the fish will manage its own ruin. Worms are taken greedily towards night and early in the morning; also when the sun is very powerful at mid-day. Akin to this sort of angling is fishing with salmon roe, concerning which we remark, that in autumn it is the most fatal method of capturing trout, and is coming much into practice in the south of Scotland.'

The same enthusiastic brother of the rod next proceeds to treat of minnow-fishing, which he says is by far the pleasantest mode of capturing trout, next to angling with the fly:—' If you wish to engage in this pleasant sport, provide your minnows by means of a small drag-net or hook. Select those of a moderate size, and which shine whitest. They may be salted, but are best perfectly fresh. The tail of a small trout or par is no bad substitute, if minnows cannot be had. Our only reason for preferring the fresh to the salted minnow is, that by its silvery appearance, and more rational form, it better attracts the fish; at the same time it is well known that a trout loves a salt bait, and will repeat its attack upon a minnow of that description, while it refuses to do so upon one newly taken. Fish in rapid streams, also in deep discoloured pools, and during a smart curl. Manage the minnow as you would your fly, throwing it down and across as far as you are able; bring it towards you about six inches or more below the surface, spinning rapidly by the aid of several swivels. When a fish rises, give him time before you strike; let him turn and gorge the bait, then strike sharply, and he is yours: all fly-fishers are apt to strike too soon, and miss the fish.

Trout seize a minnow by the middle or near the head, and you generally hook them on the upper hooks. In rivers where numbers of minnows are found, you must angle with the very smallest, not above an inch in length, and use a proportionate tackle. The trout in such waters love delicate tid-bits, and are absurdly nice in their feeding. Artificial minnows are sometimes employed by anglers, but generally fail, except in muddy waters and lochs. Mother-of-pearl makes one of the best imitation—there is a virtue in it which few fish can resist.'

'Trolling with par for large trout,' he continues, 'is a glorious pastime, especially on a Highland loch circled with mountain scenery—the craft of nature by incantation wrought, when the morning stars sang together. It needs intellect to enjoy it well, and a poet's heart to know its luxury. Take with you some choice and idle spirit, a rower he must be, that can manage your airy shallop as the winds do a weathercock—can chant a ballad of yore, of ladye and chieftain, and pranksome elf and kelpie wild—can speak to the echoes and to yourself, cheering you with wit and wisdom, and admiring your science and skill, and the gorgeous fish you are playing, twenty fathom off, with a strong and steady hand, your heart "high fluttering the while, like woman's when she loves."

Tackle for trolling should be dressed upon tried gimp. Bait as you do with a minnow; use a strong rod, heavy lead, and a long line of oiled cord wound upon an easy reel. Choose a sunny day, with a stiffish breeze, and troll near, but not amongst the weediest parts of the loch. Plant yourself at the boat stern, and get rowed gently at the rate of three miles an hour, letting out from twenty to thirty yards of line betwixt you and your bait. Trout from six to nine pounds' weight cause the best sport when hooked; a larger one seldom leaps or makes any violent exertion to escape; he swims sullenly, and at ease, regarding the angler with a sort of sovereign contempt. You must row after him, and turn him if you can before he gets among weeds; never slack your line for an instant, and look well about you. Land as soon as you are able, and play him from the shore. Your companion will assist you at the death.

So much for the different kinds of bait-fishing practised in Scotland. We esteem it folly to talk of the less popular baits used by the *virtuosi*—of frogs, grubs, and leeches, water-rats, and mice—all of which animals trout will devour. It might be asked, may fish not be taken with anything? They have been known to swallow money, rings, and many other glittering marvels; nevertheless they seem to have no pleasure in snapping at the bait of the unskilful angler, and refuse to die under his hands.'

Fishing with Fly.—This, after all, is the true angling, all other efforts at taking fish being either somewhat childish or murderous. A long flexible rod, fine lines, and appropriate flies, are the necessary equipment; and the best time for making the attempt is on a dark lowering day, at anyrate not in bright sunshine. If the moon has shone brightly the previous night, it will have prevented the trouts from feeding freely, and they will accordingly bite more readily when tempted with the artificial fly. Great skill and nicety are required in throwing the fly-line. Mr Stoddart gives the following directions how to proceed:—

'Your rod and tackle being ready, the wind in your favour down the river, draw out with your left hand a few yards of line from your reel, dip the top of your rod in the water, and with a rapid jerk you will lengthen as you wish that part you intend for throwing. A thirteen-foot wand will cast from six to seven fathoms of line. With a large double-handed rod you may manage a much greater length. Always, if you can, angle from a distance. Trout see you when you least imagine, and skulk off without your notice. Noise they care little about; you may talk and stamp like a madman without frightening them, but give them a glimpse of your person, and they wont stay to take another. Some ichthyologists attribute to them an acute sense of hearing: this we are disposed to question; for how happens it that the most obstreperous rattling of stones, when wading, causes no alarm, although conveyed to them through the medium of water, a good conductor of sounds? We remember angling one still night by St Mary's Loch, when our movements were heard distinctly by some shepherds at the distance of a mile, and yet the fish rose eagerly at our very feet, following our fly to the shallowest parts of the margin—a fact which, if it does not prove obtusity of hearing on the part of the fish, at anyrate renders it a matter of little consequence to the angler.

It requires some art to throw a long line. The beginner should commence with a short one, and without flies, lengthening it gradually as he improves. The best method of casting is to bring the rod slowly over the right or left shoulder, and with a turn of the wrist, make the line circle behind you, then, after a pause, fetch it forward again in the same manner, and your flies will descend softly upon the water. All jerks are apt to whip off your hooks or crack your gut. A fly-fisher may use two, three, or four flies on his casts, according to pleasure. When angling with small hooks, we adopt the medium number. Large ones ought to be fished with in pairs, and well separated. In throwing the cast, the lowermost or trail-fly should be made to alight foremost; its fall ought to be almost imperceptible; it should come down on the water like a gossamer, followed by the droppers. The moment a fly touches the surface, it is ten times more apt to raise a fish than during the act of drawing it along. At no time are we stanch advocates for the system of leading our hooks either against or across a stream; our method is rather to shake them over it for a moment, and then repeat the throw. A trout will discover your fly at the distance of several yards, if feeding, and will dart at it like lightning. Always, if you can, fish with the wind, and do not concern yourself, as some do, from what quarter it comes. In spring, no doubt, a south-west breeze is preferable to all others; yet we have seen even easterly winds not the worst on many waters, especially during summer months, when the natural fly is apt to become over-plenty.

Trout will sometimes take in the most unlikely weathers, so that the angler should not despair at any time. Hunger causes them to feed at least once in the twenty-four hours, and generally much oftener. If the wind blows down the river, commence at the pool head, and fish every inch of good water; you may pass over the very rough and very shallow parts, also those which are absolutely dead calm, and clear, unless you see fish rising in them, when, should your tackle be light, there is no harm in taking a throw or two. Dead water, however, when rippled or discoloured, may be angled in with great success. When you raise a good trout, strike slowly, or hardly at all; only continue the motion of your hand without slacking it; the fish, if large, will hook itself. Small trout and par may be whipped in with rapidity: it is folly to play or use ceremony with such trifles. Should the fish miss your fly altogether, give him another chance, and a third, if that will not do; a touch of your barb, however, will sharpen his wits, so as to prevent him from again rising. He prefers flies without stings. When you hook a trout, if you can, turn his head with the stream, and take him rapidly down. Thus you will exhaust him in the shortest time; whereas by hauling against the current, you allow him to swim freely in his natural direction, and also exert three times more strength upon your tackle than is really needful. A good-sized fish, handled in this foolish manner, can never be taken; it is impossible to tire him out, and the strongest line will give way to his resistance. When your victim is exhausted, draw him gently ashore upon the nearest channel or most level part of the margin. He will come in sideways, and generally lie motionless for a few seconds, during which time you will be able to run forward and seize him. Beware of catching hold of your line until he is properly banked. Many a famous trout have we seen lost by this inadvertence on the part of anglers, who think so to save time and labour. One should remember how the spring of the rod is thus removed, and how there remains no proper curb to the strength of the fish, which easily breaks a single gut, or tears itself from a sharp hook, and wishes the astonished angler better sport further on.'

The practice of double-rod fly-fishing for trout or for salmon is a murderous kind of sport, and should be prohibited by law. A line stretched between two rods, and hung with flies, is taken down the stream by two individuals on its opposite sides, so that every part of the water is gone over, and every feeding trout raised. By this plan large numbers are caught, but many also are wounded, and escape, to pine away for months at the bottom, unable either to feed or spawn.

Salmon-Fishing.

This may be described as a gigantic trout-fishing, the principle of alluring and capturing being the same, but all the tackle requiring to be stronger, and a greater degree of physical power being necessarily called into operation. The salmon has a peculiar habit very likely to upset the calculations of beginners: it consists of the ugly practice of running off at a violent speed as soon as he feels himself hooked, darting up the stream, throwing himself several times out of the water, and generally in the end hastening into some sheltered haunt under the banks where he expects to be safe. Great tact is necessary on these occasions, first to give line, and then to keep him from burying himself in these unapproachable nooks.

With respect to the minutiæ of the art, both in throwing and striking, the recommendations of Mr Younger of St Boswell's are well worthy of attention:—'I recommend a beginner,' says he, 'to practise throwing the line on a broad smooth pool, where he can see that it is delivered out properly, and falls lightly, without splashing. In such a case the practitioner will perceive something which he cannot easily account for: and that is, that after he has even attained a great degree of perfection in the art, he will not be able to distinguish how it happens that in one throw his long line will proceed direct out, his fly alighting first on the water; in another throw the middle of his line will fall first, while the further part, still obedient to the general impulse, will proceed out the full length, the fly falling the last on the surface. This last throw is not so good as the former; for this reason, that the main current having caught the middle of his line first, carries it too quickly down, leaving the fly lagging, to form an awkward curve, as, before it comes over above the fish, the fly should lie on the water, so as to have the appearance of plying at an angle against the current. And the angler should so manage his rod, that while he lets his line float round at its full length, yet to cause his fly to come as slowly as possible over the main spot. In this case the salmon will sometimes rise at once, rather before you expect him, but more generally will follow the fly to the eddy, or edge of the deep, where, if on examination he feel disposed to seize the hook, he has it before you perceive a head, fin, or tail above the surface. Indeed, before you perceive the web of his tail, he generally has the hook in his jaw a foot below water, as in descending he goes, like other divers, head foremost.'

Having managed to place the fly over the desired spot, our authority continues—'He will make no perceptible motion to keep his fly on the surface (except on a sluggish pool), but let it sink a little, depending on feeling rather than on sight; and though apparently keeping no pull on his line, yet all the while able to detect the touch of a minnow. On a *boil*, or other appearance of a fish, he pulls up his line, not twitchingly but actively, steps a yard or two back, rests a minute to let the fish resume his lair and attention, and perhaps feels inclined to alter his fly, before he annoy and disgust or alarm his fish, to a shade darker or a size smaller, when he will most probably come up and seize it in earnest. Should he not rise again, or rise and pass it thrice, leave him quietly alone for the present, and return to try him some time afterwards. On taking the fly, the fish means to return with it to his precise select *spot* of lair, on rock, stone, or gravel, at the bottom; and the fine angler, holding him gently, often in the first instance allows him to do so, but soon, too surely feeling his awkward predicament, he bolts off "indignant of the guile." Then is the time when the fisher is attentive; with the butt end of his rod resting on his thigh or groin, he keeps the top nearly erect, never allowing it to fall below the proper angle of forty-five degrees, as relative to the situation of the fish, as in this position the elasticity of the rod never allows the line to slacken in the least degree for a single instant, however the fish may shake, flounce, jerk, or plunge. With two or three fingers and the thumb of his left hand the angler holds his rod while the wheel-line runs out, regulated by the first or first and second fingers, relieved or assisted as occasion may suggest by the right hand, when it can be spared from its necessary occupation of rolling up the wheel line, as the fish settles a little or returns inwards. In this manner the fish is allowed to run right out, up, down, or across, as he may choose. But if in an outright dash of thirty or fifty yards salmon, ending in an outward-bound fling above water, the inexperienced angler should feel flustered, which he is very likely to do, and by some involuntary twitch of the running line let the top of his rod be pulled down to a level with his own head, then the tug of the last plunge will assuredly break his hook or line, or tear the hook from the mouth of the fish. Or, what is as bad, a sudden jerk or turn of the fish will give the line a momentary slackening, when the hook's hold, already so strained as to have widened its incision, will fall out, and your fish is gone for ever.'

Now is the critical moment for the salmon-fisher, who must keep up his rod and give line. 'The fish will then,' continues John, 'allow himself to be led at ease to the angler's side of the river, like a bridegroom to the altar, when, on finding the water shallowing, he will again make another desperate effort, probably a new dash into the middle current; but too much exhausted to resist the still continued pull upon him, he will soon again fall into the shallow, where, on a sight of his enemy, he is again alarmed into a new effort, and again exhausted by turning his outward-bound head down with the water, again and again, and again, as if the parties were in the amusement of forming circles, until his own last efforts to keep swimming are made subservient to the cautious angler in moving him by degrees into the shallow, where, half dry, he must, like all the strong, at last yield to his fate, and fall panting on his side, while the line rolled up to within rod length, which is to be held with its top landwards, without slackening, and the fisher seizing him with the fore finger and thumb of his right hand across by the root of the tail (which is by far the surest method of seizure), lifts or rather slides him out head foremost over gravel and grass, and in mercy fells him with a blow on the back of the neck.

After going through this process with a twenty-two pounder (and the process would be the same with a forty-four), the writer can aver, that he does not conceive that from the moment he has hooked such until he was laid on the grass he ever for an instant had three ounces of more or less pull on the fish; for in all circumstances of run, regularity of pull is the sure test of true skill and final success. Indeed I have seen many a fine fish laid on the dry gravel when the hold of the hook in the lip of his mouth was so slight as to be smaller than the steel of the hook—so much for equal pull and cautious management in the run. And, in short, a man is never a master angler so long as a desire to have his hooked fish to land excites in his feelings the least agitation, as the matter should be managed with that cool philosophical ease of mind which is alike above the paltry calculations of loss and gain and the common ridicule, which often tends to stir up a degree of childish fretfulness. This perfect nonchalance is absolutely necessary to first-rate excellence and ultimate success.'

Leistering is the name usually given to a murderous kind of sport pursued by salmon fishers in Scotland. Armed with *leisters*, or spears with three-barbed prongs, a set of fishers proceed to the river's bank, and there attract the fish by the glare of torches held over the water by members of the party. When a salmon is discovered, one selects it as his prey, and by a cool but rapid blow transfixes it with his spear. In many cases the fish cannot be secured or landed without plunging into the water; but this usually forms no obstacle, and several men may be seen floundering in the depths of the stream while shouts and confusion prevail among the spectators on the banks. Sir Walter Scott in his novel of 'Guy Mannering,' has presented a vivid picture of this species of sport, which is still pursued on the Tweed and its tributaries, but mostly by parties of rude marauders who are regardless of law, and kill vast numbers of fish during 'close time,' or when the rivers are legally shut. As the law at present stands, all salmon-fisheries north of the Tweed close on the 14th September; Tweed net-fishing on the 15th October; and Tweed rod-fishing on the 7th November. The fisheries north of the Tweed open on the 1st of February; and those of the Tweed, both for rod and net, on the 15th of the same month.

The Par.

The par is a small fish, which is found in great abundance in almost all rivers which are clear, and have a free communication with the sea. It varies in size of course according to its age, but seldom reaches a greater length than six inches, and is usually found below that magnitude. It is silvery in appearance, and marked by peculiar bluish bars or marks along the body; while a more nicely-forked tail, and one regular row of scarlet spots along the sides in place of two or three, aid further in distinguishing the par from the trout, the fish which it most resembles.

Of the actual character of the par, whether it is an independent species or the fry of salmon, there has been a long-continued controversy. Many naturalists were inclined to hold it as a kind of mule—a creature betwixt the trout and salmon breeds. The dispute, however, may be said to have been terminated recently by Mr Shaw of Drumlanrig, whose lengthened and ably-conducted experiments establish the par to be the natural produce or fry of the salmon. In a memoir communicated to the Royal Society of Edinburgh, Mr Shaw mentions that his first experiment on the subject consisted in the removal of a number of pars from their native stream to a pond, when he found that all of them assumed the perfect appearance of *salmon fry* or *smolts*, at the end of periods of time proportioned to their bulk when placed in the pond. He also satisfied himself that the change from the state of par to that of smolt, which is marked by the appearance of a covering of silvery scales over the blue bars, always takes place at the age of *two years*; and that then, for the first time, the metamorphosed fry take their downward departure for the sea.

But it was objected to these experiments, that Mr Shaw might have mistaken young salmon for pars in the first instance, so rendering his conclusions of no weight. To settle all disputes, he began his experiments with the *ova* or *eggs* of the salmon, first constructing ponds for their reception. These ponds, three in number, he protected by falls, pipes, and gratings, in such a way as to seclude them in a perfect manner from all interference on the part of any other fishes whatsoever. Having provided a proper net, Mr Shaw was successful in capturing a pair of adult salmon, male and female, while engaged in depositing their spawn. By expressing a portion of the ova from the female, and of the milt from her companion, he had it in his power to transfer fertilised ova to his ponds on the 27th of January 1837. 'On the 21st of March, fifty-four days afterwards, the embryo fish were visible to the naked eye. On the 7th of May, they had burst the envelop, and were to be found among the shingle of the stream. It is this brood which I have now had an opportunity of watching continuously for a length of time.'

Mr Shaw's descriptions of the brood, read to the Royal Society, and accompanied with specimens, will best show the general scope of the results. At the age of forty days after the exclusion from the egg, the symmetry of the young fish's form was but imperfectly developed. 'After the lapse of two months (7th July) the shape was found to be materially improved, and to exhibit in miniature much of the form and proportions of a mature fish. At the age of four months (7th September), the characteristic marks of the par were clearly developed. Two months later (six months old, 7th November), an accession both of size and strength was apparent; and on comparing the pond specimens with those of the river, no marked difference was perceptible. The average length at this time was 3 inches.

During the winter months, the general temperature of the rivers is so low, and the consequent deficiency of insect food so great, that the whole of the Scottish salmonidæ which inhabit the fresh waters during that season are well known to lose rather than gain in point of condition. The same rule holds in regard to the young salmon in the experimental ponds, although not to the same degree, they having maintained comparatively a superior condition throughout the winter to those found in the river of a corresponding age and size. The temperature of the ponds, averaging about 40 degrees during the winter, not only keeps the young fishes which occupy them in a more active condition, but the insects themselves are also more abroad, and thus afford a convenient supply of food not to be obtained by those at that time in the river, the average temperature of which, in ordinary winters, barely exceeds 34 degrees. I shall now refer more specially to the specimens before the Society.

Number six is a specimen from pond number one, of the age of nine months, taken in the middle of February 1838. It exhibits little or no particular accession of size or condition to that of number five, but may serve to show the general appearance of the several broods of the young salmon in my possession at the age of nine months.

Number seven is a specimen twelve months old, taken from pond number one, on the 10th May 1838. It is much improved in condition, as well as in external appearance, in comparison to that taken in February, and has exchanged its dusky autumnal and winter coating for that which may be called its summer dress. It measures about three and three-quarter inches in length, and is denominated, along with those of a corresponding age and size in the river, the *May Par*. Immediately after the migration of the two-year-old par (which the latter always effect about the beginning of May, under the name of salmon-fry), there is no other par, besides such as have been recently hatched, to be found in the river, save those which correspond with this specimen, which is the *Pink* of the river Hoddor, alluded to by Mr Yarrell. As the summer advances they increase in size, and are actually the little fish which afford the angler in salmon rivers so much light amusement with the rod during the months of August, September, and October. They remain over the second winter in the river, during which period the males shed their milt, and are found continuing their kind along with the female adult salmon, although still bearing all the external markings of the par, as I shall afterwards more particularly mention.

Number eight is a specimen eighteen months old, taken from pond number one, on the 14th November 1838. It measures six inches in length, and has now attained that stage when all the external characteristic markings of the par are strikingly developed, and, in point of health and condition, cannot be exceeded by any taken from the river. All the males, at the age of eighteen months, of the several broods in my possession, last autumn (1838) attained a most important corroborative stage—namely, that of showing a breeding state, by having matured the milt, which could be made to flow freely from their bodies by the slightest pressure of the hand. The females of the same broods, however, although in equal health and condition, did not exhibit a corresponding appearance in regard to the maturing of roe. The male and female pars in the river, of a similar age, are found respectively in precisely a corresponding state, which may surely be admitted as important evidence in support of the fact, that all these individuals are, in truth, specifically the same.

Number nine is a specimen two years old, taken from pond number one on the 20th May 1839, *after having assumed the migratory dress.* The commencement of the change, which was perfected by the whole of the broods about the same time, was first observable about the middle of the previous April, by the caudal, pectoral, and dorsal fins assuming a dusky margin, while at the same time the whole of the fish exhibited symptoms of a silvery exterior, as well as an increased elegance of form. The specimen in question, so recently a par, exhibits a very perfect example of the salmon fry or smolt.'*

These experiments, conducted in an unexceptionable way, were confirmed by other observations. Being satisfied that the par never migrated to the sea until the age of two years had been attained, and the change from par to smolt had taken place, Mr Shaw watched to discover the descending shoals. He was successful on three occasions. 'The first of these was in the first week of May 1831. I was able deliberately to inspect them as the several shoals arrived behind the sluices of a salmon cruive; and while they yet remained in the water, and were swimming in a particular direction, indistinct transverse lateral bars might still be seen; but as they changed their position, these became as it were lost in the silvery lustre. I also examined many of them in the hand, and could there also, by holding them at a certain angle in relation to the eye, produce the barred appearance; but when the fish were held with their broad side directly opposed to view, the character alluded to could not be seen. Its actual existence, however, could be easily proved by removing the deciduous silvery scales, when the barred markings became apparent, and of course continued so to whatever light exposed. The third opportunity to which I shall here refer occurred in May 1836, at which time, as I have stated, I compared a few of the descending smolts with those which (having been two years in my possession as par) had, in the confinement of the pond, assumed the corresponding silvery aspect of the salmon fry. The river during this month being remarkably low, I was thus enabled to ascertain more accurately the time during which they continued to migrate, which I found to be nearly throughout the whole of the month, but more especially in the course of the second week, in which the shoals were both larger and more frequent in their successive arrivals. Their external aspect was the same as that of the former shoals, and the average length, as usual, from six to seven inches.'

To conclude this subject, it may be added that pars are never found where salmon do not exist; and that large pars are always observed to disappear when smolts disappear; being, indeed, as Mr Shaw shows, the same animals slightly changed. Other points in the history of the par are fully elucidated by Mr Shaw, whose memoir the disciple of Walton would do well to consult. The same subject has more recently engaged the attention of several experimentalists who have arrived at similar results.

Pars are caught by the rod and fly, or with worm-bait, in the same manner as trouts; and fishing for them forms a common and amusing sport to the juvenile anglers in our Scottish rivers. At two years old—that is, after passing from the par state—the salmon weighs six or eight pounds, and generally requires five or six years to attain the weight of ten or twelve pounds. A young fish under two pounds weight is called a *salmon-peel*, and a larger one a *grilse*. The adult fish having spawned, being out of condition, and unfit for food, are considered as unclean. They are then termed *kelts*; the male fish is sometimes also called a *kipper*, and the female a *shedder* or *baggit*.

FISH PONDS.

Artificial ponds for the rearing of fish and supplying them when wanted for the table, were common in ancient times. The luxurious Romans possessed such preserves, and we learn that one belonging to Lucullus sold after his decease for upwards of £24,000. Comparatively little has been done in modern times in the way of establishing artificial ponds, and those which exist are chiefly to be found in noblemen's preserves. Yet artificial fish ponds may, with little or no trouble, be made to yield a large and regular supply of fish, and may be constructed at a most insignificant expense in any piece of low-lying waste ground intersected by a rivulet of pure water.

The fish most suitable for ponds are trout, carp, dace, roach, bream, tench, perch, and minnows. Eels also thrive in ponds; and what has frequently been a matter of surprise, these animals sometimes find their way to ponds of their own accord, without actual transfer. It is extremely probable that the spawn or young of eels and other fish is gobbled up and voided by birds in appropriate localities; there is at least no

* One or two of each of the three broods assumed the migratory or smolt dress at the age of twelve months.

other rational means of accounting for the spontaneous stocking of remote fish ponds and lakes.

The size of a pond may be from one to twenty acres; but a piece of water of from two to three acres is considered the most convenient dimensions. Of whatever size, the pond must not be overstocked, and it must not be left too long unfished. Fish ponds, to be on the most effective scale, should be in a series of two or three, the water running from the one to the other. This will allow means for periodical changing, if required, and for having a choice of fish. Some remarks of Daniel may here be introduced:—'In ponds so situated as to have communication with each other, never put into the upper of them either a pike, a bream, or a roach; the spawn will get through the gratings, and by that means all the lower ponds will unexpectedly swarm with them. The pike will destroy the fry of the carp and tench, and the two latter will consume all the food which should be the subsistence of both parents and progeny. Pike, bream, and roach should therefore on no account be ever put into the first or highest of a succession of ponds.' He continues—'Some have recommended, in raising carp, to have three ponds: one wherein the fish are to spawn (which is mostly from May to July), and in which they should continue during the summer and ensuing winter. A second for the convenience of nursing up the young fry, into which they should be put at the end of March, or early in April following, choosing a calm but not sunny day for their removal, and being careful to prevent their being destroyed when coming to the sides of their new habitation. In this pond they may remain two years, and become four, five, or six inches long. The third or main pond is for the reception of those that are so grown as to measure a foot or more in length, including their heads and tails.'

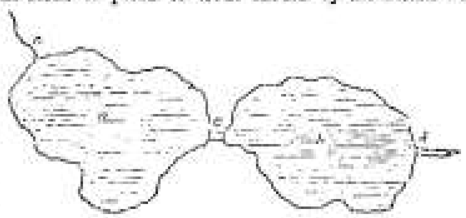
The proportions advised for the stocking these different ponds are—for the first sort, per acre, 'three or four male, and six or eight female carps, those of five, six, or seven years old, in good health, with full scale, and fine full eyes and a long body, without any blemish or wound,' are to be preferred. The pond must be previously cleaned of all sorts of voracious fishes and other animals, as 'perch, pike, eels, and trout; the water beetle, and also the frogs; the newts or lizards;' have a warm and open exposure with soft water, and all kinds of water-fowl kept from it. For the nursing pond, a thousand or twelve hundred carp may be not more than sufficient for an acre; and for the main pond, one to every square of fifteen feet is the allowed space, as their growth depends greatly on the room they enjoy and the quantity of food.' As to tench, which are not generally held in the estimation they deserve, Mr Yarrell recommends that large and fine fish be chosen as breeders, as being the most certain mode of obtaining sizeable fish for table in the shortest space of time. Two males to one female, or not less than three to two, should be the proportion of the sexes; and from the pond, which is found by experiment favourable for breeding, the small fish should be in part withdrawn from time to time, and deposited elsewhere, to afford more accommodation for all.

Our friend Mr Stoddart likewise treats of fish ponds, but mainly in reference to Scotland, where the fish must be of the hardier kinds—perch, pike, and trout. In either case the transfer of the fish to the ponds may be made with little difficulty. On being caught with a hoop-net, place them in large jars of water, and cart them to their new habitation; if this be inconvenient, they may be carried in wet moss or straw. All fish bear carriage best in winter, and better during the night than during the day.

'Ponds intended solely for perch do not require to be made large; they should slope gradually down towards the middle, from a depth of six inches to one of five or six feet. Water weeds ought not to be greatly encouraged. A series or chain of small basins, at different elevations, is preferable to a single large reservoir for this fish. These basins should be connected by a sluice and flood-gate, so that one may be readily emptied into another for the mutual convenience of cleaning and repairing. Also the uppermost ought to be shallower than those below, and more exposed to the sun, so as to serve for a nursery and breeding-pond. Bream live well with perch in a warm situation; they are not, however, obtained readily in Scotland. Perch ponds should be let off and paved with channel stones every four or five years; many allow them to remain fallow for some months, and others sow them with grass and oats—a conceit laboriously encouraged by theoretical writers of bygone days.'

The following engraving represents a pair of perch ponds: *a* is the upper or breeding-pond; *b*, the lower pond; *c*, a covered sluice with movable gratings; *d*, the sluice with outlet; and *e*, the small feeder.

'The pike-pond,' proceeds our authority, 'if for breeding and fattening to some extent, ought to be large, covering from eight to twenty acres; its mean depth six or seven feet. One end, however, should be much shallower, and sown with bulrushes or other water-plants. Previous to stocking it with this fish, a sub-stock of perch or trout should by all means be



introduced; otherwise, without a great supply of such sustenance, pike will not only become thin and ill-tasted, but quarrel and devour each other. To facilitate a steady supply of perch, small tanks should be constructed alongside of the leading preserve, with connecting sluices and flood-gates, so as to expel, when necessary, a shoal of live food.'

Our author next treats of trout ponds:—'Choose from six to twenty acres, less or more of an oval shape, but indented with small bays. Cast a long trench through the middle, from head to foot noticing that you can readily divert along it the stream just mentioned, which stream is intended as a spawning place, seeing that trout never shed their roe in dead water. Let this trench deepen gradually as the ground descends; so that at the intended foot of the pond it should sink nearly three yards, while the upper part thereof is kept shallow. Dig from either side of your trench, keeping its slope and level until within four fathoms of the intended margin of the fish pond. When this is done, turn your attention to what is called the dam-head, at the outlet or lowest part of the pond. From it continue your trench for a short distance in the form of a paved sluice. Build stones, grass-sods, and clay, along the bank on each side, if needful, and drive in a few piles to strengthen it. Then set a flood-gate at the outlet, and another to serve as a check in case of accident, three yards further down, where your paved sluice terminates. A few cart-loads of coarse channel, not from the sea, ought to be emptied over the earthy parts of your pond, which otherwise are apt to get covered with weeds, or else to encourage eels, the marked enemies of trout in all stages. After this is done, let loose your stream and form your preserve, introducing trout of about six inches in length, eight or ten to every acre. Raise also at the head a small nursery of minnows, connecting it by distinct sluices both with the pond and its feeder. These are favourite food of trout, and fatten them at a quick rate.'

To these remarks it may be added that little care need be taken to bring apparently fine breeds of any species of fish from a great distance, as what may seem poor fish at the period of transfer will greatly improve by good pond-feeding, and the easy unharassed life which they there enjoy.

SEA-FISHERIES.

Whether considered in reference to the natural history, the manual operations, or the economical advantages they involve, the marine fisheries of Britain form a subject of no inconsiderable interest. To the naturalist, the specific characters of the fish, their food, their migrations, and the seasons at which they become proper objects of capture, are points of attractive inquiry; while to the economist the various modes of capture and curing, the whole art, in fact, by which an unlimited natural production may be converted into a cheap and available source of human comfort, are matters of high importance. In the present sheet we mean to direct attention to this branch of our national industry—to its leading features in reference to the whale, seal, cod, ling, haddock, herring, pilchard, and the like—remarking at the outset, that in no department are our fisheries one-half developed, partly from imperfect modes of curing and preparing, but chiefly from the paltry and unskilful manner of capture. To this point we shall hereafter advert, urging not only the adoption of more skilful modes on the part of the fisherman, but the introduction of vessels constructed and equipped in a more systematic manner.

WHALE-FISHING.

The cetaceous order of animals, of which the whale is the most remarkable and important member, is distinguished by various peculiarities, which render it a link, as it were, between the creatures of the land and the sea. While living in part or wholly in the ocean, and so formed as to make their way through its waters with ease and velocity, the cetacea differ from the true fish-tribes in being *mammalian*, or suck-giving animals, in being warm-blooded, and in having organs for respiring the atmospheric air, like the ordinary inhabitants of the land. These striking distinctive features would be sufficient in themselves to render this order of animals an object of interesting study (see Zoology, p. 136); but the cetacea have also strong claims upon attention, as being of very great consequence to the wants and comforts of man. This is especially the case as regards the members of the whale family—*Balænidæ*—which form the subject of notice in the present section. With the exception of a few points, which will be noticed afterwards, the characters of the Greenland whale—*B. mysticetus*—are identical with those of the whole tribe, and by calling attention to the peculiarities of structure in this species, in the first instance, much repetition may be avoided.

Greenland Whale.

The size of the common whale was the subject of very exaggerated notions until within a very recent period. About fifty years ago, a standard writer in natural history asserted that whales were frequently 'to be seen above a hundred and sixty feet long;' and that even at this standard, the animal was much smaller than it had been before man began to disturb and destroy the race. Mr Scoresby, however, a very high authority on the subject, declares that the common whale seldom or never exceeds seventy feet in length, and is much more frequently under sixty. Out of three hundred and twenty-two whales which he had personally aided in capturing, *not one* exceeded fifty-eight feet; and the largest ever taken, of which he knew the reported measurement to be authentic, came up only to sixty-seven feet. The body of a large individual of this family measures from thirty to forty feet round the body at the thickest point, or a short way behind the head, which is of great proportionate size, and occupies about one-third of the whole extent from snout to tail. The bulk of the head, which is somewhat conical in form, and has a sort of round eminence above and posteriorly, renders the aspect of the mysticetus clumsy and unshapely. (See No. 9.) A very slight diminution of the circumference indicates the position of the neck, and behind this the body swells to its greatest calibre, whence it tapers sharply away again towards the tail. The animal has no back or dorsal fin. The two side or pectoral fins are placed about two feet behind the angles of the mouth, and are nearly five feet broad by nine feet in length. The tail is something in the shape of a crescent, with an indentation in the middle of the concavity, the convex side being united to the body. This appendage is placed horizontally, and is about twenty-four feet broad. It is an instrument of immense power, and the whale has sometimes given a stroke with it which has sent large boats high into the air in a thousand splinters. The colour of the body is mainly a velvety black; the under part of the head and abdomen, and the junction of the tail, being partly white, and partly of a freckled gray. In old whales, much more of the body assumes the latter tint, and the streaks sometimes resemble a beautiful landscape of trees. The eyes of the whale are about a foot behind the angle of the mouth, and are not much larger than those of the ox. The iris is of a white colour, and the organs are guarded by lids and lashes, as in quadrupeds. The two blow-holes of the whale, situated on the summit of the head, and descending perpendicularly through it for a length of twelve inches or so into the top of the windpipe, are the only other external features worthy of notice.

The mouth of the common whale is an organ of very wonderful construction. In a large specimen of the race, it may measure, when fully opened, about sixteen feet long, twelve feet high, and ten feet wide—an apartment, in truth, of very goodly dimensions. It contains no teeth; and enormous as the bulk of the creature is, its throat is so narrow that it would choke upon a morsel fitted for the deglutition of an ox. An inch and a-half is stated to be the diameter of the gullet in the very largest whales. From this peculiarity of formation, it may be anticipated that the food of the animal is of a very minute nature, notwithstanding the vastness of the cavity which is prepared for its primary reception. The animal is indeed supported upon a multitude of smaller inhabitants of the deep; and to permit this, its mouth is provided with a remarkable apparatus, composed of what is called the *baleen*, or the well-known *whalebone* of commerce. The baleen is arranged in two rows of laminæ or thin plates, projecting laterally from a line in the centre of the arch of the palate, somewhat like the laminæ of a feather. Towards the point of origin they are comparatively few in number, and strong, while towards the lips they divide and taper away into mere bristles, forming a loose hanging fringe or border. There are about three hundred of these plates on each side; and when dried, they weigh usually above a ton. The longest plate, which is always placed about the centre of the series on each side, measures about two feet in length by fifteen inches in breadth. The use of these elastic plates, with their pendulous fringes, is to retain, as in a net, the multitude of small animals which are floated into the mouth of the whale whenever it is opened. Were it not for such a drainer, formed by these fringes with the aid of the tongue, which is merely a great mass of fat tied down to the lower jaw, the emission of the water would be attended by the escape of all the objects which entered with it. As it is, the most minute matters are retained; and shrimps, sea snails, small crabs, medusæ, beroë, &c. are thus entrapped to support the great monster of the deep.

The remaining features in the structure of the whale need not be individually described at the same length. The skin consists, first of the scarf-skin, or epidermis, which is moistened by an oily fluid, enabling it to resist the action of water; secondly, of the *rete mucosum*, a layer usually held to contain the colouring matter of all animal surfaces; and thirdly, of the true skin, which, for particular purposes, is open in texture, so as to contain oil, or blubber as it is called, in great quantities. This mass of oil, surrounding the whole animal to a thickness of from one to two feet, and sometimes weighing more than thirty tons in all, serves the important end of keeping the animal warm by its weak conducting powers, amid the coldest recesses of the polar ocean, and is also calculated to resist the enormous pressure to which the body of the creature must be subjected at the depths to which it often descends. Moreover, being inferior in specific gravity to the water, it is obvious that all this body of oil must be of incalculable use in augmenting the buoyancy of the animal's frame. Below the skin are situated the muscles or flesh, and the character of this structure is much the same in the whale as in the ox or horse. With the exception of the tail, the arrangement of the various muscles of the whale does not differ very much from that of quadrupeds, and the same remark applies to the osseous structure. The fins are merely rudimental arms, containing nearly the same bones as in man, and the chest strongly resembles that of ordinary quadrupeds. The vertebral column of the rorqual whale contains sixty-three bones, those of the Greenland whale are not quite so numerous. The skull consists of the crown-bone, from which the facial bones and upper jaw project forward, while the lower jaw is composed of two long curved bones, that meet at the point or fore-part of the mouth. These are often put up over gates, and make a handsome archway. The whole of these bones are hard and porous, and some of them, as the lower jaw-bones, contain oil, but they have no proper medulla or marrow.

The organs of respiration in the whale are formed upon the same principle as those of land animals, but with modifications to suit the peculiar element in which the creature lives. It is plain that some provision was required to permit the whale to breathe, without the risk of having the lungs filled with water. This is accomplished by the extension of the top of the windpipe into the nostrils or blow-holes, or rather into the passage which terminates in these in the common whale. By this contrivance the creature can inhale air while it is feeding or has its mouth full of water. As with terrestrial animals, the air gives a red colour to the blood, or, in other words, oxygenates it, and sustains the animal heat. The whale has frequently to come to the surface, accordingly, to get its air, but this operation is rendered less frequently necessary by the provision of a reservoir of oxygenated blood, which can be drawn upon when required. This is the cause why the animal has such a vast proportionate quantity of blood in its frame. The brain of the whale is held by Cuvier to be large in relation to the animal, but no determinate conclusions have been reached on the subject. The arrangements of the whole nervous system are equally little understood. It is known that whales possess pretty acute vision, but there is a doubt whether or not they have any external ear. Their sense of smell seems to lie in the blow-holes; yet the strongest reason for ascribing such a faculty to them at all is founded upon the half-traditionary notion of sailors, that if certain strong-smelling substances are thrown overboard, whales will fly from the spot at once. The mammæ or dugs of the common whale are two in number, and attached to the abdomen; in the case of some other varieties they are placed on the breast. The milk of the animal is said to be rich and creamy.

Such are the general characters of structure in the whale tribe, and on regarding them attentively, one cannot but feel amazed at the seeming simplicity of the whole supplementary contrivances by which a mammalian animal, so thoroughly terrestrial, one would say, in its general formation, is fitted to live in the deep. The Greenland whale, or mysticetus, to which, more particularly, the preceding description applies, is said by Scoresby never to be found beyond the limits of the arctic seas. There is an excellent reason for this localisation. Within the polar latitudes, vast pasture-fields are spread out for the animal, which warmer climes have never been known to provide. These feeding-grounds, if they may be called so, consist of large tracts of *green water*, covering in all not less than twenty thousand square miles of the Greenland seas. This *green water* is of a deep olive hue, and remarkably opaque. Mr Scoresby discovered its peculiar appearance to arise from the presence of innumerable animalcules of the medusa family, one common species of which is known by the name of 'sea-blubber.' These creatures, many of which are visible only through the microscope, do not all directly serve as aliment to the whale, but they feed myriads of the smaller fishes upon which the whale does live. When feeding, it swims with open mouth under the water, and all the objects that lie in the way of that vast moving cavern are caught by the baleen, and make their egress no more. It is gregarious in its habits, being found in shoals, and migrating in this manner (according to most writers) from one ocean to another. When a herd of large ones is seen gambolling together, the sight is as magnificent as the range of nature presents. Let the reader imagine what an effect on the eye must be produced by the sight of one of these enormous living masses leaping right into the air, clear altogether out of the water. This is a feat which they frequently perform, to the high admiration of all who are at a safe distance. They effect it by means of their tail, which is the great instrument of motion, and which derives its prodigious power from the termination and concentration in it of all the muscles and tendons of the spinal column. With the aid of this same instrument they can travel through the water horizontally or downwards, at the rate of eight or ten miles an hour; but their usual undisturbed rate of travelling does not exceed four miles in that time.

When the Greenland whale ascends to the surface, which it does usually once in ten minutes, or at the most in twenty, it breathes nine or ten times, and a loud noise accompanies the act, along with an emission of light vapour in a straight column. This is called the *blowing* or *spouting* of the whale. When alarmed, it snorts much more loudly than usual. It is believed that some whales have other vocal organs, but the mysticetus seems to have no power of making noise but by the blow-holes. The spoutings of the whale consist of the ejection of jets of water to the height of twenty or thirty feet through the same apertures, in such a manner that the act is both seen and heard at the distance of several miles. There is a doubt among naturalists whether this be an ejection of mucus secreted in the blow-holes, or of water merely from the mouth. The quantity emitted would lead one at once to say that it must be water, were there not a doubt as to the possibility of water entering the blow-holes in this way. The most probable explanation is, that the animal, acting beneath the water, forces up the fluid by means of the air from the lungs.

No point relative to the habits of the Greenland whale affects one so much as the creature's love and care for its offspring. The period of gestation is supposed to be about ten months, and scarcely any dam has ever been observed to have more than one young one in attendance. In suckling, the mother throws herself on her side, for the convenience of her offspring, and this usually takes place on the surface of the water, to permit, no doubt, of free breathing. At birth, the young whale measures from ten to fifteen feet, and continues a nursling for about a year. It attains to its full growth very slowly; not sooner, according to most naturalists, than in twenty years. The whale-fishers turn the strong affection of the whale for its offspring to most fatal account. They try to strike the young one with the harpoon, and if they effect this, are sure of the old one, for she will not leave it. Mr Scoresby mentions a case where a young whale was struck beside its dam. She seized it and darted off, but the fatal line was fixed in its body. Regardless of all that could be done to her, she remained beside her dying offspring, without moving, until she was struck again and again, and finally perished. Sometimes, however, she becomes furious on these occasions, wheeling in rapid circles round the object of her affection, lashing the water with her tail, and anon dashing at the approaching boats with irresistible force.

The Greenland whale is captured, it is scarcely necessary to say, chiefly for its oil, about thirty tons of which are procured from the body of a large individual, being nearly the half of its whole weight. It is for this that mariners from all quarters of the civilised world expose themselves to the dangers and privations attending the pursuit of the animal in the polar seas. If recent statements be correct, however, these sufferings and risks may be greatly diminished by the adoption of new fishing routes. Scoresby, as has been mentioned, says that the Greenland whale is to be found only within the arctic circle; but other observers aver that the mysticetus, as well as other varieties, migrate southwards every year, and in reality make an annual tour round Cape Horn, beginning their travel about March or April. The main objection to this statement is, that the *green water* exists only near the poles, and that at the very time when these journeyings are said to be in progress, our fishers are finding and killing whales by hundreds in the north. At the same time it is undeniable that the whale is migratory in its habits, and the matter is worthy of a thorough investigation, as the establishment of fishing-stations in warm latitudes would prevent much of the suffering at present endured in the North-Sea fishing.

The Rorqual.

Being by far the most valuable and frequent object of the fisheries, the Greenland whale has received much more attention here than it is necessary to bestow on the great rorqual—*B. physalis*—though that variety exceeds all others in magnitude, and is indeed the largest of living creatures. Two specimens have been observed which measured the enormous length of one hundred and five feet. One of these, it is stated by Scoresby, was found floating lifeless in Davis' Straits, and the skeleton of the other was observed by Captain Clarke on Columbia River. This last individual, when alive, must have measured nearly one hundred and twelve feet, allowing six or seven for the tail, and it may therefore be regarded as the largest creature of which we have authentic measurement. Other specimens have measured a hundred, and others from ninety to eighty feet. That cast a-shore at North Berwick, and preserved by Dr Knox of Edinburgh, was eighty-three feet in length. The colour of the rorqual is a pale bluish-black, with the abdominal regions of a grayish tint. In shape, the body is not nearly so cylindrical as that of the mysticetus, but is compressed on the sides, and angular on the back. Hence the common name of 'razor-back;' and from the dorsal fin, which is low down, and of small size, springs the equally familiar name of 'finner.' The blubber of the rorqual is less abundant than that of the Greenland whale, and is seldom more than half a foot in depth, and eight or ten tons in weight; while its baleen also is much shorter, coarser, and everyway less valuable. This latter circumstance arises partly from the upper jaw being less arched than in the common whale. There is another cause for the inferior fineness of the baleen in the rorqual, which is the greater size of the objects which it employs as food. In the stomach of one individual, six hundred great cod, and immense quantities of other large fish, were found. The gullet, accordingly, is much wider than in the mysticetus. Another striking feature in the rorqual, and the one from which the name is derived, is an immense sort of fold or pouch along the under jaw. This was thought to be an air-bag or swimming bladder, till the observations of Dr Knox satisfied every one that it was merely a great water reservoir for augmenting the capacity of the mouth, otherwise so much diminished in this creature by the want of curve in the upper jaw.

The great rorqual has two blow-holes, through which it blows violently, and very loudly; and it swims with much speed, its rate of motion varying from five to twelve miles an hour. The species is very numerous in the arctic seas, and particularly about Spitzbergen and Nova Zembla. It is a much bolder animal than the mysticetus, and having so little oil in its frame, fishers seldom meddle with it, and dislike indeed to see it, as it is supposed to be avoided by the more valuable varieties of its race. If struck by the harpoon, it is excited to most dangerous energy; and on one occasion an individual drew a whole whaling-vessel, with its crew, with such violence on a bank of ice, that every man on board perished.

Spermaceti Whale.

The cachalot—*Physeter macrocephalus*—or spermaceti whale, of which there are several varieties, is distinguished by teeth in the lower jaw, by one blow-hole, and by the want of baleen. The leading distinctions between the various kinds of the sperm whale lie in the possession of two fins or three fins; of a spout in the neck or in the snout; of flat teeth or sharp teeth; and finally of a black, a blue, or a whitish back. But generally speaking, the characters now to be noticed are proper to all. The sperm whale attains to a great size, varying between sixty and eighty feet. The head is enormous in bulk, being fully more than a third of the whole body, and it ends like an abrupt and steep promontory in front. On the upper part of the snout is placed the blow-hole, often verging a little to one side; and it is a remarkable fact, that this is but one of the various deformities, whether congenital or acquired in the terrible battles waged by the creatures with one another, which are commonly found on the body of this whale. Its eyes are unequal, and the left frequently useless. The back has a greenish-gray tint, and below, much of the creature is white. On the back there are in most of the species one or two small fins, with large protuberances; the side fins are also of small size; but the tail is an instrument of amazing power. The teeth are usually about forty-two in number, and fit into depressions in the upper jaw. In this whale the gullet is wide enough to admit a man, and the animal feeds on large fish. A cephalopod mollusc (*Sepia octopus*), called *squid* by the sailors, is its chief food in deep seas. (See ZOOLOGY, pp. 177, 178.)

The size of head in the sperm whale has a very extraordinary purpose to serve. To assist in floating the animal, a great cavity in the interior of the skull is filled with a fine oil, which becomes concrete on cooling, and forms the spermaceti of commerce. Some of this oil is also found along the vertebral column; and in a bag in the intestines another valuable substance lies, the ambergris of traders. Some authors, it is proper to state, assert that the ambergris is merely the animal's fæces. These are the principal objects of the sperm whale-fishery, the blubber procured from this variety of the cetacea not being nearly so abundant as in the case of the mysticetus. At the same time, the blubber of the sperm whale is valuable, and is usually called sperm oil. The sailors know this whale at a great distance by the act of blowing, which it performs with great regularity, at intervals of ten minutes or so. The spout sent up is visible at a distance of two or three miles, and has the appearance of a misty cloud or bush. Having thus blown, or expired, sixty or seventy times, and made inspirations as often, the animal descends, and can remain under water more than an hour, subsisting on the store of blood which it has oxygenated, and keeps in the reservoirs already described. This alternation of appearances and disappearances is gone through by the animal with undevisiting regularity, unless it be disturbed. The sperm whale is timid before man, yet it fights fiercely with those of its own race. Fights usually take place when male whales, or 'bulls,' as they are called, and one or two of which always attend a particular herd of females, meet with rivals desirous of entering their company. They lock jaws with one another, and exert a dreadful degree of power at one another's cost. When alarmed, or harpooned, they sometimes roll over and over on the surface of the water in an amazing manner. Still they are not furious or dangerous towards the mariner, but are commonly killed with ease. The sailors call a herd a 'school,' and the old bulls the 'schoolmasters.' The females are said to be smaller than the males by a fourth. They are, like the Greenland whale, very fond of their young, and also of one another; so much so, that by cautious management, a whole herd may be destroyed, as they will scarcely quit a wounded companion.

Though exposing themselves on these occasions with so much simplicity, the sperm whales are nevertheless very careful to avoid peril in the first instance. They have the power of raising their heads perpendicularly out of the water to a very considerable height, and when in this attitude, which seems to be assumed for the purpose of viewing the surrounding expanse, they present the appearance of huge black rocks. They are said to have the ability also, on noticing any object, to communicate the intelligence to their companions, though the manner in which this is done remains a secret. Mr Beale gives it as his opinion that the sperm whale can communicate signals to a distance of four, five, and even seven miles. This cannot be effected by sounds, for, above water at least, the animal utters no noise whatever, if we except the hissing sound accompanying the act of respiration. With regard to its other habits, the sperm whale much resembles the Greenland whale. It is often seen, like its northern congener, to leap directly out of the water, or to *breach*, as the sailors call the action. Its purpose is to get rid of various sucking fish and crabs, which are fond of effecting a lodgment upon its mountainous body, and which often remain there till plucked from off the captured animal by the whalers.

The cachalot is seldom or never seen in the Greenland seas, at least by modern navigators. It is spread, however, over an immense expanse of the ocean, having been captured, at some time or other, almost everywhere between the latitude of 60° south and 60° north. The coasts of New Guinea and the adjacent archipelagoes, the shores of New Holland, Mitchell's Group, New Zealand, Navigator Isles, Ellis's Group, the shores of Peru, Chili, California, Japan, the Persian Gulf, the Chinese seas, the Moluccas, and many other regions of the ocean, abound more or less with this valuable cetaceous species.

Modes of Pursuit and Capture.

Whale-fishing is a practice of long standing in the world. It is natural to suppose that those nations dwelling on the shores of the arctic seas would be the parties earliest engaged in such pursuits; and accordingly we find that not only did the Norwegians and other Northmen precede all the other nations of Europe in this perilous but profitable line of enterprise, but they also were the first introducers of it among the southern nations. The shores of the Bay of Biscay, where the Normans formed early settlements, became famous, through them, for the whale-fishing there carried on. In the same region was it first made a regular commercial pursuit, and as whales then visited the Bay in great quantities, the traffic was convenient and easy. The Biscayans maintained it with great vigour and success in the twelfth, thirteenth, and fourteenth centuries. We find from the work of Noel, 'Upon the Antiquity of Whale-Fishing,' that in 1261 a tithe was laid upon the tongues of whales imported into Bayonne, they being then a highly-esteemed species of food. In 1338, Edward III. relinquished to Peter de Puyanne a duty of £6 sterling each whale, laid on those brought into the port of Biarritz, to indemnify him for the extraordinary expenses he had incurred in fitting out a fleet for the service of his majesty. The Biscayans, however, soon gave up the whale-fishing, from the want of fish, which ceased to come southward, no longer leaving the icy seas. The voyages of the Dutch and English to the Northern Ocean, in order to discover a passage through it to India, though they failed in their primary object, laid open the remote haunts of the whale. The British Muscovy Company obtained a royal charter, prohibiting all vessels but theirs from fishing in the seas round Spitzbergen, under pretence that it was discovered by Sir Hugh Willoughby. The fact, however, was, that Barentz, a merchant-seaman of Amsterdam, had discovered it in 1596; and neither Dutch, Spaniards, nor Frenchmen, were at all disposed to admit the justice or propriety of the claim made by the English. An extraordinary scene succeeded in the northern seas. The Muscovy Company sent out six or seven strongly-armed vessels, which took up a position near Spitzbergen, and commenced an attack on all foreign ships that refused either to quit the region at once, or pay the very moderate toll of one-half the proceeds of their fishing. The English succeeded so far as to annoy everybody else, and to prevent themselves from taking almost a single fish, so busy were they in looking after others. All the nations of Europe remonstrated loudly through their envoys against these proceedings; but the Dutch, ever fearless at sea, sent out a strong fleet, which effectually guarded their own fishing. At length, in 1618, a general engagement took place, in which the English were worsted. Hitherto the two governments had allowed the fishing adventurers to fight out their own battles; but in consequence of the event mentioned, it was considered prudent to divide the Spitzbergen bays and seas into fishing stations, where the companies might not trouble each other. After this period, the Dutch quickly gained a superiority over their rivals. While the English prosecuted the trade sluggishly, and with incompetent means, the Dutch turned their fisheries to great account, and in 1680 had about 260 ships and 14,000 sailors employed in them.

After the cessation of the Muscovy Company, a Greenland Company, with an actual capital of £45,000, entered on the trade, and in nine years came to a ruinous close. In 1725, the South Sea Company took up the adventure, and in eight years, after the outlay of a vast amount of money, they also were compelled to submit to a dead loss of their capital, and threw up the attempt. The legislature now tried a new scheme, being sincerely desirous to encourage and establish the trade, as well as to make it a nursery for seamen. In 1732, a bounty of 20s. a ton was granted to every ship of 200 tons burden that engaged in the fishing. In 1749, it was thought necessary to raise the bounty to 40s., when, as Mr M'Culloch observes, as many ships seem to have been fitted out for catching the bounty as for catching fish. But a trade supported on any other principle than that of direct benefit received from it by the parties engaged therein can never be of an enduring nature, and this truth soon appeared in the present case. In 1777, the bounty was reduced to 30s., the consequence of which was, that during the next five years the number of ships employed in the trade was reduced from 105 to 39! In 1781, the bounty was raised again to its old level, and an inducement was thus held out for the revival of the spirit of trade. But after all, what a million and a-half of money, expended in successive donations under the name of bounty, was totally inefficient to do, the spirit of private enterprise, once fairly awakened, speedily accomplished. The British whale-fisheries throve rapidly between 1781 and 1795; and the legislature found themselves justified in reducing the bounty, at intervals, from 40s. to 20s. The long continental troubles consequent on the French Revolution put a complete period almost to the Dutch fishing, while in the same space of time the British fisheries were continually improving, the conduct of them being left entirely to the private spirit of the nation. A small bounty, indeed, was given even down till 1824; but it was uninfluential, and was then withdrawn altogether. Of the change which has of late years come over the whaling traffic of Britain, a few words will be said before bringing the general subject to a close.

No species of fishery, prosecuted anywhere on the face of the ocean, can compare in intensity of interest with the whale-fishery. The magnitude of the object of the chase, and the perilous character of the seas which it peculiarly frequents, are features which prominently distinguish the profession of the whale-fisher from all similar pursuits, and which invest the details of its history with the strong charm inseparable from pictures of stirring exertion, privation, and danger. Such being the case, we shall present, chiefly from the writings of Captain Scoresby, the highest authority on the subject, a full description of the proceedings connected with the British whale-fishery.

The ships designed for the whale-fishery are usually from 300 to 400 tons in burden, and require to be very substantially built, in order to resist the pressure of the ice. With the view of increasing their strength, most of them have additional planks and timbers, and often also iron plates and stanchions, introduced into their structure, both internally and externally. Such appurtenances and provisions are technically known by the names of *doublings, treblings, fortifyings, pointers, carlings, &c.* Of course the whale-ship is also furnished with an ample stock of the apparatus and instruments used in the fishing, as well as with the peculiar boats which are employed in the capture.

The whale-boat is from twenty to twenty-eight feet in length, and provided with from four to six pair of oars. It should float lightly on the water, and be so formed as to move with speed, and to turn easily round. They are 'carver-built,' as it is called, and the best-made ones are composed of straight oak planks, suppled and bent to the required shape, by which means their elasticity is greatly increased. The rapid and dangerous movements of the whale render these various qualities indispensable. The principal weapons with which whale-fishers are supplied are the *harpoon* and the *lance*. The harpoon is an iron instrument about three feet long, and consists of three conjoined parts—the 'socket,' 'shank,' and 'withers,' or barbs. The socket is about six inches in length; the shank, which is between the withers and socket, is nearly eighteen inches long; and the withers are eight inches long by six in breadth. The united withers are triangular in shape, and the shank is fixed between them. The shank of the harpoon is the most important part of the weapon. It is formed of the most pliable iron, old horse-shoe nails being usually preferred for the purpose; and it is not more than four-sixteenths of an inch in diameter. Much attention is paid to the manufacture of the shank, because on its flexibility the retention of a harpooned whale depends. If the shank should break during the plunges of the whale, the animal is lost to the fishers. Unless the shank will bear to be wound round an inch bar of iron, in the form of a close spiral, and to be again unwound, it is held to be of imperfect materials. The socket is hollow, and strong, and swells, from the point of its junction with the shank, to a diameter of two inches. It is only necessary to add to this description of the harpoon, that each of the withers has at its point a smaller and reversed barb, like the beard of a fish-hook. The use of this provision is obvious.

The lance is a more simple instrument. It is nearly ten feet long, and consists of a hollow socket into which a fir stock is inserted, of a shank of iron about half an inch in diameter, and of a sharp flat point or tongue of steel, seven inches long by two in breadth. This instrument and the harpoon, together with lines and boats, are all the apparatus absolutely necessary for capturing the whale. Some ships have a harpoon gun, or a gun which projects the harpoon; but this weapon has been found extremely uncertain when put to use.

The ships destined for the Greenland fishery put to sea in March, or during the first days of April. The crew of one of these vessels usually consists of from forty to fifty men, comprising various classes of inferior officers, such as harpooners, boat-steerers, line-managers, carpenters, landsmen, and others. Steering from the direction of Shetland, on a course to the east of north, the whalers commonly reach and pass the west side of Spitzbergen in the end of the month of May. From this point they continue their course till they arrive at the latitude of 78° or 78½° (the best parallel for fish), or till they meet with whales. There is a remarkable indentation in the ice lying between longitude 5° and 10°, which the whalers for the most part strive to enter; but their course must be regulated greatly by the state of the ice. On reaching a fishing station where whales are seen, preparations are immediately made for commencing the business of capture. Two or three boats at the least are always kept suspended from cranes by the side of the ship, in such a position that they can be lowered into the water, with their complements of men, and the whole necessary apparatus, in the space of one minute. Previously to this time, the harpoons and lines have been got in order. The socket of the harpoon has been furnished with a stock or handle, six or seven feet long, and fastened in its place by means of a splice of strong rope, called a *foreganger*, the eye of which is kept firmly fixed to the iron of the harpoon by the *swelling* of the socket. To the loose end of the foreganger are attached five or six fathoms of line, called the 'stray line,' and this again is connected with the other lines of the boat. In each boat there are about 4320 feet of rope, neatly though loosely coiled up in six separate portions, and laid down in places appointed for the purpose. The line or rope is made of the best hemp, and is about 2½ inches in circumference. An axe, to cut the lines if necessary, a bucket to lave them, and keep them from being overheated by friction, and a few other articles, are also laid down in the boats.

Whenever there is a probability of seeing whales, the master, or some experienced officer, keeps a close look-out from the *crow's nest*, a station at the mast-head so called. With the assistance of a telescope he scans the surface of the waters around, ready, at the first glimpse of a fish, to give notice to the watch on deck. In fine weather a boat is kept afloat, manned, and engaged also in the look-out. The short time during which whales usually remain above water to breathe (being only two minutes), renders the discovery of them less easy than might be anticipated from their great bulk. Besides, while below water, the animal frequently traverses a space of half a mile in the ten or fifteen minutes intervening between the respirations; and hence the spot at which it may again rise, after being once seen and again disappearing, is left in a great measure a subject of conjecture. The previous direction of the whale's movements, and occasionally a sort of eddy on the surface, are the only guides to the boatmen in this particular. When the whale does come up within reach of a harpoon-cast, and lies unconscious of the approach of its enemies, 'then,' says Captain Scoresby, 'the hardy fisher rows directly upon it, and an instant before the boat touches it, buries his harpoon in its back. But if, while the boat is yet at a little distance, the whale should indicate his intention of diving, by lifting his head above the common level, and then plunging it under water, and raising its body until it appear like the large segment of a sphere, the harpoon is thrown from the hand, or fired from a gun, the former of which, when skilfully practised, is efficient at the distance of eight or ten yards, and the latter at the distance of thirty yards or upwards. The wounded whale, in the surprise and agony of the moment, makes a convulsive effort to escape. Then is the moment of danger. The boat is subjected to the most violent blows from its head or its fins, but particularly from its ponderous tail, which sometimes sweeps the air with such tremendous fury, that both boat and men are exposed to one common destruction.

The head of the whale is avoided, because it cannot be penetrated with the harpoon; but any part of the body between the head and tail will admit of the full length of the instrument, without danger of obstruction. The harpoon, therefore, is always struck into the back, and generally well forward towards the fins, thus affording the chance, when it happens to drag and plough along the back, of retaining its hold during a longer time than when struck in closer to the tail.

The moment that the wounded whale disappears, or leaves the boat, a jack or flag, elevated on a staff, is displayed, on sight of which those on watch in the ship give the alarm, by stamping on the deck, accompanied by a simultaneous and continued shout of "a fall!"* The sleeping crew, roused by the sound, jump from their beds, rush upon deck, with their clothes tied by a string in their hands, and crowd into the boats, at a temperature of zero. They generally contrive to dress themselves, in part at least, as the boats are lowered down; but sometimes they push off in the state in which they rise from their beds, row away towards the "fast boat"—that is, the boat attached by its harpoon and line to the whale—and have no opportunity to clothe themselves for a length of time afterwards.

The first effort of a "fast fish," or whale that has been struck, is to escape from the boat by sinking under water. After this, it pursues its course directly downwards, or reappears at a little distance, and swims with great celerity, near the surface of the water, towards any neighbouring ice among which it may attain an imaginary shelter; or it returns instantly to the surface, and gives evidence of its agony by the most convulsive throes, in which its fins and tail are alternately displayed in the air, and dashed into the water with tremendous violence. The former behaviour, however —that is, to dive towards the bottom of the sea—is so frequent, in comparison of any other, that it may be considered as the general conduct of a fast fish.

A whale struck near the edge of any large sheet of ice, and passing underneath it, will sometimes run the whole of the lines out of the boat in the space of eight or ten minutes of time. This being the case, when the fast boat is at a distance, both from the ship and from any other boat, it frequently happens that the lines are all withdrawn before assistance arrives, and, with the fish, entirely lost. In some cases, however, they are recovered. To retard, therefore, as much as possible the flight of the whale, it is usual for the harpooner who strikes it to cast one, two, or more turns of line round a kind of post called a bollard, which is fixed within ten or twelve inches of the stern of the boat for the purpose. Such is the friction of the line when running round the bollard, that it frequently envelopes the harpooner in smoke; and if the wood were not repeatedly wetted, would probably set fire to the boat. During the capture of one whale, a groove is sometimes cut in the bollard, near an inch in depth; and were it not for a plate of brass, iron, or a block of lignum vitæ, which covers the top of the stem where the line passes over, it is apprehended that the action of the line on the material of the boat would cut it down to the water's edge in the course of one season of successful fishing. The approaching distress of a boat, for want of line, is indicated by the elevation of an oar, in the way of a mast, to which is added a second, a third, or even a fourth, in proportion to the nature of the exigency. The utmost care and attention are requisite on the part of every person in the boat when the lines are running out; fatal consequences having been sometimes produced by the most trifling neglect. When the line happens "to run foul," and cannot be cleared on the instant, it sometimes draws the boat under water; on which, if no auxiliary boat or convenient piece of ice be at hand, the crew are plunged into the sea, and are obliged to trust to the buoyancy of their oars, or to their skill in swimming, for supporting themselves on the surface. To provide against such an accident, as well as to be ready to furnish an additional supply of lines, it is usual, when boats are sent in pursuit, for two to go out in company, and when a whale has been struck, for the first assisting boat which approaches to join the fast boat, and to stay by it until the fish reappears. The other boats likewise make towards the one carrying a flag, and surround it at various distances, awaiting the appearance of the wounded whale.

The average stay under water of a wounded whale, which steadily descends after being struck, according to the most usual conduct of the animal, is about thirty minutes. The longest I ever observed was fifty-six minutes; but in shallow water, I have been informed, it has sometimes been known to remain an hour and a-half at the bottom after being struck, and yet has returned to the surface alive. The greater the velocity, the more considerable the distance to which it descends, and the longer the time it remains under water, so much greater in proportion is the extent of its exhaustion, and the consequent facility of accomplishing its capture. Immediately on its reappearing, the assisting boats make for the place with their utmost speed, and as they reach it, each harpooner plunges his harpoon into its back, to the amount of three, four, or more, according to the size of the whale and the nature of the situation. Most frequently, however, it descends for a few minutes after receiving the second harpoon, and obliges the other boats to await its return to the surface before any further attack can be made. It is afterwards actively plied with lances, which are thrust into its body, aiming at its vitals. At length, when exhausted by numerous wounds and the loss of blood, which flows from the huge animal in copious streams, it indicates the approach of its dissolution by discharging from its blow-holes a mixture of blood along with the air and mucus which it usually expires, and finally jets of blood alone. The sea, to a great extent around, is dyed with its blood, and the ice, boats, and men are sometimes drenched with the same. Its track is likewise marked by a broad pellicle of oil, which exudes from its wounds. Its final capture is sometimes preceded by a convulsive struggle, in which its tail reared, whirled, and violently jerked in the air, resounds to the distance of miles. In dying, it turns on its back or on its side, which joyful circumstance is announced by the capturers with the striking of their flags, accompanied by three lively huzzas!'

The writer of this animated description points out how remarkably nature seems to assist man in the capture of the whale. By no efforts of its human assailants could the strength of the creature be so far reduced as to permit of its destruction, were it not that its descent, through fright, to a depth of 700 or 800 fathoms, must subject its body to the exhausting pressure of more than 200,000 tons of superincumbent water! It is through this cause, rather than from the wounds the whale has received, that it comes to the surface in so helpless a state of exhaustion. The space of time in which different individuals are captured and killed varies considerably, and in part, for the same reason. Large whales have been sometimes killed in twenty minutes, while in other instances the animal costs his assailants a struggle of sixteen hours' duration, and in some cases much more, and may escape from them after all. The average time, under favourable circumstances, is one hour; but two or three hours are no uncommon period for the contest to last, even in favourable circumstances. Two harpoons usually despatch a whale of middling size, and its movements may commonly be restrained within the limits of 600 fathoms of line. On the career or flight of a first-size whale no check can be placed, until its own exertions exhaust its powers. On the other hand, the ease with which some whales are subdued, and the slightness of the entanglement by which they are taken, have often

* The word "fall," as well as many others used in the fishery, is derived from the Dutch language. In the original it is written *val*, implying jump, drop, fall, and is considered expressive of the conduct of the sailors when manning the boats, on an occasion requiring extreme despatch.

been the cause of agreeable surprise to fishers—the accidental coil of a harpoon line round the body, or even the mere grasping of one between the jaws, having been known to alarm the animal so much, that it exhausted itself almost as speedily as though regularly struck by the harpoon.

The whale-fishing is apt to be impeded, as may readily be imagined, by the great masses of ice everywhere abounding in the northern seas. The usual course of proceedings in open water has been described; in different circumstances, different plans must be adopted. *Pack-fishing* is the name given to the chase of the whale on the borders of close packs of drift-ice. The animal loves to shelter his vast bulk under the ice of these frozen masses, and when struck, usually flies to them for refuge, thus endangering the lines and lives of the whalemen. The common method of providing against such contingencies is either to strike the fish with two harpoons from different boats at the same moment, or to affix the line of a second boat to that of the one from which the whale has been harpooned, so that the strength of two lines is brought into play against the fish. Sometimes, when a fish gets entangled in the drift-ice, the adventurous seamen climb over it, and lance the animal from that perilous station. Altogether, pack-fishing is troublesome and dangerous, and were it not that the largest whales very frequently resort to such situations, whalers would seldom attempt to fish there.

On the other hand, *field-fishing*, as it is called, or fishing on the edges of those wide connected plains of ice termed fields, is one of the most productive of all the modes of fishing prosecuted in the Greenland seas. When the weather is tolerably mild, it is also a pretty secure mode. The most marked of the advantages held out by field-fishing is the curtailment of the range of the whale's movements. When harpooned, it commonly descends obliquely beneath the field, and, being unable to rise through the ice, is forced to return to the edge, or nearly to the spot where it made the plunge. Thus the ship's boats, if stationed along the margin of the field, can at once harpoon it a second time, and despatch it. In open water, the whale, by rising at a spot far apart from where it dived, gains time to breathe freely and recruit its strength, and so either breaks away altogether, or greatly protracts the struggle. For this reason, six boats at a field will do the work of twelve in open sea. Two or more fish are frequently taken at a field at one time, and on a particular occasion six fish were actually captured at once by the seven boats of a single ship. Even in such weather as renders fishing impracticable elsewhere, field-fishing can be prosecuted with success. But there are disadvantages also attendant on this mode. The movements of fields of ice are so rapid, various, and unaccountable, and their powers of doing mischief so unlimited, that the utmost prudence and skill cannot entirely secure vessels lying in their vicinity from the risk of severe damage or total destruction. Small fields or floes are especially dangerous, particularly if they contain small cracks or holes in the centre of them. The chance of a sudden movement in such floes is much greater than in the case of the large fields; and moreover, after being struck, the whale generally makes for the apertures in the ice, and there breathes freely, rendering it necessary for the men to cross the field on foot, and despatch their prey with the lance. Even when they succeed in doing this, there is no way of getting out the whale but by sinking it, and dragging it from below the ice, at the great risk of pulling out the harpoon altogether; or by cutting the blubber away, and transporting it over the surface of the floe piece by piece. These operations are attended with vast labour and loss of time.

If whalers could choose their own ground for fishing, many of them would probably prefer a position among open, navigable drift-ice, where the force of the sea is broken, and heavy swells prevented from affecting the vessel. This kind of fishing is called *open pack-fishing*, and is held to be advantageous for the capture of whales. Where the ice is crowded, however, and affords room only for boats to pass through it, the chase becomes difficult and hazardous. Still, as the fishers must take the seas as they find them, fishing is often conducted in this situation of things. Success depends on the boats being spread widely, on the incessant watchfulness of the harpooners, and on their occasionally taking the benefit of a mass of ice, from the elevation of which the fish may sometimes be seen blowing in the interspaces. Celerity in rowing, and the highest degree of activity in all the proceedings, can alone secure success in open pack-fishing.

Whalers must also be prepared to meet and combat all the difficulties attending the prosecution of their employment in *storms* and *fogs*. When a gale occurs during a chase, and after a fish has been harpooned, fishers are often obliged to cut the lines, and let their prize go. Sometimes this takes place even when the fish is killed; and it is worthy of remark, that a whale so abandoned becomes the lawful prize of the ship that first gets hold of it, though this may occur in the face of the original captors. But it is common enough for whalers during a storm to keep a fish secured by a hawser to the ship, and to retain it thus till the return of moderate weather. Few whalers venture to commence fishing while a storm exists, and it is a matter of equal difficulty and uncertainty to fish during a fog. The mist on such occasions is so thick, that it is impossible to see objects, however large, above 100 or 150 yards off; and when a boat is led away by the chase to such a distance that a bell or a horn cannot be heard, its situation becomes very perilous.

Captain Scoresby gives an interesting account of the plan pursued by himself in *bay-ice fishing*. Being locked up with his ship in a field of thin bay-ice, that was unfit in many places to bear a man's weight, he placed a number of boats in various openings which existed a short way from the vessel. When a whale came to those apertures to breathe, it was struck, and the men endeavoured to drown it, when it darted below the ice, by keeping a steady strain on the line. If this plan failed, Captain Scoresby planted his feet in a pair of ice-shoes, formed simply of thin deal-boards, to the centre of which the feet were tied, and then he boldly crossed the thin ice to the point where, by the direction of the line, he knew the fish would rise. In three instances he was fortunate enough to see the whale through the ice, and to plunge his harpoon into its body, after which he used his lance, till in each case the fish was killed. The fish actually rose once or twice beneath the very spot where he stood, and broke through the ice with its head. He was lucky enough to escape all injury, however, though the ice in most places could not have borne the weight of a boy standing in common shoes.

Of course, in all these various ways of fishing, circumstances now and then occur which set at defiance all ordinary rules. The whale, for example, when struck near the margin of a small floe, is usually held in restraint, and killed by the use of the lines from at most *two* boats; but instances are known where the lines of three and even four boats have been insufficient. In 1812, the *Resolution* of Whitby ran out nearly six miles of lines before the final capture of a middle-sized fish. Nor does the harpoon always produce a fatal loss of blood, even after the lapse of a considerable period. An Aberdeen whaler struck a fish, which got off in consequence of a storm occurring, and rendering it necessary to cut the lines. Next day the same fish was struck, and again got off; and on the third day the identical whale was harpooned and captured.

Having killed a fish, the first operation performed by the sailors is to pierce two holes in its tail, and to lash it to a boat. The fins are also roped to the body, and then the whole of the boats, joined in a line, unite their efforts in towing it to the ship. Here it is placed with its side parallel to that of the vessel, and is arranged for the operation of *flensing*. In consequence of its enormous weight, it cannot be raised altogether out of the water. Only about one-fifth part of its body is brought above the surface, and here it is firmly secured by ropes, with the abdomen uppermost. Men, armed with spurs on their feet to prevent slipping, then leap on the body, and begin to divide the fat and skin into separate pieces or compartments by means of blubber knives or spades. A hook called a spec-tackle, which hangs from a capstern or winch on deck, is attached to each piece of fat, and draws it upwards as it is flayed off. Pieces weighing from half a ton to a ton are taken up at a time in this manner, and are cut on deck into smaller pieces, which are then cast down into the main hatches and stowed away. On the blubber being removed from one part, the whale is turned partially round by the ropes and windlass, and this cutting and turning are repeated until the whalebone and blubber have all been removed. The stripped carcass is then allowed to sink. A British whaling-crew will usually flense a common-sized whale in four or five hours. The operation is followed, when the flens-gut, or blubber-box, under hatches is filled with blubber, by another process which is termed *making-off*, from its being the finishing process. The blubber is brought on deck, separated from the skin and fibrous or muscular structure, cut into pieces of a few inches in size, and finally introduced into casks through the bung-hole.

The instinctive fear of being enclosed in the ice during the cold seasons, and of finding no apertures for respiration, appears to be the reason for the descent of the whales into the open and more southerly seas. In the month of July, when the ice becomes broken, the cetaceous tribes again enter the arctic waters, and are unassailable by fishers. The whalers, with a lesser or greater amount of cargo, or perhaps, if they have been very unlucky, with what is emphatically called a *clean* ship, are then obliged to return home to their respective ports, where the blubber is separated from its refuse, and converted into oil by boiling, and the whalebone scraped, cleaned, and dried for sale. These operations require no special description, the names of the processes sufficiently indicating their character. The greatest cargo ever borne to the shores of Britain by a whaling vessel was that brought from Spitzbergen by Captain Souter of the Resolution of Peterhead, in the year 1814. It consisted of 44 whales, which produced 299 tons of oil, value, reckoned at £32 per ton, the average price of that year, £9568; and when to this sum is added the value of the whalebone, and the bounty, the freight would appear to have reached £11,000. When oil rose to £60 per ton, smaller cargoes, in several instances, amounted to an equal value. In 1813, the Scoresbys, father and son, respectively brought home cargoes which produced £11,000. Captain Scoresby, senior, in the course of 28 voyages, captured the immense number of 498 whales, the oil and whalebone of which amounted in value to above £150,000. But few cargoes produce such sums, it must be allowed, as £11,000, and few men have such a career of activity to look back upon as Captain Scoresby.

Statistics of the Greenland Whale-Fishery.

In the years 1814, 1815, 1816, and 1817, 392 vessels sailed from England, and 194 from Scotland, for the whale-fishery. Of these, the port of Hull, which has long taken the precedence in this trade, sent out not less than 229 vessels, while London, Aberdeen, Leith, and Whitby, the next in proportion, sent out respectively 77, 55, 40, and 39. The total number of whales killed by British ships in the same years was 5030. They yielded 54,508 tons of oil, and 2697 tons of whalebone. The average to each ship was 8·6 whales, 93 tons of oil, and 4·6 tons of whalebone. By comparison with the following more recent years, the progressive condition of the trade will be seen. In 1821, when the number was greatest, there were 159 ships, of 50,709 tons, and with 7385 men, engaged in the service; in 1824, 111 ships, of 35,013 tons, and 4640 men. In 1829, a great falling off had taken place, the ships numbering only 89, of 28,812 tons. During the years consequent upon that period, a still greater decline took place in the number of employed whale-ships. In 1832, there were only 81 engaged in the trade. In 1837, the number was reduced to 52; and in 1842 to 18. This unfortunate change—for every declension in commerce, generally speaking, must be held a misfortune—merits some attention.

The decline of the British northern whale-fisheries appears to be owing to three principal causes. In the first place, the introduction of gas into universal use of late years in the island has materially lessened the demand for whale-oil and the necessity for its supply. In the second place, the former fishing-fields around Spitzbergen have been greatly exhausted, and whalers have been under the necessity of venturing into more perilous latitudes for the objects of their pursuit. The third cause is in a measure a corollary of the preceding one. In consequence of entering the broken ice of Davis' Straits and other similar seas, a loss of life and property has taken place of late years so extensive, and alarming, that mercantile men have become unwilling to risk their capital, and seamen their existence, in such ill-fated expeditions. The great increase of danger is shown by the fate of the fishing-vessels during the last few years, as compared with the results of former ones. Of 586 ships sent out in 1814, 1815, 1816, 1817, only 8 were lost. In 1819, out of 63 ships sent to Davis' Straits, 10 were lost; in 1821, out of 79, 11 were lost; in 1822, out of 60, 7 were lost; and in 1830, not less than 19 out of 91 were lost. The mischief has progressively increased. In 1837, the Davis' Straits whale-fleet lost several of its number, and many vessels were locked up in the ice through the winter, to the loss of the greater part of their crews, and at the cost of almost unparalleled sufferings to the petty remnants of them which escaped with life. And while the perils of the trade have thus largely increased, the profits, owing to the greater difficulty of finding whales, have suffered a corresponding decrease. In 1830, 21 out of the 87 vessels sent out to Davis' Straits returned *clean*; not a fish was taken by them. In the most of the years that have followed, the majority of the whalers have returned with comparatively paltry freights, and many without a pound of blubber or of bone.

The declension and apparent approaching extinction of the northern whale-fishing, which has so long been an important pillar of our commercial greatness, could not but excite uneasiness and regret in the minds of many persons who have opportunities of making observations on the subject. Accordingly, we find that various plans have been proposed for the revival of this branch of the trade of Britain. Although we conceive that the substitution of gas for oil is one important cause of the decreased ardour for whaling enterprises, and a cause, besides, neither to be deplored nor capable of remedy, and although it also appears to us that the exhaustion of the old whaling fields is another source of the evils complained of, and one only to be affected by time, yet there might, we believe, be plans adopted which would help at once to restore the lucrative character of the whale-fishery, and to alleviate, or entirely prevent, the misfortunes which have attended its prosecution of late years. The most rational scheme which we have yet seen proposed is to establish a settlement of active and enterprising whale-fishers on some favourable spot in the vicinity of Davis' Straits, and to employ only so many large vessels as may be necessary to carry out provisions to the colony, and fetch home the oil, blubber, whalebone, and other articles which may be thought worth importing. The practicability of carrying such a plan into effect, and the advantages likely to result from it, are the only two points that fall to be noticed here. The testimony of recent travellers, as well as of seamen who have been compelled to winter in the high latitudes, goes to prove the practicability of establishing and maintaining there an efficient colony. Captain Ross's remark, that 'the temperature of sensation is more relative than is imagined, the body soon contriving to find a new and much lower scale of comfortable or endurable heat,' has been completely verified by all who have visited the Polar regions. The attention now paid to the quality of ship provisions, and the improved methods of preserving them, have not only put a stop to the inroads of scurvy, but have tended materially to increase the comfort of those who choose to lengthen their stay in cold countries. Nor would they be dependent altogether on the supplies carried with them, or procured from the mother country. The musk ox, the reindeer, the white bear, the hare, and a number of other quadrupeds, would afford them at once sport and a valuable addition to their means of sustenance. Birds, too, and fresh fish of various kinds, would not be wanting to give variety to their repasts; while lobsters, mussels, and other shell-fish, could be had as abundantly as at home. To avoid all risks of famine, it would be proper to have always in the settlement provisions for two years; although it could hardly ever happen that the settlers would be so completely shut up as to be inaccessible during the whole of the summer months.

The advantages of having a numerous body of fishers on the spot, instead of sending them out annually, can easily be made apparent. 1*st*, There would be a saving of outlaid capital. For some time past, the ships sent from Great Britain to Davis' Straits may have averaged 100 each year; and we believe we speak within limits when we assert that the oil and whalebone which they have brought home might easily have been carried by one-fifth of the number. Suppose a permanent colony of 4000 fishers were established at Davis' Straits, and twenty of the 100 vessels employed in the carrying trade, the other 80 vessels might at once be withdrawn, making a saving of outlaid capital to the extent of at least £320,000. In this calculation we take merely the cost of the ships, as the boats, harpoons, casks, and other apparatus, and the provisions included in the outfit, would all be required in the settlement. 2*d*, The fishery would have a better chance of being successful. At present it sometimes happens that vessels cannot get into the proper fishing station till the season is so far advanced that they are under the necessity of returning home without lowering their boats, and this difficulty arises not from the want of open sea within the Straits, but from accumulations of ice drifted from the north extremity of Baffin's Bay to the Labrador coast. A settlement of fishers wintering inside, would in most cases make a good fishing before the British ships had penetrated far up the Straits.

The Sperm-Whale-Fishery.

There is no occasion for describing the vessels or apparatus employed in the sperm-fishery, these being similar, in every essential point, to those already described; with this exception, that the ships are always found and provisioned for a period of three years—the period of their general absence from England. Timid as it is, the cachalot often causes such peril by its convulsive efforts to escape, as render its capture not less exciting than that of the mysticetus. Young bulls, in particular, frequently give a world of trouble to their pursuers, and sometimes turn upon them with unbounded fury, intent on mischief, and effecting it both with teeth and tail. The South Sea whalers, like their northern brethren, have their particular cries and watchwords in the prosecution of the chase. When a whale is seen by the man at the look-out, the cry bursts from his lips, 'There she spouts!' Instantly the captain starts on deck, with the responsive exclamation, 'Where away?' An answer is scarcely needed, for all on board soon perceive the huge animal, blowing regularly at intervals of ten seconds, if within a moderate distance. For a half minute the men stand gazing, and at every spout the spirited cry breaks forth from them simultaneously, 'There again!' But idleness is not long the order of the day. The boats are lowered, the men rush into them, and soon are pulling towards the monster, every boat eager to reach him first. As they approach, they see him spouting more slowly. 'Ah, he is going down!—he will be lost!'—is the exclamation. But one boat nears him. 'One more spout (says Mr Beale's animated narrative) is seen slowly curling forth—it is his last for this rising—his back is bent, his enormous tail is expected to appear every instant, but the boat shoots rapidly alongside of the gigantic creature. "Peak your oars!" exclaims the mate, and directly they are flourished in the air; the glistening harpoon is seen above the head of the harpooner; in an instant it is darted with unerring force and aim, and is buried deeply in the side of the huge animal. "It is socket up;" that is, it is buried in his flesh up to the socket, which admits the handle of the harpoon. A cheer from those in the boats, and from the seamen on board, reverberates along the still deep at the same moment.' Now the pained whale plunges violently, and lashes the sea with his tail, so that the noise can be heard for miles. Suddenly he throws up his tail in the air, and disappears. Out fly the lines, and those of another boat are attached. Eight hundred fathoms are run out, and at last the whale re-appears at the surface, somewhere in the vicinity, spouting hurriedly and agitatedly. By coiling their lines, the boatmen run rapidly up to him, and then the headsman buries his lance in the vitals of the trembling monster. 'Stern all!' is at the same moment vociferated, and the boat backs away from the side of the whale. He now becomes infuriated, and rushes at the boats, often upsetting them. The lance is again driven into his sides; his motions become wild and irregular; and after what is called the mortal flurry, he turns over on his side, suffocated most commonly by the internal flux of blood from his wounds.

As in the case of the Greenland fishery, bounties were given to the sperm-whalers up to 1821, when the trade was fairly left to private enterprise. In 1791, the sperm oil imported into Britain amounted to 1258 tons; in 1827, 5552 tons were imported; and in 1836, the amount was 7001 tons. One good whale will yield forty barrels of oil, and ten barrels of spermaceti are frequently taken from one head. About ten large barrels make a ton. Both sperm oil and spermaceti bear a high price in the market, and are of great utility in various respects. Of late years, this fishery has also fallen off; so much so, that in 1845 not a single vessel cleared out for it from a British port.' 'This decline,' says M'Culloch, 'is a consequence partly of the growing scarcity of the whales in their old haunts, and of the greater difficulty experienced in their capture; but more of the competition of the Americans, and of the colonists in New South Wales and Van Diemen's Land. The situation of the latter gives them peculiar advantages for the prosecution of the fishery, which they now carry on to a great extent, and with much spirit and success.' In 1841 there were no fewer than 193,000 tons of shipping belonging to the United States engaged in sperm-fishing.

SEAL-FISHING.

The seal tribe—*Phocidæ*—according to the classification of modern naturalists, forms the last or most lowly-organised of the Carnivorous order. The family is sufficiently distinguished from all the rest by the peculiar adaptation of the animals composing it to a marine residence. Their feet are so short, and so enveloped in the skin, that they are of little use in progression on land. In fact the seal employs them only when clambering, wriggling itself forwards along a plane surface by the action of the abdominal muscles. The intervals between the toes are occupied by membranes, so as to convert the feet into oars. The body is lengthened, and the spine very flexible, as in the Cetacea and Fishes; and the animals are covered with a short, close, glistening fur, sitting flat upon the skin. All these adaptations combine to render them able swimmers; and they pass the greatest part of their time in the water, which they only quit to bask in the sunshine, and to suckle their young. Of the two genera, the *Seals* and the *Morses*, which this family contains, the former presents the least departure from the general type of the order. It possesses all three kinds of teeth; but the canines are not particularly large, and the molars are neither adapted for shearing nor for grinding the food, but are furnished with angular points adapted to keep hold of and crush the slippery prey. The head of the seal resembles that of a dog, presenting the same mild and expressive physiognomy. These animals seem to possess considerable intelligence; they are easily tamed, and become much attached to their feeder. They subsist on fish, which they always devour in the water, closing the nostrils by a kind of valve. Seals of various species are extensively diffused through the polar regions of both hemispheres, becoming scarcer in the temperate zone. They are occasionally seen on the coast of South Britain, but are more abundant on the north of Scotland. The fur-seal of the South Seas is extremely abundant in some localities; for a period of fifty years not less than 1,200,000 skins were annually obtained from a single island. The species to which the foregoing remarks more particularly refer are—the common seal, *Phoca vitulina*, which is found from four to five feet in length; the Greenland seal, *P. Groenlandica*, about six feet in length; the bearded seal, *P. barbata*, from seven to ten feet long; and the hooded seal, which averages about eight feet long in full-grown specimens. The walrus (also called morse, sea-cow, sea-horse) resembles the seal in the general form of the body and limbs, but differs considerably in the head and teeth. The lower jaw has neither incisors nor canines, and is compressed laterally, to pass between two enormous canines or tusks, which issue from the upper one, and are directed downwards, sometimes attaining a length of two feet. These seem to be used by the animal in hooking up the sea-weeds on which it partly feeds. The morse is a very bulky creature, exceeding the largest bull in size, and generally attaining the length of twenty feet.

Seals, we have said, are gregarious, and fond of reposing on ice-fields—situations where the greatest numbers are killed. These icy haunts are termed 'seal-meadows,' and the hunters endeavour to surprise the animals while sleeping, and to intercept their retreat to the water. They attack them with muskets and bludgeons, but principally with the latter, the seal being readily despatched by a blow on the nose. They are hunted chiefly for their oil and skins—a full-grown animal yielding in spring, when they are in best condition, from eight to twelve gallons of oil, and a small one from four to six gallons. The oil, when extracted before putrefaction has commenced, is beautifully clear and transparent, free from smell, and not unpleasant to the taste. The skin, when tanned, is extensively used in the making of shoes and the like; and when dressed with the hair on, serves for the covering of trunks, &c. The walrus is also occasionally sought after, but chiefly for its ivory tusks and skin, as its carcass yields but a small proportion of oil. The seal-fishery has been long prosecuted by the Dutch, but recently, with great success, by vessels of from sixty to a hundred tons, having twenty or thirty hands on board, fitted out from the ports of Newfoundland, Nova Scotia, and the United States. Though not specially engaged in by our own fishers, British whalers always take out seal-clubs as part of their equipment, and a single ship has been known to obtain a cargo of from 400 to 500 seals, yielding nearly 100 tons of oil. Indeed of late years many of our whalers would have returned *clean*, but for the seals caught on the voyage. Seal-oil is preferred to whale-oil, and brings, accordingly, a higher price in the market.

Of the value of the seal to the inhabitants of the arctic regions, some idea may be formed from the following passage from Scoresby's 'Arctic Regions:'—'Its flesh forms their most usual food: the fat is partly dressed for eating, and partly consumed in their lamps; the liver, when fried, is esteemed even among sailors as an agreeable dish. The skin, which the Esquimaux dress by a process peculiar to themselves, is made water-proof. With the hair off, it is used as coverings instead of planks for their boats, and as outer garments for themselves; shielded with which, they can invert themselves and canoes in the water without getting their bodies wet. It serves also for coverings for their tents, and for various other purposes. The jackets and trousers made of seal-skins by the Esquimaux are in great request among our whale-fishers for preserving them from oil and wet.'

COD OR WHITE-FISHING.

Under this term is included not only the fishery of the common cod, but of haddock, whiting, ling, hake, torsk, and others—all remarkable for the excellence of their flesh, which is white, firm, separates readily into flakes, is agreeable to the taste, and wholesome. They belong to the order of soft-finned fishes, and constitute a family known by the name of *Gadidæ*, which is distinguished by the following natural characters:—A smooth oblong body, covered with small soft deciduous scales; head scaleless; eyes lateral; jaws and anterior part of the mouth furnished with several ranges of unequal pointed teeth; the gills large, seven-rayed, and opening laterally; and a small beard or barbule at the tip of the lower jaw. Almost all the species have two or three dorsal fins, one or two anal, and one distinct caudal fin; and they have a large, strong, swimming bladder. They live for the most part in the seas of cold or temperate climates; and from their size, and their tendency to congregate in particular localities, as well as from the value of their flesh, they are of first-rate importance to man. As our space will not permit us to notice individually the members of this extensive family, we shall direct attention chiefly to the cod, as the head and representative—premising that the natural habits, modes of capture, curing, and preparation, are much the same in all.

The common cod—*Gadus morrhua*—must be sufficiently well known, either in its green, pickled, or dried state, to every British reader. Its body is of moderately long shape, with the abdomen very thick and prominent; the head is large, as also are the eyes; the jaws of equal length, and the lower furnished with a single barbule. The dorsal and anal fins are rather large, the pectoral and ventral rather small; the tail of moderate size, and even at the end. As to colour, the upper part of the head, cheeks, back, and sides, are mottled and spotted with dull yellow; the belly white or silvery; the lateral line white; and the fins dusky. The animal sometimes grows to a very large size. Pennant gives an instance of one taken at Scarborough which weighed seventy-eight pounds, and measured five feet eight inches in length, and five feet in girth round the shoulders; and Mr Yarrell mentions one caught in the Bristol Channel which weighed sixty pounds. The general size, however, is much less, and the weight from about fourteen to forty pounds; and those of middling size are most esteemed for the table. 'In the seas with which Europeans are best acquainted,' says the last-mentioned naturalist, 'the cod is found universally, from Iceland very nearly as far south as Gibraltar, but does not exist in the Mediterranean. It is also found and taken in abundance as far west as the shores of Newfoundland. In this country it appears to be taken all round the coast: among the islands to the north and west of Scotland it is abundant: most extensive fisheries are carried on; and it may be traced as occurring also on the shore of almost every county in Ireland. In a natural state, the cod spawns about February; and nine millions of ova have been found in the roe of one female. Cod fish are in the greatest perfection as food from the end of October to Christmas. It may, in fact, be said of the whole family of *Gadidæ*, that they are in the best condition for the table during the cold months of the year.

The cod-fish is very voracious; a favourable circumstance for the fishermen, who experience little difficulty in taking them with almost any bait, whenever a favourable locality is ascertained. As these fish generally inhabit deep water—from twenty-five to forty, and even fifty fathoms—and feed near the ground, on various small fish, worms, crustacea, and testacea, their capture is only attempted with lines and hooks. Two sorts of lines, adapted for two very different modes of fishing, are in common use. One mode is by deep-sea lines, called *bulters*, on the Cornish coast: these are long lines, with hooks fastened at regular distances along their whole length, by shorter and smaller cords called *snoods*. The snoods are six feet long each, and placed on the long line twelve feet from each other, to prevent the hooks from becoming entangled. Near the hooks, these shorter lines, or snoods, are formed of separate threads loosely fastened together, to guard against the teeth of the fish. Some variations occur at different parts of the coast as to the number of hooks attached to the line, as well as in the length of the snood; but the distance on the long line between two snoods is always double the length of the snood itself. Buoys, buoy-ropes, and anchors or grapples, are fixed one to each end of the long line; the hooks are baited with sandlaunce, limpet, mussel, whelk, &c.; the lines are always laid, or, as it is termed, *shot* across the tide; for if the tide runs upon the end of the line, it will force the hooks together, by which the whole tide's fishing is irrecoverably lost. The lines are deposited generally about the time of slack water, between each ebb and flow, and are taken up or hauled for examination after being left about six hours, or one flood or ebb. An improvement upon this more common plan was some years ago suggested by Mr Cobb, who was sent to the Shetlands by the commissioners appointed for the improvement of the fisheries. He fixed a small piece of cork within a certain distance of the hook, about twelve inches, which suspended and floated the bait so as to prevent its falling on the ground, by which method the bait was more freely shown to the fish, by the constant and variable motion produced upon it by the tide. In the old way, the bait was frequently hid from the fish by being covered with sea-weed, or was consumed by some of the numerous star-fish and crabs that infest the ground.

The fishermen, when not engaged in shooting, hauling, or rebaiting the lines, fish with hand-lines, armed with two hooks kept apart by a strong piece of wire. Each fisherman manages two lines, holding one line in each hand; a heavy weight is attached to the lower end of the line not far from the hooks, to keep the bait down near the ground, where the fish principally feed. These two modes of line-fishing are practised to a great extent nearly all round the coast; and enormous quantities of cod, haddock, whiting, coal-fish, pollack, hake, ling, torsk, and all the various flat fish, usually called by the general name of "white fish," are taken. Of cod-fish alone, the number taken in one day is very considerable. From 400 to 550 fish have been caught on the banks of Newfoundland, in ten or eleven hours, by one man; and a master of fishing vessels trading for the London market told me that eight men, fishing under his orders off the Dogger Bank, in twenty-five fathoms water, have taken eighty score of cod-fish in one day. These are brought to Gravesend in stout cutter-rigged vessels, of eighty or one hundred tons burden, called "store boats," built for this traffic, with a large well, in which the fish are preserved alive; and of these a portion is sent up to Billingsgate market by each night-tide. Well boats, for preserving alive the fish taken at sea, came into use in this country early in the last century. They are said to have been first built at Harwich in 1712. The store boats remain as low down as Gravesend, because the water there is sufficiently mixed to keep the fish alive. If they were to come higher up, the fresh water would kill them.

'A change has lately taken place,' continues our authority, 'from the cod having shifted their ground. Formerly the Gravesend and Barking fishermen obtained few cod nearer than the Orkneys or the Dogger Bank; but for the last two or three years the supply for the London market has been obtained by going no further than the Lincolnshire and Norfolk coasts, and even between that and London, where previously very few fish could be obtained.'

As already stated, cod are largely used in a fresh state; they are also pickled green in barrels, and perhaps still more largely when split up, salted, and dried. It is impossible to arrive at anything like an accurate account of the quantity taken along our own coasts, and far less of that obtained from Newfoundland, the celebrated fisheries of which are now almost entirely in the hands of the French and Americans. The same remarks are applicable to the fisheries of haddock, ling, hake, ray, sole, turbot, and other white fish. All that we know for certain is, that vast numbers are annually taken, and consumed either fresh or dried; or, as in the case of the haddock, half-dried and smoked, under the title of *Aberdeen* or *Finnan fish*, though this mode of preparation is followed extensively at other stations. Besides their flesh, for which the cod and ling are chiefly sought after, their air-bladders, popularly called *sounds*, are prepared separately, and sold pickled. The roes, which are of large size, are also used as food, or, preserved in brine, are sold, to be employed to attract fish. Another produce is the oil extracted from the liver, which is used either for lamps, or medicinally in cases of rheumatism, consumption, &c.—cod-liver oil being now a recognised article in Materia Medica.

SALMON-FISHING.

In a previous number (43) were detailed at length the natural history of the salmon, and the various devices resorted to by the angler for its capture: we shall now direct attention to its capture as a branch of industry, involving the annual transfer in Britain of perhaps a quarter of a million sterling. The modes of fishing are extremely varied—differing according to the nature of the locality, be it sea-shore, tidal estuary, or running river. Along the shores of the open sea and estuaries the salmon is continually traversing and re-traversing during summer, and in such situations the stake-net is generally employed. This consists of a long wide-meshed net, supported on poles, which runs seaward in a straight line between high and low water-mark. From this main line various bending offsets are made, so as to form chambers or traps. As the fish push along shore, they are intercepted by the main line of net, and find their way into one or other of the traps, from which there is no retreat. Higher up the rivers sweep-nets are used, one end being made fast to the shore, and the other run rapidly out by a boat, so as to enclose any fish that may be seen ascending. As soon as a salmon is observed by the outlook, a signal is made, the net run out as described, and then dragged on shore, encircling the object of capture. The central portions of wide rivers are usually worked by fishermen in boats called *cobles*, with long sweeping seine-like nets—a laborious, but not unsuccessful process. Still higher up, in certain rivers, weirs or dams are built, with enclosed places in the dam wall called *cruives*. The fish, as they push up the stream, enter these spaces, through which the water rushes, and are prevented by a grating of peculiar contrivance from getting out. In some places stages are erected, from which fishers with bag-nets intercept the ascending salmon; and at linns or water-falls spearing is occasionally resorted to. By one or other of these methods immense numbers of salmon are annually taken—and, we wish we could add, always taken with honest, judicious care in reference to the reproduction and preservation of the species. The fish so captured are chiefly used in a fresh state, the quantity now pickled and kippered being inconsiderable.

With regard to the statistics of the salmon-fishery, it is extremely difficult to arrive at correct information; indeed beyond a few broad facts, any attempted statement is little better than guess-work. The following facts are gleaned from a somewhat rambling notice in the 'Statistical Account of the British Empire:'—'Salmon being rarely caught except in estuaries or rivers, is in most instances private property: the fisheries frequently producing a large revenue to their owners. It is found in most English rivers, but seldom in such abundance as to make fishing an object of much attention. London derives the principal part of its supply from Scotland; and Liverpool, Manchester, &c. from Ireland. The fishery in the Tweed is important and valuable. About twenty years ago it produced a rental of from £15,000 to £18,000 a year; but in the interval the decline has been such, that at present it does not yield above £4000 or £5000 a year to its proprietors. This extraordinary decline is principally owing to a nearly corresponding falling off in the catch of salmon—the exports from Berwick having sunk from 9000 or 10,000 boxes a year to 3000 or 4000. Exclusive of the Tweed, there are valuable salmon-fisheries in the Tay, Forth, Dee, Don, Findhorn, Spey, Ness, and other Scottish rivers; but they are mostly all in the same condition as those of the Tweed. There is everywhere a growing scarcity of fish, and a corresponding decline in rental. Most persons seem to think that the declining state of the salmon-fisheries is mainly owing to the prevalence of poaching, or to the destruction of the breeding-fish and fry in the upper parts of the rivers during *close-time*. On the whole, we rather incline to think that fully as much injury is done in most rivers by the *weirs*, and other obstructions placed in the way of the fish when ascending the rivers to spawn, as by anything else. The fishery has also perhaps been injured by the temptation to over-fish, caused by the high price of salmon, and in a still greater degree by the too limited duration of the close-time. The last-mentioned cause of decline is thought by many good judges to be the most powerful of the whole; and it is justly objected to the Acts for the regulation of the Scotch Fisheries, that they prolong the period for fishing too far into the spawning season. The fisheries in the north of Ireland are said to have been seriously injured by the steeping of flax in waters communicating with the rivers which salmon frequent. The fisheries in the Bann, near Coleraine, the Bulick, near Ballyshannon, the Boyne, above Drogheda, and in various other Irish rivers, are still very productive; and it is owing to this cause, as well as to the recent imports from Holland, that the price of salmon has been kept at so low a figure, notwithstanding the falling off in the supply from Scotland.

Formerly, the greater part of the salmon caught in the Tweed and other Scotch rivers was pickled or kitted, after being boiled, and sent to London under the name of 'Newcastle Salmon'—a little only being brought up fresh during the early spring months. But about 1790, the plan suggested by Mr Dempster of Dunichen, of packing salmon in boxes with coarsely-pounded ice, began to be introduced; and by this ingenious contrivance it is now brought quite fresh from the most distant parts of Scotland and Ireland. This discovery immediately raised the price of salmon in the remoter parts of the country almost to the London level, and restricted its consumption within the narrowest limits. At present, the value of the salmon (fresh and pickled) imported from Scotland into the metropolis is estimated at £150,000 a year; and the average selling price at 10d. per lb.—a price which all but debars it from the middle classes, and wholly from the bulk of the population.

HERRING-FISHING.

This well-known fish—*Clupea harengus*—is ranked by naturalists in the same family with the pilchard, sprat, shad, anchovy, and white bait. The body, which is about ten or twelve inches in length, and of a handsome, regular shape, is covered with thin roundish scales; the upper part is blue or green, according to the light, and the lower of a silvery white. The belly is carinated, but not serrated, as in the sprat—a distinction which is obvious and permanent. Owing to the gill-covers being very loose, and opening wide, the animal dies almost the instant it is taken out of the water. The herring varies considerably in size and condition, but five or six ounces may be taken as the ordinary weight. The opinion of the older naturalists, that the herring periodically migrates from the arctic seas to deposit its spawn in the warmer latitude of Britain, is rejected by modern authorities. 'The herring,' says Yarrell, 'inhabits the deep waters all round the British coasts, and approaches the shores in the months of August and September for the purpose of depositing its spawn, which takes place in October or the beginning of November. It is during the two first months that the great fishing is carried on; for after the spawning is over, it returns to deep water. The mode of fishing for herrings is by drift-nets, very similar to those employed for taking mackerel and pilchard, with a slight difference in the size of the mesh. The net is suspended by its upper edge from the drift-rope, by various shorter and smaller ropes, called "buoy ropes;" and considerable practical skill is required in the arrangement, that the net may hang with the meshes square, smooth, and even in the water, and at the proper depth; for according to the wind, tide, situation of their food, and other causes, the herrings swim at various distances from the surface. . . . The size of the boat used depends on the distance from shore at which the fishery is carried on; but whether in deep or in shallow water, the nets are only in actual use during the night. It is found that the fish strike the nets in much greater numbers when it is dark than when it is light; the darkest nights, therefore, and those in which the surface of the water is ruffled by a breeze, are considered the most favourable. It is supposed that nets stretched in the day-time alarm the fish, and cause them to quit the places where that practice is followed; it is therefore strictly forbidden.' The only other legal restriction is as to the size of the mesh, and the leaving of nets so as to foul the ground with dead fish.

Respecting the history and statistics of the herring-fishery, which is the most important to the community at large, we glean the following particulars chiefly from the 'Cyclopedia of Commerce:'—This fishery has been prosecuted on the British shores from a remote period; but its early history is involved in obscurity. The progress of the Dutch herring-fishery is well known. There is a popular saying in Holland, that 'the foundation of Amsterdam is laid on herring-bones,' in allusion to the fishery having formerly been its great staple. Under the Stadtholders this fishery was considered the right arm of the republic, and it was always entitled the 'Grand Fishery.' When in the height of its prosperity (1650), the total number of vessels which it employed, including those engaged in bringing salt and transporting the fish, was stated at 6400, and the number of mariners and fishermen at 112,000. The extraordinary progress of that people led to various measures in this country for encouraging the British fisheries. These measures assumed a variety of forms at different times, such as fishing towns built at the public expense; associations under royal patronage; the strict observance of Lent; remission of the salt duties; the importation, duty free, of foreign commodities received in exchange for fish; lotteries; collections in churches; rendering it obligatory upon victuallers to take yearly a certain quantity at 30s. a barrel; and lastly, direct bounties. These 'encouragements' all failed in communicating anything like permanent prosperity to the fishery; and some of them, particularly bounties, led to great abuses. It would exceed the limits of this article to specify the different changes which took place in the bounty system. It may be mentioned, however, that in 1820, after various modifications, an allowance of 20s. a ton, increasing under certain circumstances to 30s., was granted on all vessels from 15 to 60 tons fitted out for the shore-fishery, exclusive of a premium of 4s. per barrel on herrings cured and gutted, and 2s. 8d. per barrel on those exported. In a few years afterwards the principle of bounties was abandoned; in 1826 the export bounty was withdrawn, and the bounty of 4s. was reduced 1s.

each succeeding year until 1830, when it ceased altogether. The withdrawal of the bounties, so far from having injured the herring-fishery, has had a contrary effect. The fishermen, no longer encouraged to look to extraneous aid, and relieved from the intrusion of landsmen, who engaged for a few weeks in the fishery for the purpose of obtaining the bounty, have redoubled their exertions, and are now better clothed and fed, and more temperate than before; while in many cases they have been enabled by their industry to substitute for the small boats formerly used others of much larger dimensions, and to provide themselves with superior fishing materials. Notwithstanding the repeal of the bounties, the fishery is still under the surveillance of a 'Herring Board,' which has officers at the different fishing stations to superintend the curing department, and who affix an official brand to barrels containing a certain quality of fish.

Herrings are brought to market in three principal forms: *fresh herrings* are the condition in which they are taken from the sea; *white or pickled herrings* are merely salted and put into barrels; *red herrings* are gutted and salted, and afterwards hung and fired with the smoke of greenwood; and to these we may add the recent invention of *kippering*—that is, splitting up the fresh fish, passing it through brine, and subjecting it to a slight firing with greenwood smoke. Fresh herrings are consumed in considerable quantities during the fishing season; but it is the pickled and red herrings which form the great objects of the fishery. The *boat-fishery* is that chiefly pursued when the fishing ground is not at a great distance from shore. The *deep-sea fishery*, where the fishermen go out to sea wherever the fish are to be found, requires vessels of a larger description (from thirty to eighty tons) as the herrings are pickled and stowed on board. The vessels fitted out for this fishery commonly meet with the earliest and best herrings; and owing to the circumstance of the fish deserting certain parts of the coast which they have been accustomed to frequent, it is a more regular source of profit than the boat-fishery, though it requires larger capital. The British cured herrings, though now much better than formerly, are still inferior to the Dutch—the British fishery depending for its prosperity more on quantity than quality. The fishery is mostly on the north-east coast, particularly at Wick, Helmsdale, Fraserburgh, Peterhead, Anstruther, and Dunbar; it is also extensively pursued in the Orkney and Shetland islands; on the west coast of Scotland, which yields the famed Lochfine herrings; the Isle of Man; the Yorkshire coast; and at Yarmouth, where red herrings (Yarmouth bloaters) are largely cured for the home market. In 1844 the quantity of herrings cured (gutted and ungutted) at the different stations amounted to 665,360 barrels; and this independently of what was consumed in the fresh state. In the same year the number of boats employed amounted to 14,667; the number of fishermen and boys, 60,457; coopers, 2306; packers, gutters, &c. (chiefly women), 28,177; miscellaneous labourers, 7104; and fish-curers, 1611. Of the cured herrings, about one-half (320,000 barrels) are annually exported.

The herring-fishery of Ireland, until lately, was of very little consequence. In 1842, however, a Board of Commissioners was appointed for its improvement and regulation, and under this superintendence it is gratifying to observe a rapid and marked change. The whole coast has been divided into 28 districts, each of which is placed under a local officer; and it appears, from the reports of these officials, that in 1845 there were 19,883 vessels of all sizes, and 93,073 men and boys, wholly and partially engaged in the fishery.

PILCHARD FISHING.

The Pilchard—*Clupea pilchardus*—bears a close resemblance to the herring, not only in general appearance, but in its habits. When full grown it is about nine inches in length, is somewhat rounder and lumpier in form than the herring, and is covered with considerably larger scales. The head is rather flat, and the mouth is destitute of teeth; the back is of a bluish cast, the belly and sides silvery, and the upper angle of each of the gills is marked with a large black spot. They feed with voracity on small crustaceous animals, their stomachs being occasionally found crammed with thousands of a minute species of shrimp not larger than a flea. They are also partial to the spawn of fishes; hence the custom of the French fishermen to throw salted pea-roe about their nets to attract the shoals. They appear annually on the southern coasts of England and Ireland, where they are captured in immense quantities either by *seans* or by drift-nets. The same reason, until late years, was assigned for the periodical return of the pilchards as for that of the herring—namely, their presumed migration from the arctic seas to warmer regions for the purpose of spawning; but this opinion is now all but abandoned. Indeed it has been established beyond doubt by Mr Couch and others that the pilchard inhabits our own seas, merely forsaking the deep waters, and coming towards the shore to deposit their spawn—thus fulfilling a great law of nature in the propagation of their species, and at the same time providing multitudes of human beings with a cheap and delicious food. The following account of the English pilchard-fishery is obtained chiefly from M'Culloch and Yarrell, as furnished, we believe, by Mr Couch of Cornwall:—

It is carried on along the coasts of Cornwall and Devon, its principal seats being St Ives, Mounts Bay, and Mevagissey. The fish usually make their appearance in vast shoals in the early part of July, and disappear about the middle of October; but they sometimes reappear in large numbers in November and December. They are taken either by drift-nets or by seans; but principally by the latter. The outfit of the former consists of a number of nets, great in proportion to the wealth of the proprietor and size of the boat; but commonly about twenty, each from 15 to 18 fathoms long and 7 fathoms deep; so that a string of driving-nets will sometimes reach three-quarters of a mile. These nets are fastened to each other in length, and on to a head-line appropriated to each, along which runs a row of cork buoys; another line runs loosely along the middle of the nets, to afford additional strength, but no weights are used at the bottom. The nets are carried in common fishing-boats, some of which, as at Mounts Bay, are luggers, and most of the others have sprit-sails: the crew consists of four men and a boy. The fishery begins a little before sunset, and the nets are drawn in about two hours, to be again shot as morning approaches; for pilchards enter the nets better at these seasons. A rope from one end of the string is fastened over the quarter of the boat, and the nets are left to float with the tide, no sails being set, except rarely in very calm weather, to prevent the nets being entangled. The number of fish taken by a drift-boat in a night's fishing varies exceedingly: from 5000 to 10,000 is considered moderate: it often amounts to 20,000. For the season's fishing about 150,000 fish would be considered favourable.

The other mode—namely, fishing by sean—is more profitable and expeditious. A sean is a net varying from 200 to 300 fathoms in length, and from 10 to 14½ fathoms in depth, having cork buoys on one edge, and lead weights on the other. Three boats are attached to each sean—namely, a boat (*sean-boat*) of about fifteen tons burden for carrying the sean; another (*follower*) of about the same size, to assist in mooring it; and a smaller boat (*lurker*) for general purposes. The number of hands employed in these three boats varies from 13 to 18, but may be taken at an average of 16. When the shoals of fish come so near the shore that the water is about the depth of the sean, it is employed to encircle them; the fishermen being directed to proper places for casting the nets by persons (*huers*) stationed for that purpose on the cliffs and in the boats. The practice is to row the boat, with the sean on board, gently round the shoal; and the sean being at the same time thrown gradually into the water, assumes, by means of its buoys and weights, a vertical position—its loaded edge being at the bottom, and the other floating on the surface. Its two ends are then fastened together; and being brought into a convenient situation, it is moored by small anchors or grapnels; sometimes, however, one or two smaller seans are employed to assist in securing the fish. At low water the enclosed pilchards are taken out by a *tuck-net* and carried on shore. A single sean has been known to enclose 3000 hogsheads of fish; but it is seldom that even a third of that amount is enclosed at a time. The 'take,' in fact, depends upon so many accidental circumstances, that while one sean may catch and carry in from 1000 to 2000 hogsheads, others in the neighbourhood may not get a single fish. An instance has been known where 10,000 hogsheads have been taken in one part in a single day—thus providing the enormous multitude of 25,000,000 of living creatures drawn at once from the ocean for human sustenance. In some places the tides are so strong as to break the seans, and set the fish at liberty; and occasionally this happens from the rush and pressure of the fish themselves. When the quantity enclosed is large, it requires several days to take them out, as they must not be removed from the water in greater numbers than the curers can conveniently manage.

As soon as the fish are brought on shore they are carried to cellars or warehouses, where they are piled in large heaps, having a sufficient quantity of salt interspersed between the layers. Having remained in this state for about thirty-five days, they are, after being carefully washed and cleaned, packed in hogsheads, each containing on an average 2600 fish. They are then subject to a pressure sufficient to extract the oil, of which each hogshead yields—provided the fish be caught in summer—about three gallons; but those that are taken late in the season do not yield above half this quantity. This oil usually sells from 12 to 15 per cent. under the price of brown seal oil. The broken and refuse fish and salt are sold to the farmers, and are used as manure with excellent effect. The skimmings which float on the water in which the fish are washed are called *dregs*, and are chiefly sold as grease for machinery. Pilchards are not used in England, except in the counties in which they are taken, where about 3000 hogsheads are retained for home consumption. They are chiefly exported to Italy.

The following is a statement, perhaps nearly approaching the truth, where absolute certainty is unattainable, of the amount of property engaged in the pilchard-fishery in the year 1827, when the bounty began to be withdrawn:—Number of seans employed, 186; not employed, 130; total number of seans, 316; number of drift-boats, 368; men employed on board drift-boats, 1600; number of men employed on seans at sea, 2672; number of persons (chiefly women) on shore to whom the fishery affords direct employment, 6350; total number of persons employed in the fishery, 10,521. Cost of seans, boats, &c. employed in the fishery, £209,840; cost of drift-boats and nets, £61,400; cost of cellars for curing and other establishments on shore for carrying on the fishery, £169,175; total capital invested directly in the pilchard-fishery, £441,215. It is but right to add to this estimate, made in reference to 1827, that in 1847 Mr M'Culloch sets down the total capital as not exceeding £250,000. The outfit of a sean amounts to about £800; a string of drift-nets will cost £6 the net; and the boat from £100 to £150; but this is used throughout the year for the other purposes of fishing. The nets are supposed to last about six years, and ought of course to produce their own value within that time, together with an adequate profit; but it is the complaint of the fishermen that this is not the case. The profit of the men depends on the share of the fish, which is divided into eight parts, of which the boat has one-eighth part, the nets three, and the men four: a boy that accompanies them is rewarded with the fish that may fall into the sea as the nets are drawn, to secure which he is furnished with a bag-net at the end of a rod. The annual average produce of the Cornish pilchard-fisheries is stated at 21,000 hogsheads; in 1845 it amounted to upwards of 33,000 hogsheads. The annual export is about 17,000 hogsheads; in 1842 it exceeded 20,000.

MACKEREL FISHING.

The mackerel—*Scomber scomber*—is described as 'one of the most beautiful of fishes as regards the brilliancy of its colours, and at the same time one of the most useful as regards the food of man.' It is a native of the European and American seas, generally appearing at stated seasons in immense shoals round particular coasts. The periodical appearance of these vast shoals was formerly imputed to its migration from north to south; but many facts are opposed to this idea; and there is abundant reason to believe that it inhabits the deeper parts of the seas around our island throughout the year, and that its periodical appearance on our coasts in such vast numbers, is solely due to its seeking the shore for the purpose of depositing its spawn. The usual length of the mackerel is about fourteen inches, or varying from twelve to sixteen; but in the northern seas it is occasionally found of a larger size. Its colour on the upper parts, as far as the lateral line, is a rich deep blue, accompanied by a varying tinge of green, and marked by numerous black transverse streaks, which in the male are nearly straight, but in the female beautifully undulated. The jaws, gill-covers, and abdomen, are of a bright silvery hue, with a slight cast of gold green on the sides. The scales are small, oval, and transparent; the spurious fins or pinnules are five in number both above and below; the tail is crescent-shaped; the head is pointed, with the lower jaw projecting. Beautiful as are the colours of the mackerel when alive, no sooner is it caught than its lustre begins to disappear. It is a voracious feeder, and its growth is rapid; but it is not the largest fish that are accounted the best for the table. Those taken in May or June are considered superior in flavour to such as are caught either in early spring or in autumn. The mackerel spawns in June; and 540,000 ova are said to have been counted in one female. For mackerel roaming hither and thither through the waters of the ocean, no successful mode of capture could be adopted; but at their periodical returns to the shore millions are taken by the net, sean, or line, and yet the number caught is but a mere fraction of the countless shoals that escape.

For the following statistics in reference to the capture, &c. of this esteemed fish, we are indebted to Mr Yarrell. 'At our various fishing-towns on the coast, the mackerel season is one of great bustle and activity. The frequent departures and arrivals of boats at this time form a lively contrast to the more ordinary routine of other periods; the high price obtained for the early cargoes, and the large return gained generally from the enormous numbers of this fish sometimes captured in a single night, being the inducement to great exertions. The most common mode of fishing, and the way in which the greatest numbers are taken, is by drift-nets. The drift-net is 20 feet deep, by 120 feet long; well corked at the top, but without lead at the bottom. They are made of small fine twine, which is tanned of a reddish-brown colour, to preserve it from the action of the sea water; and it is thereby rendered much more durable. The size of the mesh is about two and a-half inches, or rather larger. Twelve, fifteen, and sometimes eighteen of these nets are attached lengthways, by tying along a thick rope, called the "drift-rope," and at the ends of each net, to each other. When arranged for depositing in the sea, a large buoy attached to the end of the drift-rope is thrown overboard, the vessel is put before the wind, and as she sails along, the rope with the nets thus attached is passed over the stern into the water till the whole of the nets are run out. The net thus deposited hangs suspended in the water perpendicularly twenty feet deep from the drift-rope, and extending from three-quarters of a mile to a mile, or even a mile and a-half—depending on the number of nets belonging to the party or company engaged in fishing together. When the whole of the nets are thus handed out, the drift-rope is shifted from the stern to the bow of the vessel, and she rides as if at anchor. The benefit gained by the boat's hanging at the end of the drift-rope is, that the net is kept strained in a straight line, which, without this pull upon it, would not be the case. The nets are shot in the evening, and sometimes hauled once during the night, at others allowed to remain in the water all night. The fish roving in the dark through the water, hang in the meshes of the net, which are large enough to admit them beyond the gill covers and pectoral fins, but not large enough to allow the thickest part of the body to pass through. Early in the morning preparations are made for hauling the nets. A capstan on the deck is manned, about which two turns of the drift-rope are taken. One man stands forward to untie the upper edge of each net from the drift-rope, which is called "casting off the lashings;" others hand in the net with the fish caught, to which one side of the vessel is devoted; the other side is occupied by the drift-rope, which is wound in by the men at the capstan. The whole of the net in, and the fish secured, the vessel runs back into harbour with her fish, or depositing them on board some other boat in company, that carries for the party to the nearest market, the fishing vessel remains at sea for next night's operations. Indeed the boats engaged in fishing are usually attended by other fast-sailing vessels, which are sent away with the fish taken. From some situations these vessels sail direct for the London market; at others they make for the nearest point from which they can obtain land-carriage for their fish. From Hastings and other fishing towns on the Sussex coast the mackerel are usually brought by vans, which travel up during the night.' It is scarcely necessary to remark, that the facilities now afforded by railways have entirely changed the aspect of affairs, and that fresh fish are now often sooner in Billingsgate than in the market-places of the ports where they are landed!

Mr Couch describes two other modes of fishing for mackerel: the one by means of a long deep net, with small meshes, by which the fish are surrounded, and then either taken from the water by baskets, or hauled direct to the land, in the manner of a ground-net; the other by means of a hook and line, called *trailing*. The latter forms a first-rate marine sport, and is thus performed:—'The mackerel will bite at any bait that is used to take the smaller kinds of fish; but preference is given to what resembles a living and active prey, which is imitated by what is termed a *lask*—a long slice cut from the side of one of its own kind, near the tail. It is found also that a slip of red leather or piece of scarlet cloth, will commonly succeed; and a scarlet coat has therefore been called a mackerel bait for a lady. The boat is placed under sail, and a smart breeze is considered favourable; hence termed a "mackerel breeze." The line is short, but weighed down with a heavy plummet; and in this manner, when these fish abound, two men will take from 500 to 1000 in a day. It is singular that the greatest number of mackerel are caught when the boat moves most rapidly, and that even then the hook is commonly swallowed. It seems that the mackerel takes its food by striking across the course of what it supposes to be its flying prey. A gloomy atmosphere greatly aids this kind of fishing.'

Mackerel-fishing being extremely uncertain and irregular, there is no possibility of arriving at anything like its annual value. It is, in fact, a lottery, as the following recorded instances will show:—In May 1807, the first Brighton boat-load of mackerel sold at Billingsgate for forty guineas per hundred—seven shillings each, reckoning six score to a hundred—the highest price ever known at that market. The next boat-load produced but thirteen guineas per hundred. Mackerel were so plentiful at Dover in 1808, that they were sold sixty for a shilling. The success of the fishery in 1821 was such, that the value of the catch of sixteen boats from Lowestoft, on the 30th of June, amounted to £5252; and it is estimated that in that season not less than £14,000 were realised by the owners and men concerned in the fishery of the Suffolk coast. In March 1833, on a Sunday, four Hastings boats brought on shore 10,800 mackerel; and the next day two boats 7000. Early in February 1834, one boat's crew from Hastings cleared £100 by the fish caught in one night; and in March of the same year they were cried through the streets of London three for a shilling. Mackerel are always consumed fresh, and the fresher the better; but the French salt them down like herrings—a practice occasionally followed by the fishers and country people of Cornwall.

CRAB AND LOBSTER FISHING.

Under this head may be included the capture of the shrimp, prawn, crab, lobster, and allied crustacea, some of which are greedily sought after by epicures, though all are indifferently nutritious and difficult of digestion. The shrimp, which looks like a lobster in miniature, is found abundantly in the shallow waters of our flat sandy coasts. It has ten feet, and its motion consists of leaps. When full-grown, it does not exceed two inches in length; the tail is as long as the body, and terminates in a spreading fan-like flap; it has no large anterior claws. During life, the body is semi-pellucid, and is scarcely distinguishable from the water. The shrimp is in great request for the table, and its capture affords employment for women and boys, who wade in the sandy shallows, pushing a sort of dredge-net before them at the end of a long pole. A more certain and profitable mode is to collect them by means of sweep-nets, drawn over the ground they frequent, by men in small boats. The prawn is less abundant, but is equally esteemed. The species sold by the fishmongers is about three inches long, of a pale-red colour, and distinguished by its long frontal serrated spine.

The common edible crab is too well known to require description. The most remarkable feature in its economy, and which indeed is common to all crustaceans, is the process of sloughing, or moulting at regular periods the entire calcareous covering or crust. As it is obvious that the hard shell, when once perfected, cannot change with the growth of the animal, it becomes necessary that it should be shed entirely. When the season of shedding arrives, the aquatic crabs generally seek the sandy shores of creeks and rivers, and having selected a place of rest, the change begins. The body seems to swell; the larger upper shell begins to separate from the breast or corslet; the muscles of the limbs soften and contract, which allows of their slipping from their cases; the parts about the head and antennæ undergo a similar change; and gradually the animal escapes from the crust, soft, helpless, and incapable of exertion or resistance. In twenty or thirty hours, however, a thin crust has again overspread its various parts and members, and in the course of a few days it is enabled to resume its wonted habits. During the moulting season, as well as during the period of spawning, crabs are worthless; at other times they are excellent. On the rocky coasts they frequent they are either drawn at ebb-tide from the holes and crevices, by means of an iron hook, or they are fished for, in four or five fathoms water, by traps or cages baited with garbage. Immense numbers are annually consumed in all our seaports.

Lobsters, which are also caught either by pots and cages, by baited nets, or, in some countries, by torch-light, with the aid of wooden forceps, stand at the head of our native crustacea, and generally bring extravagantly high prices in the market. They are usually in their best season from the middle of October to the end of May, when they commence to shed their spawn; and it is provided by an act of George II. that 'no lobsters must be taken on the coast of Scotland between 1st June and 1st September, under a penalty of £5 for each offence.' In summer they are found near the shore, but in winter they are seldom taken in less than twelve or fifteen fathoms water. A sizeable specimen weighs from one to two pounds. The consumption of lobsters in London is immense—the number annually sold at Billingsgate being reckoned at 2,000,000. The supply is derived partly from the Shetland Islands and east coast of the island as far south as the Humber, but chiefly from Norway. It has been estimated by Sir John Barrow (see Encyclopædia Britannica) that London alone pays not less than £12,000 a year to the Danes and Norwegians for lobsters!

OYSTER FISHING.

The shell-fish gathered by hand, dredged, or otherwise collected along our shores, are chiefly periwinkles, limpits, mussels, cockles, and oysters. Unless in the case of oysters, none of the others are supplied to our markets with regularity; not from want of demand, but because few direct their attention to these matters as a branch of industry. And yet if things were rightly directed, how many of the poorer classes might obtain an honest livelihood by reaping from the endless supply of shell-fish with which nature has furnished our sea-coasts! Mussels and cockles are to be found in many of our estuaries, in extensive beds of the finest quality; and at certain seasons our rocky shores are profusely studded with limpits and periwinkles. All that is needed are regularity of supply and attention to the proper season of collecting, and, we may add, a higher degree of skill in preparing them in some agreeable manner for the table.

The case is altogether different with the oyster—*Ostrea edulis*—which has been highly prized by epicures in all ages, and has accordingly furnished an important article of trade. The common oyster, which is abundant on the shores of Britain and most other countries, inhabits an unequal bivalve shell, externally of a coarse and dirty appearance, each shell being composed of laminae irregularly closed down on each other. The animal itself is of a very simple structure: on separating the valves, four rows of gills, or what are called *beards*, are seen at a little distance from the fringed edge of the mantle; the abductor muscle is situated near the centre of the body, where the heart may be observed; and the mouth lies beneath a hood formed by the union of the two edges of the mantle near the hinge. Altogether, unless on close inspection, the creature looks more like a mass of delicate animal jelly than an organised body. Though apparently dull, and stationary beyond comparison, the oyster is said to possess the power of locomotion. This is performed by suddenly closing the shells, by which the water is ejected with force sufficient to throw them backward or in a lateral direction; and thus, by a repetition of this process, considerable progress is obtained.

The principal breeding time of the oyster is in April or May, when their spawn is usually cast: this appears at first like spots of grease, which fasten upon rocks, or other hard substances that happen to be near. Very commonly they adhere to adult shells, and thus are formed the large masses called oyster-banks. In about a year and a-half the young oysters have attained a profitable size, and are then dredged up and conveyed direct to market, or are transferred to artificial pits or beds within tide reach, where they are fattened to the desired size. Though this practice of transference has been carried on from the time of the Romans downwards, it has nothing to recommend it beyond convenience, and certainty of obtaining a regular supply; for the transplanted oysters, or *exiles*, according to connoisseurs, are never found in such perfection as *natives*. As with every other article of luxury, so with oysters; certain varieties are more fashionable and popular than others. In London, the Colchester and Milton oysters are held in most esteem; Edinburgh has her 'whiskered Pandores,' and latterly Aberdour oysters; and Dublin the Carlingford and Powldoodies of Burran. The British trade in oysters is of very considerable importance, and ranks next to that in salmon and herrings. Besides the large supply obtained from our own coasts, upwards of 200,000 bushels are annually imported from Jersey, where, according to Mr Inglis, 1500 men, 1000 women and children, and 250 boats, are engaged in the fishery.

From spawn time till the end of July the oysters are said to be *sick*, or out of season; and their capture, or the removal of anything to which they adhere, is then prohibited by law. On the 4th of August Billingsgate opens with great bustle, and the supply continues till the 12th of May following. Private right in oyster-beds is protected by act of parliament; and by a convention between Britain and France, the subjects of each power enjoy the exclusive right of fishery within the distance of three geographical miles from low water-mark along the whole of their respective coasts. The oyster fishery beyond these limits is common to the subjects of both countries.

Such is a hasty outline of our British Sea-Fisheries, from which it will readily be seen that, important as some of them are, not one has reached that stage of development which the inexhaustible supply of the material and the wants of our population would lead the statistician to expect. 'That this harvest,' says Sir John Barrow, 'ripe for gathering at all seasons of the year, without the labour of tillage, without the expense of seed or manure, without the payment of rent or taxes, is inexhaustible, the extraordinary fecundity of the most valuable kinds of fish would alone afford abundant proof. To enumerate the thousands and even millions of eggs which are impregnated in the herring, the cod, the ling, and indeed in almost the whole of the esculent fishes, would give but an inadequate idea of the prodigious multitudes in which they flock to our shores; the shoals themselves must be seen, in order to convey to the mind any just idea of their aggregate mass.' And yet with all this superabundance on the one hand, and the wants of a needy population on the other, our fisheries, on the whole, are conducted in a very rude, meagre, and imperfect manner. Not only are more skilful modes of capture necessary, but a heavier and more efficient equipment, a different style of vessel, the application of steam-power instead of sails, and the adoption of deep-sea fishing in preference to a paltry and uncertain creeping along shore, are all indispensable to the advancement of this branch of industry. Nor is this advancement to be gained by any pampering or bounties on the part of government; these have hitherto miserably failed, and must ever do so. What is wanted is a liberal outlay of capital, in the expectation of a certain and liberal remuneration; and there need be no hope of any important change in the present system until parties, calculating upon a full supply and increasing demand, enter the field with the necessary means. Regularity and cheapness, which can only be obtained by the adoption of a better system, are sure to increase the demand, and all the more readily now that railways have opened up a facility of transport which may be said to place our seaport and inland towns on an equal footing as regards a fresh and abundant supply of our maritime produce. Already is railway transport beginning to lower prices and increase demand; placing fresh fish within the reach of such towns as Birmingham and Manchester, for example, at a fourth of the rates formerly charged. A new era, indeed, seems to be dawning upon our fisheries, and fishmongers of capital are directing attention to other apparatus, vessels, and modes than those now in general operation. Sir John Barrow has estimated the annual value of our fisheries, foreign and domestic, at eight millions; Mr M'Culloch thinks half that sum to be nearer the mark; but whether four millions or eight millions, there cannot be the shadow of a doubt that either amount is far below what they might be made to produce under a more skilful and efficient system.

PRESERVATION OF HEALTH.

A HUMAN being, supposing him to be soundly constituted at first, will continue in health till he reaches old age, provided that certain conditions are observed, and no injurious accident shall befall. This is a proposition so well supported by extensive observation of facts, that it may be regarded as an established axiom. It becomes, therefore, important to ascertain what are the conditions essential to health, that, by their observance, we may preserve for ourselves what is justly esteemed as the greatest of earthly blessings, and dwell for our naturally appointed time upon the earth. A general acquaintance with these conditions may be easily attained by all, and to render them obedience is much more within the power of individuals than is commonly supposed.

The leading conditions essential to health are:—1. A constant supply of pure air; 2. A sufficiency of nourishing food, rightly taken; 3. Cleanliness; 4. A sufficiency of exercise to the various organs of the system; 5. A proper temperature; 6. A sufficiency of cheerful and innocent enjoyments; and, 7. Exemption from harassing cares. These conditions we shall now treat in succession, taking as our guides the most recent and eminent of physiological authorities.

AIR.

The common air is a fluid composed mainly of two gases, in certain proportions; namely, 20 parts of oxygen and 80 of nitrogen in 100, with a very minute addition of carbonic acid gas. (See CHEMISTRY, p. 295.) Such is air in its pure and normal state, and such is the state in which we require it for respiration. When it is loaded with any admixture of a different kind, or its natural proportions are in anyway deranged, it cannot be breathed without producing injurious results. We also require what is apt to appear a large quantity of this element of healthy existence. The lungs of a healthy full-grown man will inhale the bulk of twenty cubic inches at every inspiration, and he will use no less than fifty-seven hogsheads in twenty-four hours. And not only is this large quantity necessary, but the air that surrounds us must be in free circulation, in order that what we expire may be speedily carried away, and allowed to commingle with the atmosphere, which is subject to never-ceasing causes tending to its restoration and renewal.

Now there are various circumstances which tend to surround us at times with vitiated air, and which must accordingly be guarded against. That first calling for attention is the miasma or noxious quality imparted to the atmosphere in certain districts by stagnant water and decaying vegetable matter. It is now generally acknowledged that this noxious quality is, in reality, a subtile poison, which acts on the human system through the medium of the lungs, producing fevers and other epidemics. A noted instance of its acting on a great scale is presented in the Campagna di Roma, where a large surface is retained in a marshy state. The exhalations arising from that territory at certain seasons of the year, obliges the inhabitants of the adjacent districts of the city to desert their homes, and escape its pernicious influence. All marshes, and low damp grounds of every kind, produce more or less miasma, and it is consequently dangerous to live upon or near them. Slightly-elevated ground, with a free exposure to light and air, should accordingly in all cases be chosen for the sites of both single houses and towns. Tanks and collections of water of every kind are dangerous beneath or near a house, because, unless their contents be constantly in a state of change, which is rarely the case, their tendency is to send up exhalations of a noxious kind. Some years ago, Viscount Milton—a youth of great promise, and who had recently become a husband and father—died of a fever which was traced to the opening of an old reservoir of water underneath the country-house in which he dwelt. More recently, a similar but more extensively fatal tragedy took place at a farmhouse in the south of Scotland. Not only did the farmer, his wife, and a female servant sink under a malignant fever, but a son and daughter, and several other servants, narrowly escaped with their lives, and only by removing from the house. It was observed in this case that removal produced instantaneous improvement of health, but a return to the devoted dwelling at once renewed the ailment. On proper investigation, it was found that immediately behind the house was a kind of mill-pond, into which every kind of refuse was thrown, or allowed to discharge itself; and that this collection of putrid matter had not been once cleared out for a long series of years, no one dreaming of any harm from it. The momentous consequences from a cause so trifling, and the consideration that they might have been warded off by only a little knowledge of natural causes, furnish melancholy matter for reflection. Many analogous cases, which might be referred to, demonstrate that we are yet but in the infancy of an understanding of the subject of aërial poisons.

Putrid matter of all kinds is another conspicuous source of noxious effluvia. The filth collected in ill-regulated towns—ill-managed drains—collections of decaying animal substances placed too near or within private dwellings—are notable for their effects in vitiating the atmosphere and generating disease in those exposed to them. (See No. 30.) In this case also it is a poison, diffused abroad through the air, which acts so injuriously on the human frame. This was probably the main cause of the plagues which devastated European cities during the middle ages. In those days there were no adequate provisions for public cleaning, and the consequence was, that masses of filth were suffered to accumulate. The noxious air diffused by these means through the narrow streets and confined dwellings would tend to the most fatal effects. In old drains there is generated a gas (sulphuretted hydrogen) which is calculated to produce dreadful consequences in those exposed to its inhalation. It has lately been discovered that it is the presence of this gas, arising from the shores, river deltas, and mangrove jungle of tropical Africa, which causes the peculiar unhealthiness of that region. It is ascertained that small animals, such as birds, die when the air they breathe contains one fifteen-hundredth part of sulphuretted hydrogen, and that an infusion six times greater will kill a horse. It follows that we can scarcely attach too much importance to measures for cleaning and improving the sewerage of cities. There are as yet no large towns in Britain kept in a state so clean as is desirable for the welfare of their inhabitants; nor will they be so till the measures now in agitation for improved modes of construction, for adequate supplies of pure water, and for thorough scavengering and sewerage be adopted.

The human subject tends to vitiate the atmosphere for itself, by the effect which it produces on the air which is breathed. Our breath, when we draw it in, consists of the ingredients formerly mentioned, but it is in a very different state when we part with it. On passing into our lungs, the oxygen, forming the lesser ingredient, enters into combination with the carbon of the venous blood (or blood which has already performed its round through the body); in this process about two-fifths of the oxygen is abstracted and sent into the blood, only the remaining three-fifths being expired along with the nitrogen nearly as it was before.

In place of the oxygen consumed, there is expired an equal volume of carbonic acid gas, such gas being a result of the process of combination just alluded to. Now carbonic acid gas, in a larger proportion than that in which it is found in the atmosphere, is noxious. The volume of it expired by the lungs, if free to mingle with the air at large, will do no harm; but if breathed out into a close room, it will render the air unfit for being again breathed. Suppose an individual to be shut up in an air-tight box; each breath he emits throws a certain quantity of carbonic acid gas into the air filling the box; the air is thus vitiated, and every successive inspiration is composed of worse and worse materials, till at length the oxygen is so much exhausted, that it is insufficient for the support of life. He would then be sensible of a great difficulty in breathing, and in a little time longer he would die.

Most rooms in which human beings live are not strictly close. The chimney and the chinks of the door and windows generally allow of a communication to a certain extent with the outer air, so that it rarely happens that great immediate inconvenience is experienced in ordinary apartments from want of fresh air. But it is at the same time quite certain that in all ordinary apartments where human beings are assembled, the air unavoidably becomes *considerably vitiated;* for in such a situation there cannot be a sufficiently ready or copious supply of oxygen to make up for that which has been consumed, and the carbonic acid gas will be constantly accumulating. This is particularly the case in bedchambers, and in theatres, assembly-rooms, churches, and schools. An extreme case was that of the celebrated Black Hole of Calcutta, where a hundred and forty-six persons were confined for a night in a room eighteen feet square with two small windows. Here the oxygen, scarcely sufficient for the healthy supply of one person, was called upon to support a large number. The unfortunate prisoners found themselves in a state of unheard-of suffering, and in the morning all were dead but twenty-three, some of whom afterwards sunk under putrid fever, brought on by breathing so long a tainted atmosphere.

Although the vitiation of the air in ordinary apartments and places of public assembly does not generally excite much attention, it nevertheless exercises a certain unfavourable influence on health in all the degrees in which it exists. Perhaps it is in bedrooms that most harm is done. These are generally smaller than other rooms, and they are usually kept close during the whole night. The result of sleeping in such a room is very injurious. A common fire, from the draught which it produces, is very serviceable in ventilating rooms, but it is at best a defective means of doing so. The draught which it creates generally sweeps along near the floor between the door and the fire, leaving all above the level of the chimney-piece unpurified. Yet scarcely any other arrangement is anywhere made for the purpose of changing the air in ordinary apartments. To open the window is a plan occasionally resorted to, but it is not always agreeable in our climate, and sometimes it produces bad consequences of a different kind.

It would nevertheless be easy to produce an effective draught from any room in which a fire is kept. It is only necessary to make an aperture into the flue, near the ceiling of the room, and insert therein a tin tube, with a valve at the exterior, capable of opening inwards, but closing when at rest, or when a draught is sent the contrary way. The draught produced by the fire in the flue would cause a constant flow of air out of the upper *part* of the room (where most vitiated); and the valve would be an effectual protection against back-smoke, should there be the least tendency to it. This plan was adopted in Buckingham Palace. It could be applied to any existing house at a mere trifle of expense. A more effectual plan, and one which operates when there is no fire in the room, is to establish a tin tube, of two or three inches diameter, out of each apartment to be ventilated, causing them all to meet in one general tube, the extremity of which passes into some active flue—for example, that of the kitchen, which is rarely cold. Thus there might be a constant passing of fresh air into and through every room of a large house, so that it would be at all times as healthy in this respect as the open fields. At the same time the supply might, by means of graduated valves, be regulated to any degree which might be deemed agreeable. (For various modes of ventilation, see No. 23.)

FOOD.

The second requisite for the preservation of health is—a sufficiency of nutritious food.

Organic bodies, in which are included vegetables as well as animals, are constituted (as explained under PHYSIOLOGY) upon the principle of *a continual waste of substance supplied by continual nutrition.*

The Nutritive System of animals, from apparently the humblest of these to the highest, comprehends an *alimentary tube* or *cavity*, into which food is received, and from which, after undergoing certain changes, it is diffused by means of smaller vessels throughout the whole structure. In the form of this tube, and in the other apparatus connected with the taking of food, there are in different animals varieties of structure, all of which are respectively in conformity with peculiarities in the quality and amount of food which the particular animals are designed to take. The harmony to be observed in these arrangements is remarkably significant of that Creative Design to be traced in all things.

Man designed to live on a Mixed Diet.

Some animals are formed to live upon vegetable substances alone; others are calculated to live upon the flesh of other animals. Herbivorous animals, as the former are called, have generally a long and complicated alimentary tube, because the nutritious part of such food, being comparatively small in proportion to the whole bulk, requires a greater space in which to be extracted and absorbed into the system. The sheep, for example, has a series of intestines twenty-seven times the length of its body. For the opposite reasons, carnivorous or flesh-devouring animals—as the feline tribe of quadrupeds and the rapacious birds—have generally a short intestinal canal. The former class of animals are furnished with teeth, calculated, by their broad and flat surfaces, as well as by the lateral movement of the jaws in which they are set, to mince down the herbage and grain eaten by them. But the carnivorous animals, with wide-opening jaws, have long and sharp fangs to seize and tear their prey. These peculiarities of structure mark sufficiently the designs of nature with respect to the kinds of food required by the two different classes of animals for their support.

The human intestinal canal being of medium length, and the human teeth being a mixture of the two kinds, it necessarily follows that man was designed to eat both vegetable and animal food. As no animal can live agreeably or healthy except in conformity with the laws of its constitution, it follows that man will not thrive unless with a mixture of animal and vegetable food. The followers of Pythagoras argued, from the cruelty of putting animals to death, that it was proper to live on vegetables alone; and eccentric persons of modern times have acted upon this rule. But the ordinances of Nature speak a different language; and if we have any faith in these, we cannot for a moment doubt that a mixture of animal food is necessary for our wellbeing. On the other hand, we cannot dispense with vegetable food without injurious consequences. In that case, we place in a medium alimentary canal a kind of food which is calculated for a short one, thus violating an arrangement of the most important nature. A balance between the two kinds of food is what we should observe, if we would desire to live a natural and healthy life.

Rules connected with Eating.

In order fully to understand how to eat, what to eat, and how to conduct ourselves after eating, it is necessary that we should be acquainted in some measure with the *process of nutrition*—that curious series of operations by which food is received and assimilated by our system, in order to make good the deficiency produced by waste.

Food is first received into the mouth, and there the operations in question may be said to commence. It is there to be chewed (or masticated) and mixed with saliva, preparatorily to its being swallowed or sent into the stomach. Even in this introductory stage there are certain rules to be observed. Strange as it may appear, to know *how to eat* is physiologically a matter of very considerable importance.

Many persons, thinking it all a matter of indifference, or perhaps unduly anxious to despatch their meals, eat very fast. If we are to believe the accounts of travellers, the whole of the mercantile classes in the United States of America eat hurriedly, seldom taking more than ten minutes to breakfast, and a quarter of an hour to dinner. They tumble their meat precipitately into their mouths, and swallow it almost without mastication. This is contrary to an express law of nature, as may be very easily demonstrated.

Food, on being received into the mouth, has two processes to undergo, both very necessary to digestion. It has to be masticated, or chewed down, and also to receive an admixture of saliva. The saliva is a fluid arising from certain glands in and near the mouth, and approaching in character to the gastric juice afterwards to be described. Unless food be well broken down or masticated, and also well mixed up with the salivary fluid, it will be difficult of digestion. The stomach is then called upon to perform, besides its own proper function, that which properly belongs to the teeth and saliva, and it is thus overburdened often in a very serious manner. The pains of indigestion are the immediate consequence, and more remote injuries are likely to follow.

The importance of the saliva has been shown in a striking manner on several occasions when food was received into the stomach otherwise than through the mouth. A gentleman, who, in consequence of a stricture in the gullet, had his food introduced by an aperture into that tube, used to suffer severely from indigestion. It is recorded of a criminal, who, having cut his throat in prison without fatal consequences, required to get his food introduced by means of a tube inserted by the mouth, that every time he was fed there was an effusion of saliva to the amount of from six to eight ounces. We cannot suppose that a fluid of a peculiar character would have been prepared in such quantity, when water would serve as well merely to moisten the food, if it had not been designed to act an important part in the business of nutrition.

With regard to mastication, the evidence of its importance is still more decided. A few years ago, a young Canadian, named Alexis St Martin, had a hole made by a shot into his stomach, which healed without becoming closed. It was therefore possible to observe the whole operations of the stomach with the eye. His medical attendant, Dr Beaumont, by these means ascertained that when a piece of solid food was introduced, the gastric juice acted merely on its outside. It was only when the food was comminuted, or made *small*, that this fluid could fully perform its function. When the stomach finds itself totally unable to digest a solid piece of food, it either rejects it by vomiting, or passes it on into the *gut*, where it produces an irritating effect, and is apt to occasion an attack of cholic or flatulency. It must therefore be concluded that *a deliberate mastication of our food is conducive to health, and that fast eating is injurious, and sometimes even dangerous.*

The food, having been properly masticated, is by the action of the tongue thrown into the gullet. It then descends into the stomach, not so much by its own gravity, as by its being urged along by the contractions and motions of the gullet itself. The stomach may be considered as an expansion of the gullet, and the chief part of the alimentary canal. It is, in fact, a membranous pouch or bag, very similar in shape to a bagpipe, having two openings, the one by which the food is admitted, the other that by which it is passed onward. It is into the greater curvature of the bag that the gullet enters; it is at its lesser that it opens into that adjoining portion of the canal into which the half-digested mass is next propelled.

When food has been introduced, the two orifices close, and that which we may term the second stage in the process of digestion commences. The mass, already saturated with saliva, and so broken down as to expose all its particles to the action of the gastric juice, is now submitted to the action of that fluid, which, during digestion, is freely secreted by the vessels of the stomach. The most remarkable quality of this juice is its solvent power, which is prodigious.

The food exposed to this dissolving agency is converted into a soft, gray, pulpy mass, called *chyme*, which, by the muscular contraction of the stomach, is urged on into the adjoining part of the alimentary canal, called the *duodenum*. This is generally completed in the space of from half an hour to two or three hours; the period varying according to the nature and volume of the food taken, and the degree of mastication and insalivation it has undergone.

In the duodenum, the chyme becomes intimately mixed and incorporated with the bile and pancreatic juices; also with a fluid secreted by the mucous follicles of the intestine itself. The bile is a greenish, bitter, and somewhat viscid fluid, secreted by the liver, which occupies a considerable space on the right side of the body immediately under the ribs. From this organ the bile, after a portion of it has passed up into the adjacent gall-bladder, descends through a small duct, about the size of a goose-quill, into the duodenum. The chyme, when mixed with these fluids, undergoes a change in its appearance: it assumes a yellow colour and bitter taste, owing to the predominance of the bile in the mass; but its character varies according to the nature of the food that has been taken. Fatty matters, tendons, cartilages, white of eggs, &c. are not so readily converted into chyme as fibrous or fleshy, cheesy, and gelatinous substances. The chyme, having undergone the changes adverted to, is urged by the peristaltic motion of the intestines onwards through the alimentary canal. This curious motion of the intestines is caused by the contraction of the muscular coat which enters into their structure, and one of the principal uses ascribed to the bile is that of stimulating them to this motion. If the peristaltic motion be diminished, owing to a deficiency of bile, then the progress of digestion is retarded, and the intestines become constipated. In such cases, calomel, the blue pill, and other medicines, are administered for the purpose of stimulating the liver to secrete the biliary fluid, that it may quicken, by its stimulating properties, the peristaltic action.

The preceding, however, is not the only use of the bile: it also assists in separating the nutritious from the non-nutritious portion of the alimentary mass, for the chyme now presents a mixture of a fluid termed *chyle*, which is in reality the nutritious portion eliminated from the food. The chyme thus mixed with chyle arrives in the small intestines; on the walls of which a series of exquisitely delicate vessels ramify in every direction. These vessels absorb or take up the chyle, leaving the rest of the mass to be ejected from the body. The chyle, thus taken up, is carried into little bodies or glands, where it is still further elaborated, acquiring additional nutritious properties; after which corresponding vessels, emerging from these glands, carry along the fluid to a comparatively large vessel, called the thoracic duct, which ascends in the abdomen along the side of the backbone, and pours it into that side of the heart to which the blood that has already circulated through the body returns. Here the chyle is intimately mixed with the blood, which fluid is now propelled into the lungs, where it undergoes, from being exposed to the action of the air we breathe, the changes necessary to render it again fit for circulation. It is in the lungs, therefore, that the process of digestion is completed:

the blood has now acquired those nutritient properties from which it secretes the new particles of matter adapted to supply the waste of the different textures of the body. (See ANIMAL PHYSIOLOGY, p. 200.)

When food is received into the stomach, the secretion of the gastric juice immediately commences; and when a full meal has been taken, this secretion generally lasts for about an hour. It is a law of vital action, that when any living organ is called into play, there is immediately an increased flow of blood and nervous energy towards it. The stomach, while secreting the bile, displays this phenomenon, and the consequence is that the blood and nervous energy are called away from other organs.' This is the cause of that chilliness at the extremities which we often feel after eating heartily. So great is the demand which the stomach thus makes upon the rest of the system, that during and for some time after a meal, we are not in a condition to take strong exercise of any kind. Both body and mind are inactive and languid. They are so simply because that which supports muscular and mental activity is concentrated for the time upon the organs of digestion. This is an arrangement of nature which a regard to health requires that we should not interfere with. *We should indulge in the muscular and mental repose which is demanded; and this should last for not much less than an hour after every regular meal.* In that time the secretion of bile is nearly finished; the new nutriment begins to tell upon the general circulation; and we are again fit for active exertion. The consequence of not observing this rule is often very hurtful. Strong exercise, or mental application, during or immediately after a meal, diverts the flow of nervous energy and of blood to the stomach, and the process of digestion is necessarily retarded or stopped. Confusion and obstruction are thus introduced into the system, and a tendency to the terrible calamity of dyspepsia is perhaps established.

For the same reason that repose is required after a meal, it is necessary in some measure for a little while before. At the moment when we have concluded a severe muscular task—such, for example, as a long walk—the flow of nervous energy and of circulation is strongly directed to the muscular system. It requires some time to allow this flow to stop and subside; and till this takes place, it is not proper to bring the stomach into exercise, as the demand which it makes when filled would not in that case be answered. In like manner also, if we be engaged in close mental application, the nervous energy and circulation being in that case directed to the brain, it is not right all at once to call another and distant organ into play; some time is required to allow of the energy and circulation being prepared to take the new direction. It may therefore be laid down as a maxim, that *a short period of repose, or at least of very light occupation, should be allowed before every meal.*

It is remarkable that these rules, although the natural reasons for them were not perhaps well known, have long been followed with regard to animals upon which man sets a value, while as yet their application to the human constitution is thought of only by a few. Those intrusted with horses and dogs will not allow them to feed immediately after exercise; nor will they allow them to be subjected to exercise for some time after feeding. Experience has also instructed veteran soldiers not to dine the instant that a long march has been concluded, but to wait coolly till ample time has been allowed for all the proper preparations.

Although strong mental and muscular exercise should be avoided before, during, and immediately after a meal, there can be no objection to the light and lively chat which is generally indulged in where several are met to eat together. On the contrary, it is believed that jocund conversation is useful towards the process of nutrition. Dr Combe, in one of his invaluable works, 'The Physiology of Digestion,' observes as follows:—'The necessary churning or agitation of the food is, from the peculiar situation of the stomach, greatly assisted by the play of the diaphragm and abdominal muscles during inspiration and expiration; and the diminution of the vivacity and extent of the respiratory movement which always attends despondency and grief, is one source of the enfeebled digestion which notoriously accompanies depression of mind. The same cause also leads necessarily to an unfavourable condition of the blood itself, which in its turn weakens digestion in common with every other function; but the muscular or mechanical influence is that which at present chiefly concerns us. On the other hand, the active and energetic respiration attendant on cheerfulness and buoyancy of spirits adds to the power of digestion, both by aiding the motions of the stomach and by imparting to it a more richly-constituted blood. If to those causes be added the increase of nervous stimulus which pleasing emotions occasion in the stomach (as in the muscles and organs of secretion generally), we shall have no difficulty in perceiving why digestion goes on so well in parties where there is much jocularity and mirth. "Laughter," says Professor Hufeland of Berlin, "is one of the greatest helps to digestion with which I am acquainted; and the custom prevalent among our forefathers, of exciting it at table by jesters and buffoons, was founded on [or rather, accidentally in harmony with?] true medical principles. In a word, endeavour to have cheerful and merry companions at your meals: what nourishment one receives amidst mirth and jollity will certainly produce good and light blood."'

Kinds of Food.

It has been shown, by a reference to the structure of the human intestinal canal, that our food is designed to be a mixture of animal and vegetable substances. There is, it is to be remarked, a power of adaptation in nature, by which individuals may be enabled for a considerable time to live healthily on one or the other kind exclusively or nearly so. The above is nevertheless the general rule, to which it is safest to adhere. It has been found, for instance, that field-labourers, including ploughmen, will live healthily for many years on a diet chiefly farinaceous—that is, composed of the farina of grain. But it is to be feared that the food in this case, though apparently sufficient for health, is only so apparently; and that the constitution, being all the time not supported as it ought to be, breaks down prematurely in a great proportion of instances. It has been said again that the Irish labouring classes are a remarkably robust race, although their food consists almost exclusively of potatoes. The fact is overlooked, that the Irish eat a quantity of potatoes so enormous, as could not fail to make up in some measure for the want of animal diet. It was found by the Poor-Law Commissioners, that the greater number of the peasantry of Ireland, women as well as men, take at their two daily meals in general about nine pounds weight of this aliment! Such a case is rather to be ranked amongst instances of extraordinary adaptations to a particular variety of food, than as a proof that an unmixed potato diet is healthy.

Climate has a remarkable effect in modifying the rule as to the mixture and amount of animal and vegetable food. The former has most of a stimulating quality, and this quality is greater in beef, and flesh in general, than in fowl or fish. Now the inhabitants of torrid countries are, in their ordinary condition, least in need of stimulus: hence they find a simple diet of rice and sago sufficient for them. Those, on the contrary, who dwell in cold countries need much stimulus; hence they can devour vast quantities of flesh and blubber, with scarcely any mixture of vegetable food.

Inquiries with respect to the comparative digestibility of different kinds of food, are perhaps chiefly of consequence to those in whom health has already been lost. To the sound and healthy it is comparatively of little consequence what kind of food is taken, provided that some variation is observed, and no excess committed as to quantity. Within the range of fish, flesh, and fowl, there is ample scope for a safe choice. There is scarcely any of the familiar aliments of these kinds but, if plainly dressed, will digest in from two to four hours, and prove perfectly healthy. One rule alone has been pretty well ascertained with respect to animal foods, that they are the more digestible the more minute and tender the fibre may be. They contain more nutriment in a given bulk than vegetable matters, and hence their less need for length of intestine to digest them. Yet it is worthy of notice, that between the chyle produced from animal and that from vegetable food no essential distinction can be observed.

Tendon, suet, and oily matters in general, are considerably less digestible than the ordinary fibre; and these are aliments which should be taken sparingly. Pickling, from its effect in hardening the fibre, diminishes the digestibility of meat. Dressed shell-fish, cheese, and some other animal foods, are avoided by many as not sufficiently digestible.

Farinaceous foods of all kinds—wheat, oaten, and barley bread, oaten porridge, sago, arrow-root, tapioca, and potatoes—are highly suitable to the human constitution. They generally require under two hours for digestion, or about half the time of a full mixed meal. The cottage children of Scotland, reared exclusively upon oaten porridge and bread, with potatoes and milk, may be cited as a remarkable example of a class of human beings possessing in an uncommon degree the blessing of health. Green vegetables and fruit, however softened by dressing, are less digestible, and less healthy as a diet. One important consideration here occurs: there is need for a certain bulk in our ordinary food. Receiving nutriment in a condensed form, and in a small space, will not serve the purpose. This is because the organs of digestion are calculated for receiving our food nearly in the condition in which nature presents it—namely, in a considerable bulk with regard to the proportion of its nutritious properties. The same law applies with respect to the lower animals. When a horse is fed upon corn alone, it does not thrive. Nature did not contemplate that all horses should readily obtain a corn diet, but looked chiefly to grass and hay for their support. She therefore prepared the organs for the reception of something of considerable volume; and when a food of less volume is persisted in, her law is violated, and fatal consequences ensue. Civilised man is apt to pay little attention to this rule in his own case. Consulting taste alone, he is apt to refine his food overmuch, and reject what it were better for him to take. The present writer is much inclined to doubt the propriety of grinding off the coarse exterior of wheaten grain. It does not seem by any means likely that nature calculated the human alimentary cavity for the use of the white interior of the grain, exclusive of all the rest, which consists of very different but not less necessary chemical constituents. Wheat forms so large a part of our daily food, that if this be the case, we unquestionably make a departure of a very important kind from the laws of health. Experience is favourable to this view, for the effect of coarse brown bread in relaxing seems only comparable to that of white bread in constipating the bowels.

Quantity of Food—Number and Times of Meals.

With respect to the amount of food necessary for health, it is difficult to lay down any rule, as different quantities are safe with different individuals, according to their sex, age, activity of life, and some other conditions. There is a general and probably well-founded opinion, that most persons who have the means eat too much, and thereby injure their health. This may be true, and yet it may not be easy to assign to such persons a limit beyond which they ought not to go.

The best authorities are obliged to refer the matter to our own sensations. Dr Beaumont, for example, says that we should not eat till the mind has a sense of *satiety*, for appetite may exceed the power of digestion, and generally does so, particularly in invalids; but to a point previous to that, which 'may be known by the pleasurable sensations of *perfect satisfaction, ease, and quiescence of body and mind*.'

The number and times of meals are other questions as yet undetermined. As the digestion of a meal rarely requires more than four hours, and the waking part of a day is about sixteen, it seems unavoidable that at least three meals be taken, though it may be proper that one, if not two of these, be comparatively of a light nature. Breakfast, dinner, and tea as a light meal, may be considered as a safe, if not a very accurate prescription for the daily food of a healthy person. Certainly four good meals a day is too much. No experiments, as far as we are aware, have been made with regard to the total amount of solids which a healthy person in active life may safely take in a day. It has been found, however, that confined criminals and paupers are healthiest when the daily solids are not much either above or below twenty-four ounces.* Of course, in active life there must be need for a larger allowance, but only to a small extent. We may thus arrive at a tolerably clear conviction of the reality of that excess which is said to be generally indulged in; for certainly most grown people who have the means, not excepting many who pursue very sedentary lives, eat *much more* than twenty-four ounces.

The interval between rising and breakfast ought not to be great, and no severe exercise or taskwork of any kind should be undergone during this interval. There is a general prepossession to the contrary, arising probably from the feeling of freedom and lightness which most people feel at that period of the day, and which seems to them as indicating a preparedness for exertion. But this feeling, perhaps, only arises from a sense of relief from that oppression of food under which much of the rest of the day is spent. It is quite inconsistent with all we know of the physiology of aliment, to suppose that the body is capable of much exertion when the stomach has been for several hours quite empty. We have known many persons take long walks before breakfast, under an impression that they were doing something extremely favourable to health. Others we have known go through three hours of mental taskwork at the same period, believing that they were gaining so much time. But the only observable result was, to subtract from the powers of exertion in the middle and latter part of the day. In so far as the practice was contrary to nature, it would likewise of course produce permanent injury. Only a short saunter in the open air, or a very brief application to business or taskwork, can be safely indulged in before breakfast.

With regard to the time for either breakfast or dinner, nothing can be said with scientific authority. Dr Combe, who is by no means disposed to take lax or indulgent views with regard to dietary matters, while favourable to an early dinner hour, allows that he has himself changed his hours for both breakfast and dinner, from comparatively early to comparatively late periods, without any perceptible inconvenience. In rural life, it is found convenient to dine not long after the middle of the day; but in cities, where it is necessary to have a long uninterrupted space in the middle of the day for business, a late dinner hour is scarcely avoidable. In such a case a slight lunch serves to keep the strength from sinking; and if dinner is taken not less than five or six hours before bed-time, it is not easy to see how any injurious consequences should follow. The changes that have taken place in meal hours from old times are more apparent than real. The present substantial lunch of fashionable life occurs nearly at the same hour as the Elizabethan dinner, and the present dinner is in all respects, except name, the same as the supper of those times. The only thing which the physiologist would much insist on is, that between the two principal meals of the day there should be no long fasts. If the interval be above seven hours, a biscuit should be taken after four of the seven hours have elapsed. When the

* See two papers on food, in Nos. 366 and 368 of 'Chambers's Edinburgh Journal,' old series.

interval amounts to nine hours, the lunch should be a little more substantial, but not of animal food, particularly if any has been taken at breakfast. A glass of wine is often added to a biscuit lunch, or wine alone is taken; but neither of these practices can be commended. While a small quantity of bread or biscuit gives real strength, and is quite sufficient for the occasion, wine only gives a stimulus, serving for the time, but making the case worse afterwards.

Variety of Food.

A judicious variation of food is not only useful, but important. There are, it is true, some aliments, such as bread, which cannot be varied, and which no one ever wishes to be so. But apart from one or two articles, a certain variation or rotation is much to be desired, and will prove favourable to health. There is a common prepossession respecting *one dish*, which is more spoken of than acted upon. In reality there is no virtue in this practice, excepting that, if rigidly adhered to, it makes excess nearly impossible, no one being able to eat to satiety of one kind of food. There would be a benefit from both a daily variation of food and eating of more than one dish at a meal, *if moderation were in both cases to be strictly observed;* for the relish to be thus obtained is useful, as promotive of the flow of nervous energy to the stomach, exactly in the same manner as cheerfulness is useful. The policy which would make food in anyway unpleasant to the taste is a most mistaken one; for to eat with languor, or against inclination, or with any degree of disgust, is to lose much of the benefit of eating. On the other hand, to cook dishes highly, and provoke appetite by artificial means, are equally reprehensible. Propriety lies in the mean between the two extremes.

Beverages.

The body containing a vast amount of fluids, which are undergoing a perpetual waste, there is a necessity for an occasional supply of liquor of some kind, as well as of solid aliment. It remains to be considered what is required in the character or nature of this liquor, to make it serve as a beverage consistently with the preservation of health.

It is scarcely necessary to remark how men in all ages, and almost all climes, have indulged in liquors containing a large infusion of alcohol, or how widespread in our own society is the custom of drinking considerable quantities of wine, spirits, and beer, both at meals and on other occasions. Against habits so inveterate it is apt to appear like fanaticism to make any decided objection; yet the investigator of the laws which regulate health is bound to consider, above all things, how any particular habit bears upon the human constitution, and to state what is the result of his inquiries, however irreconcilable it may be with popular prejudice or practice.

'The primary effect of all distilled and fermented liquors,' says Dr Combe, 'is to *stimulate the nervous system and quicken the circulation.*' They may thus be said to have a larger measure of the effect which animal food has upon the system. It is therefore the less surprising that those tropical nations which live most on farinaceous diet are also found to be those which have the least propensity to the drinking of ardent spirits; while those northern nations which live most on animal food have the exactly contrary inclination with respect to liquor, the Scandinavian tribes being notoriously the greatest sots that have ever been known. Dr Combe admits that in some conditions of the system, when the natural stimulus is defective, it may be proper to take an artificial supply in the form of ardent and fermented liquors. 'There are,' he says, 'many constitutions so inherently defective in energy, as to derive benefit from a moderate daily allowance of wine; and there are many situations in which even the healthiest derive additional security from its occasional use. If, for example, a healthy person is exposed to unusual and continued exertion in the open air, or to the influence of anxious and depressing watchfulness, a moderate quantity of wine with his food may become the means of warding off actual disease, and enabling him to bear up uninjured, where without it he would have given way.' But Dr Combe at the same time declares, in the most decided language, that when the digestion is good, and the system in full vigour, the bodily energy is easily sustained by nutritious food, and 'artificial stimulant *only increases the wasting of the natural strength.*' Nearly all physicians, indeed, concur in representing ardent liquors as unfavourable to the health of the healthy, and as being, in their excess, highly injurious. Even the specious defence which has been set up for their use, on the ground that they would not have been given to man if they had not been designed for general use, has been shown to be ill-founded, seeing that *vinous fermentation*, from which they are derived, is not a healthy condition of vegetable matter, but a stage in its progress to decay. Upon the whole, there can be little doubt that these liquors are deleterious in our ordinary healthy condition; and that pure water, toast-water, milk, whey, and other simple and unexciting beverages, would be preferable (the first being the most natural), if we could only consent to deny ourselves further indulgence.

CLEANLINESS.

To keep the body in a cleanly condition is the third important requisite for the preservation of health. This becomes necessary, in consequence of a very important natural process which is constantly going on near and upon the surface of the body.

The process in question is that of *perspiration*. The matter here concerned is a watery secretion, produced by glands near the surface of the body, and sent up through the skin by channels imperceptibly minute and wonderfully numerous. From two to six pounds of this secretion is believed to exude through these channels or *pores* in the course of twenty-four hours, being in fact the chief form taken by what is called the waste of the system, the remainder passing off by the bowels, kidneys, and lungs. To promote the free egress of this fluid is of the utmost importance to health; for when it is suppressed, disease is apt to fall upon some of the other organs concerned in the discharge of waste.

One of the most notable checks which perspiration experiences is that produced by a current of cold air upon the skin, in which case the pores instantly contract and close, and the individual is seized with some ailment either in one of the other organs of waste, whichever is in him the weakest, or in the internal lining of some part of the body, all of which is sympathetic with the condition of the skin. A result of the nature of that last described is usually recognised as a cold or catarrh. We are not at present called on particularly to notice such effects of checked perspiration, but shall allude to others of a less perceptible, though not less dangerous nature.

The fluid alluded to is composed, besides water, of certain salts and animal matters, which, being solid, do not pass away in vapour, as does the watery part of the compound, but rest on the surface where they have been discharged. There, if not removed by some artificial means, they form a layer of hard stuff, and unavoidably impede the egress of the current perspiration. By cleanliness is merely meant the taking proper means to prevent this or any other extraneous matter from accumulating on the surface, to the production of certain hurtful consequences.

Ablution or washing is the best means of attaining this end; and accordingly it is well for us to wash or bathe the body frequently. Many leave by far the greater part of their bodies unwashed, except perhaps on rare occasions, thinking it enough if the parts exposed to common view be in decent trim. If the object of cleaning were solely to preserve fair appearances, this might be sufficient; but the great end, it must be clearly seen, is to keep the skin in a fit state for its peculiar and very important functions. Frequent change of the clothing next to the skin is of course a great aid to cleanliness, and may partly be esteemed as a substitute for bathing, seeing that the clothes absorb much of the impurities, and, when changed, may be said to carry these off. But still this will not serve the end nearly so well as frequent ablution of the whole person. Any one will be convinced of this who goes into a bath, and uses the flesh-brush in cleansing his body. The quantity of scurf and impurity which he will then remove, from a body which has changes of linen even once a day, will surprise him.

Considering the importance of personal cleanliness for health, it becomes a great duty of municipal rulers to afford every encouragement in their power to the establishment of public baths for the middle and working classes, and to extend and protect all existing facilities for washing clothes, as well as for private supplies of water. Baths should neither be very cold nor very warm, but in an agreeable medium; and they should never be taken within three hours of a meal. Nature may be said to make a strong pleading for their more general use, in the remarkably pleasing feeling which is experienced in the skin after ablution.

EXERCISE.

The constitution of external nature shows that man was destined for an active existence, as without labour scarcely any of the gifts of Providence are to be made available. In perfect harmony with this character of the material world, he has been furnished with a muscular and mental system, constructed on the principle of being fitted for exertion, and requiring exertion for a continued healthy existence. Formed as he is, it is not possible for him to abstain from exertion without very hurtful consequences.

Muscular Exercise.

With regard to merely bodily exercise, it is to be observed, in the first place, that we have no fewer than four hundred muscles, each designed to serve some particular end in locomotion, or in operating upon external objects. A sound state of body depends very much upon each of these muscles being brought into action in proper circumstances, and to a suitable extent. There is even a law, operating within a certain range, by which each muscle will gain *in strength and soundness* by being brought into a proper degree of activity.

The process of waste and renovation may be said to be always going on in the body, but it does not go on with permanent steadiness, unless the muscular system be exercised. Whenever one of the organs is put into exertion, this process becomes active, and the two operations of which it consists maintain a due proportion to each other. A greater flow of blood and of nervous energy is sent to the organ, and this continues as long as it is kept in activity. When one state of action follows close upon another, the renovating part of the process rather exceeds the waste, and an accretion of new substance, as well as an addition of fresh power, takes place. On the contrary, when an organ is little exercised, the process of renovation goes on languidly, and to a less extent than that of waste, and the parts consequently become flabby, shrunken, and weak. Even the bones are subject to the same laws. If these be duly exercised in their business of administering to motion, the vessels which pervade them are fed more actively with blood, and they increase in dimensions, solidity, and strength. If they be little exercised, the stimulus required for the supply of blood to them becomes insufficient; imperfect nutrition takes place; and the consequences are debility, softness, and unfitness for their office. Bones may be so much softened by inaction, as to become susceptible of being cut by a knife. In a less degree, the same cause will produce languor and bad health.

It is of the utmost importance to observe that the exercise of any particular limb does little besides improving the strength of that limb; and that, in order to increase our general strength, the whole frame must be brought into exercise. The blacksmith, by wielding his hammer, increases the muscular volume and strength of his right arm only, or if the rest of his body derives any advantage from his exercise, it is through the general movement which the wielding of a hammer occasions. One whose profession consists in dancing or leaping, for the same reason, chiefly improves the muscles of his legs. The right hands of most persons, by being more frequently employed than the left, become sensibly larger as well as stronger. A still more striking illustration of the principle is to be found in a personal peculiarity which has been remarked in the inhabitants of Paris. Owing to the uneven nature of the pavement of that city, the people are obliged to walk in a tripping manner on the front of their feet; a movement which calls the muscles of the calves of the legs into strong exertion. It is accordingly remarked that a larger proportion of the people of Paris are distinguished by an uncommon bulk in this part of their persons than in other cities.

In order, then, to maintain in a sound state the energies which nature has given us, and, still more particularly, to increase their amount, *we must exercise them.* If we desire to have a strong limb, we must exercise that limb; if we desire that the whole of our frame should be sound and strong, we must exercise the whole of our frame. It is mainly by these means that health and strength are to be preserved and improved. There are rules, however, for the application of these laws of our being.

1. That bodily exercise may be truly advantageous, the parts must be in a state of sufficient health to endure the exertion. A system weakened by disease or long inaction must be exercised very sparingly, and brought on to greater efforts very gradually, otherwise the usual effects of over-exercise will follow. In no case must exercise be carried beyond what the parts are capable of bearing with ease, otherwise a loss of energy, instead of a gain, will be the consequence.

2. Exercise, to be efficacious even in a healthy subject, must be excited, sustained, and directed by that nervous stimulus which gives the muscles the principal part of their strength, and contributes so much to the nutrition of parts in a state of activity. To explain this, it must be mentioned that to produce motion requires the co-operation of the muscular fibre with two sets of nerves, one of which conveys the command of the brain to the muscle, and causes its contraction, while the other conveys back to the brain the peculiar sense of the state of the muscle, by which we judge of the fitness of the degree of contraction which has been produced to accomplish the end desired, and which is obviously an indispensable piece of information to the mind in regulating the movements of the body. The nervous stimulus thus created, will enable a muscle in the living frame to bear the weight of a hundred pounds, while, if detached, it would be torn asunder by one of ten. It is what causes men in danger, or in the pursuit of some eagerly-desired object, to perform such extraordinary feats of strength and activity. In order, then, to obtain the advantage of this powerful agent, *we must be interested in what we are doing.* A sport that calls up the mental energy, a walk towards a place which we are anxious to reach, or even an exercise which we engage in through a desire of invigorating our health and strength, will prove beneficial, when more of actual motion, performed languidly, may be nearly ineffectual.

3. The waste occasioned by exercise must be duly replaced by food; as, if there be any deficiency in that important requisite, the blood will soon cease to give that invigoration to the parts upon which increased health and strength depend.

Kinds of Bodily Exercise.

Exercise is usually considered as of two kinds—active and passive. The active consists in walking, running, leaping, riding, fencing, rowing, skating, swimming, dancing, and various exercises, such as those with the poles, ropes, &c. prescribed in gymnastic institutions. The passive consists in carriage riding, sailing, friction, swinging, &c. (For various modes of agreeable recreation, see articles on IN-DOOR and OUT-DOOR AMUSEMENTS—Volume II.)

Walking is perhaps the readiest mode of taking exercise, and the one most extensively resorted to. If it brought the upper part of the body as thoroughly into exertion as the lower, it would be perfect, for it is gentle and safe with nearly all except the much debilitated. To render it the more effectual in the upper part of the body, it were well to walk at all times, when convenient, *singly*, and allow the arms and trunk free play. It is best to walk with a companion, or for some definite object, as the flow of nervous energy will be by these means promoted, and the exercise be rendered, as has been already explained, the more serviceable.

Very long or rapid walks should not be attempted by individuals of sedentary habits, nor by weakly persons. Their frames are totally unprepared for such violent exertion. When a person who has been long confined at still employments finds himself at liberty to indulge his inclination for a ramble of a few days in the country, he should begin with slow and short marches, and be content therewith till his body is hardened for greater efforts. This is a rule followed in the army with respect to regiments which are about to undertake long marches. Every summer many youths, from ignorance, do themselves great injury, by undertaking pedestrian excursions much beyond their strength. Jaded to the last degree, and incapable of enjoying anything presented to their observation, they nevertheless persist in making out some appointed number of miles per day, never once thinking of the outrage they are committing upon themselves, and only looking to the glory of executing their task, the only pleasure they find in the journey. Serious consequences—consumption not unfrequently—follow such ill-advised and senseless efforts.

With respect to very violent walking, Dr Johnson records some effects from it, of a remarkable nature, as occurring in his own case. 'In my own person,' says he, 'I had some years ago a very severe and alarming instance of the bad effects of too great muscular action, occasioned by a habit of walking very fast. After a day and night of unusual fatigue and rapid pedestrian exertion, together with considerable mental anxiety, I was suddenly seized with an intermission of the pulse at irregular periods. During each intermission, I felt the heart give a kind of struggle, as it were, and strike with great violence against the ribs, accompanied by a peculiar and most distressing sensation in the cardiac region, which I cannot describe.' These symptoms became aggravated, and lasted for eight weeks, 'during which time,' he continues, 'I used gentle horse-exercise, and kept, when at home, in a horizontal position. At length the heart gradually lost its morbid irritability, and at the end of fourteen or fifteen weeks I could walk as well as ever.'

Running is an exercise which is intermediate between walking and leaping; it consists, in fact, of a series of leaps performed in progression from one foot to another, and the degree of its rapidity bears a constant proportion to the length of the individual and successive leaps. During this exercise the individual is obliged to take long inspirations, and make slow expirations; the air-cells of the lungs are thereby distended, and the action of the heart being at the same time increased, and the circulation through the lungs much accelerated, a sense of oppression is felt on the chest, which is often exceedingly painful; when the violent action is discontinued, the heart palpitates with intermitting strokes, in the endeavour to recover its natural equilibrium of motion. Although this and other gymnastic exercises, such as leaping, wrestling, throwing heavy weights, &c. may, when judiciously had recourse to, invigorate the body, yet from apprehension of the evils and accidents which may be so occasioned, young persons ought not to be permitted to engage extensively in such exercises, except under the care of some one well acquainted with gymnastics.

Fencing is, of all active exercises, that which is the most commendable, inasmuch as it throws open the chest, and at the same time calls into action the muscles both of the upper and lower extremities. Add to this that it improves very much the carriage of the body; for which reason it may be reckoned a branch of polite education. The salutary effects of the other exercises which are taught in gymnastic institutions—such as exercise with the ropes, poles, pulleys, &c.—in increasing the strength of the body, will be seen by consulting Mr Roland's Treatise on Gymnastics, where will be found a table showing the amount of the increasing growth and strength of the body in a given time during the employment of these exercises.

Dancing is exhilarating and healthful, and seems to be almost the only active exercise which the despotic laws of conventionality permit young ladies to enjoy. We can scarcely consider modern quadrilles, elegant though they be, as exercise, seeing that they differ little from the most common walking movements. But country dances, reels, and hornpipes, are genuine exercise, and their less refinement may be considered as amply compensated by the superior benefit which they are calculated to confer upon health.

Riding is generally classed among the passive exercises, but in reality it is one which involves much action of the whole frame, and as such is very useful. Pursued solitarily, it has the drawback of being somewhat dull; but when two or three ride in company, a sufficient flow of the nervous energy may be obtained.

The amount of bodily exercise which should be taken must vary according to the habits, strength, and general health of the individual. It was an aphorism of Boerhaave, that every person should take at least two hours' exercise in the day, and this may be regarded as a good general rule.

Mental Exercise.

Having thus explained the laws and regulations by which exercise may be serviceable to the physical system, we shall proceed to show that the same rules hold good respecting the mental faculties. These, as is generally allowed, however immaterial in one sense, are connected organically with the brain—a portion of the animal system nourished by the same blood, and regulated by the same vital laws, as the muscles, bones, and nerves. As, by disuse, muscle becomes emaciated, bone softens, blood-vessels are obliterated, and nerves lose their natural structure, so by disuse does the brain fall out of its proper state, and create misery to its possessor; and as, by over-exertion, the waste of the animal system exceeds the supply, and debility and unsoundness are produced, so by over-exertion are the functions of the brain liable to be deranged and destroyed. The processes are physiologically the same, and the effects bear an exact relation to each other. As with the bodily powers, the mental are to be increased in magnitude and energy by a degree of exercise measured with a just regard to their ordinary health and native or habitual energies. Corresponding, moreover, to the influence which the mind has in giving the nervous stimulus so useful in bodily exercise, is the dependence of the mind upon the body for supplies of healthy nutriment. And, in like manner with the bodily functions, each mental faculty is only to be strengthened by the exercise of itself in particular. Every part of our intellectual and moral nature stands, in this respect, exactly in the same situation with the blacksmith's right arm and the lower limbs of the inhabitants of Paris: each must be exercised for its own sake.

The fatal effects of the disuse of the mental faculties are strikingly observable in persons who have the misfortune to be solitarily confined, many of whom become insane, or at least weak in their intellects. It is also observable in the deaf and blind, among whom, from the non-employment of a number of the faculties, weakness of mind and idiocy are more prevalent than among other people. This is indeed a frequent predisposing cause of every form of nervous disease.

The loss of power and health of mind from imperfect or partial exercise of the faculties, is frequently observable in the country clergy, in retired merchants, in annuitants, in the clerks of public offices, and in tradesmen whose professions comprehend a very limited range of objects. There is no class, however, in whom the evil is more widely observable than in those females who, either from ignorance of the laws of exercise, or from inveterate habit, spend their lives in unbroken seclusion, and in the performance of a limited range of duties. All motive is there wanting. No immediate object of solicitude ever presents itself. Fixing their thoughts entirely on themselves, and constantly brooding over a few narrow and trivial ideas, they at length approach a state little removed from insanity, or are only saved from that, perhaps, by the false and deluding relief afforded by stimulating liquors. In general, the education of such persons has given them only a few *accomplishments*, calculated to afford employment to one or two of the minor powers of the mind, while all that could have engaged the reflecting powers has been omitted. Education, if properly conducted, would go far to prevent these evils.

On the other hand, excessive exercise of the brain, by propelling too much blood to it, and unduly distending the vessels, is equally injurious with its disuse. And not only are fatal effects to be apprehended from undue mental taskwork, but also from that constant *stretch* of the mind which attends an unduly anxious and watchful disposition. The ancients had some notion of the impropriety of an incessant exertion of the mind, and rebuked it by their well-known proverb—*Apollo does not keep his bow always bent.* But they had comparatively little experience of the oppressive mental labours endured by large portions of modern society. Irrational, and in some respects dangerous, as many of the habits of our ancestors were, it is questionable if they suffered so much from these causes as their successors do from virtuous but overtasking exertion. To maintain what each man conceives to be a creditable place in society, now requires such close and vigorous exertions, that more, we verily believe, perish in the performance of duties in themselves laudable, than formerly sank under fox-hunting, toast-drinking, and the gout.

It is in large cities that this unintentional kind of self-destruction is most conspicuously exemplified. And it is in London, above all other places, that the frenzy is to be observed in its most glaring forms. To spend nine hours at a time in business, without food or relaxation, is not only not uncommon, but an almost universal practice, among the citizens of London: from a breakfast at eight to a chop at five, they are never, to use an expressive phrase, *off the stretch.* Upon a stomach enfeebled by exhaustion, they then lay the load of a full meal, which perfect leisure would hardly enable them to digest. But far from waiting to digest it, they have no sooner laid down knife and fork, than away they must once more rush to business—not perhaps willingly, for nature tells them that it would be agreeable to rest; but then—but then business *must* be attended to. If nature were to punish the daily transgression by the nightly suffering, we should find few who, for the sake of pecuniary gain, would thus expose themselves to misery. But unfortunately she runs long accounts with her children, and, like a cheating attorney, seldom renders her bill till the whole subject of litigation has been eaten up. Paralysis at fifty comes like the mesne process upon the victim of commercial enthusiasm,* and either hurries him off to that prison from which there is no liberation, or leaves him for a few years organically alive to *enjoy* the fruits of his labours. A life thus spent is a mere fragment of what it ought to be. The means of obtaining pleasure have swallowed up the end. The glorious face of nature, with all its sublime and beautiful alternations; the delights of social life; the pleasures arising from the exercise of the finer feelings and the cultivation of the intellect; all that higher class of gratifications which Nature has designed a moderate degree of labour to place within the reach of *all* her creatures, have been lost to such a man.

The absurdity of an ignorance or weakness of this kind is perhaps still more striking when it occurs in individuals who make the acquisition of knowledge the chief aim of life. As the world is at present situated, it is possible to acquire learning upon almost every subject, and an infinite amount of knowledge, useful and otherwise, without even by chance lighting upon a knowledge of the most indispensable observances necessary for the preservation of a sound mind in a sound body. Half of the multiform languages of Asia may be mastered, while the prodigy who boasts so much learning knows not that to sit a whole day within doors at close study is detrimental to health; or, if he knows so much, deliberately prefers the course which leads to ruin. Leyden, an enthusiast of this order, was ill with a fever and liver complaint at Mysore, and yet continued to study ten hours a day. He eventually sank, in his thirty-sixth year, under the consequences of spending some time in an ill-ventilated library, which a slight acquaintance with one of the most familiar of the sciences would have warned him against entering. Alexander Nicoll, a recent professor of Hebrew at Oxford, of whom it was said that he might have walked to the wall of China without the aid of an interpreter, died at the same age, partly through the effects of that intense study which so effectually, but so uselessly, had gained him distinction. Dr Alexander Murray, a similar prodigy, died in his thirty-eighth year of over-severe study; making the third of a set of men remarkable for the same wonderful attainments, and natives of the same country, who, within a space of twenty years, fell victims to their ignorance of the laws of mental exercise. In 1807, Sir Humphry Davy prosecuted his inquiry into the alkaline metals with such inordinate eagerness, that, through excitement and fatigue, he contracted a dangerous fever, which he, in ignorance of the human physiology, ascribed to contagion caught in experimenting on the fumigation of hospitals. His physician was at no loss to trace it to his habits of study, which were such as would have soon worn out a frame much more robust. Davy at this time spent all the earlier part of the day in his laboratory, surrounded by persons of every rank, whose admiration of his experiments added to his excitement. 'Individuals of the highest distinction,' says Paris in his biographical sketch of Sir Humphry, 'contended for the honour of his company to dinner, and he did not possess sufficient resolution to resist the gratification thus afforded, though it generally happened that his pursuits in the laboratory were not suspended until the appointed dinner hour had passed. On his return in the evening, he resumed his chemical labours, and commonly continued them till three or four in the morning, and yet the servants of the establishment not unfrequently found that he had risen before them.' Overtasked nature at length yielded under his exertions, and it was with the greatest difficulty that he was restored to health. Excessive application is known to have in like manner thrown Boerhaave into a species of delirium for six weeks, and to have on one occasion given a severe shock to the health of Newton. It unquestionably cut short the days of Sir Walter Scott, and also of the celebrated Weber, whose mournful exclamation in the midst of his numerous engagements can never be forgotten—'Would that I were a tailor, for then I should have a Sunday's holiday!'

The premature extinction of early prodigies of genius is generally traceable to the same cause. We read that, while all other children played, they remained at home to study; and then we learn that they perished in the

* Of the frequent occurrence of premature paralysis, in consequence of the mode of life above described, we are assured by a metropolitan physician of the greatest eminence.

bed, and balked the hopes of all their admiring friends. The ignorant wonder is of course always the greater when life is broken short in the midst of honourable undertakings. We wonder at the inscrutable decrees which permit the idle and dissolute to live, and remove the ardent benefactor of his kind, the hope of parents, the virtuous, and the self-devoted; never reflecting that the highest moral and intellectual qualities avail nothing in repairing or warding off a decided injury to the physical system, which is regulated by laws of a different, but of as imperative a nature. The conduct of the Portuguese sailors in a storm, when, instead of working the vessel properly, they employ themselves in paying vows to their saints, is just as rational as most of the notions which prevail on this subject in the most enlightened circles of British society.

It ought to be universally known that the uses of our intellectual nature are not to be properly realised without a just regard to the laws of that perishable frame with which it is connected; that, in cultivating the mind, we must neither overtask nor undertask the body, neither push it to too great a speed, nor leave it neglected; and that notwithstanding this intimate connection and mutual dependence, the highest merits on the part of the mind will not compensate for muscles mistreated, or soothe a nervous system which severe study has tortured into insanity. To come to detail—it ought to be impressed on all, that to spend more than a moderate number of hours in mental exercise, diminishes insensibly the powers of future application, and tends to abbreviate life; that no mental exercise should be attempted immediately after meals, as the processes of thought and of digestion cannot be safely prosecuted together; and that without a due share of exercise to the whole of the mental faculties, there can be no soundness in any, while the whole corporeal system will give way beneath a severe pressure upon any one in particular. These are truths completely established with physiologists, and upon which it is undeniable that a great portion of human happiness depends.

Repose a condition demanded by Exercise.

Exercise demands occasional periods of repose, and, in particular, that a certain part of every twenty-four hours be spent in sleep. After having been engaged in daily occupations for fourteen or sixteen hours, a general feeling of fatigue and weakness is induced; the motions of the body become difficult, the senses confused, the power of volition or will suspended, and the rest of the mental faculties, becoming more and more inactive, sink at length into a state of unconsciousness. The sense of sight first ceases to act by the closing of the eyelids; then the senses of taste and smell become dormant; and then those of hearing and touch. The muscles also dispose themselves with a certain reference to ease of position, those of the limbs having grown indolent before those that support the head, and those that support the head before those of the trunk. In proportion as these phenomena proceed, the respiration becomes slower and more deep, the circulation diminishes in impetus, the blood proceeds in great quantity towards the head, and all the functions of the internal organs become retarded. In this state, shut out, as it were, from the external world, the mind still retains part of its wonted activity, deprived, however, of the guidance of judgment and the power of *distinct* recollection; in consequence of which it does not perceive the monstrous incongruities of the imagery which sweeps before it, and takes but imperfect cognisance of the time which elapses.

It may be laid down as an axiom, that the more uninterrupted sleep is, the more refreshing and salutary will be its effects; for, during this period, the body undoubtedly acquires an accession of nervous energy, which restlessness, however induced, must disturb; and therefore the state of the body before going to sleep, the kind of bed, and the manner of clothing, require especial attention. As the functions of the body are performed more slowly during our sleeping than our waking hours, a full meal or supper, taken immediately before going to bed, imposes a load on the stomach which it is not in a condition to digest, and the unpleasant consequence of oppressive and harassing dreams is almost certain to ensue. When the sleeper lies upon his back, the heart pressing, while pulsating, on the lungs, gives rise to a sense of intolerable oppression on the chest, which seems to bear down upon the whole body, so that in this painful state not a muscle will obey the impulse of the will, and every effort to move appears to be altogether unavailing. This constitutes *incubus* or *nightmare*; and it may be observed that, as acidity on the stomach, or indigestion, gives rise to such dreams, so all dreams of this disturbed character are converse indications of indigestion; for which reason the great physiologist Haller considered dreaming to be a symptom of disease. It is certain that the dreams of healthy persons are the lightest and most evanescent.

The kind of bed on which we repose requires attention. Some are advocates for soft, others for hard beds; hence some accustom themselves to featherbeds, others to mattresses. The only difference between a soft and a hard bed is this—that the weight of the body in a soft bed presses on a larger surface than on a hard bed, and thereby a greater degree of comfort is enjoyed. Parents err in fancying that a very hard bed contributes to harden the constitution of their children; for which reason they lay them down on mattresses, or beds with boarded bottoms. A bed for young children cannot be too soft, provided the child does not sink into it in such a manner that the surrounding parts of the bed bend over and cover the body. The too great hardness of beds, says Dr Darwin, frequently proves injurious to the shape of infants, by causing them to rest on too few parts at a time; it also causes their sleep to be uneasy and unrefreshing. The universal analogy derived from other animals evinces the truth of this doctrine, both in respect to the softness and due degree of warmth of their beds. Birds line the nests of their young with feathers; the eider duck and the rabbit pluck the down from their own breasts to increase the softness of the beds of their tender offspring, and brood over them with their wings, or clasp them to their bosoms for the sake of warmth. For this reason, it is better that delicate children should sleep with a bedfellow than alone; for in this case, if any part of the body becomes cold, the child instinctively places that part in contact with the warmer body of its companion. So, also, it is better for a new-born infant to sleep with its mother in winter, or with its nurse, than in a solitary crib by the bedside.

When in bed, the head should be always higher than the feet, and those subject to palpitation of the heart should lie with their heads considerably higher. Night-clothes should never consist of more than a chemise or shirt of cotton or linen, with a flannel shirt beneath. It is also highly improper to sleep in a bed overloaded with clothes; the body is thereby heated, and feverishness and restlessness induced. Accordingly, persons who complain of sleeplessness should look to the quantity of their bed-clothing; for the unnecessary addition of a single blanket may be the sole cause of the annoyance. It is also imprudent to lie with the head entirely within the bed-clothes; for in this case the same air which has been already breathed must be again and again inhaled. For the same reason, the curtains should not be drawn closely round the bed. Washing the face and hands, and brushing the teeth, before going to bed, will be found to contribute materially to comfort. Whatever be the time chosen for sleep, it is evident that no person can with impunity convert day into night. Eight o'clock for children, and eleven for adults, may be recommended as good hours for retiring to rest. It is well known that children require more sleep than adults; and more sleep is requisite in winter than in summer. The average duration of sleep which may be recommended for adults is *eight* hours; but much depends upon habit, and many persons require only six. It is scarcely necessary to observe that, on rising in the morning, the strictest attention should be paid to washing the face, neck, and hands; the mouth and teeth should also be well cleansed. The most simple powder for the teeth is finely-pounded charcoal, a little of which will clear away all impurities, destroy any fœtor, and preserve the teeth. On leaving the bedroom, the windows should be opened, and the clothes of the bed turned down, in order that the exhalations of the body during sleep may be dissipated. If, instead of this, the bed be made immediately after we have risen, these exhalations are again folded up with the clothes—a practice which is not consonant either with cleanliness or with health.

TEMPERATURE.

The fifth important requisite for health is, that the body be kept in a temperature suitable to it.

The degree of heat indicated by 60 degrees of Fahrenheit's thermometer, or that of a temperate summer day, is what the human body finds it agreeable to be exposed to when in a state of inactivity. In air much colder, the body experiences an unpleasant sensation, unless some warm clothing be worn, or a pretty active exercise be indulged in. When, either by natural or artificial means, the body is kept in a suitable state of warmth, the functions of the circulation and perspiration in the skin go on healthily; it is red, in consequence of the blood being urged into the capillaries or minute vessels near the surface; it is also soft and moist, from the action of the glands for secreting the waste fluid and its free egress through the pores. This is a condition of great comfort; and the appearance of those who enjoy it conveys to others the notion that they are in good health. When, on the contrary, there is a much lower temperature, the functions of the vessels connected with the skin are apt to be considerably deranged. The vessels, in these circumstances, contract; the blood is driven inwards, where it sometimes occasions diseases of a dangerous nature; the perspiration also, being prevented from passing out by its usual channels, catarrhal complaints ensue, sometimes ending in consumption.

It is of the more importance to make these facts generally known, as a notion prevails that exposure to a painful degree of cold tends to induce hardiness of constitution and to promote health. Undoubtedly there may be harm from an opposite extreme, and we know well that excessive clothing and living in overheated apartments are detrimental to health. But safety lies in a medium between the two extremes. There is a degree of warmth which is both agreeable and healthy, and which it is desirable to have around us as constantly as possible—generally from 54 to 60 degrees Fahrenheit.

There is no period of life at which warmth is of more consequence than in infancy. In a very young babe, the circulation is almost altogether confined to the surface, the internal organs being as yet in a very weak state. In such circumstances, to plunge the child into cold water, from an idea of making it hardy, as is customary in some countries, and among ignorant persons in our own, is the height of cruelty and folly; for the unavoidable consequence is, that the blood is thrown in upon the internal organs, and inflammation, bowel-complaints, croup, or convulsions, are very apt to ensue. A baby requires to be kept at a temperature above what is suitable to a grown person; it should be warmly, but not heavily clothed; the room where it is kept should be maintained at a good, but not oppressive heat; and it should never be put into other than tepid water. It should not be exposed to the open air for some days after its birth.

At all periods of life, it is most desirable to avoid exposure to very low temperatures, especially for any considerable length of time. To sit long in cold school-rooms or work-rooms, with the whole body, and especially the feet, in a chilled condition, is very unfavourable to the health of young people. It is not possible that a condition so adverse to the healthy action of the cutaneous vessels should not lead, if long persisted in, to very bad consequences. Those who are compelled to be sedentary, should make it their endeavour to obtain a sufficiently high temperature, either by warming their apartments sufficiently, or thickening their clothing. Common fires, though delightful from their cheerful look, are confessedly very inadequate, in most circumstances, to heat large work-rooms, school-rooms, or even the larger class of sitting-rooms; not to speak of the great objection which has been made to them on the score of economy, three-fourths of their heat being sent off through the chimney. It is most desirable that some means in which the public could have confidence were devised for thoroughly, and at the same time healthily, warming large apartments. Stoves enclosed in large iron-plate cases (Arnott's stoves), pipes of hot water or of steam, and blasts of heated air, are amongst the most conspicuous plans tried within the last few years. But none of these plans seems to have succeeded in obtaining the hearty approbation of the public, chiefly, we suspect, from their not being accompanied by what is peculiarly necessary where they are in operation—a means of ventilation. We can speak from some experience in favour of the plan of large steam-tubes, accompanied by a ventilating process; and have very little doubt that, with the latter requisite, this and several other of the recently-suggested modes of heating might be found to serve the desired end. It is certainly of great consequence that some plan should be generally consented upon for warming the large rooms in which scholars and workpeople spend so much time, as the chilliness there so generally experienced is a fatal underminer of the human constitution. (See HEATING, No. 29.)

Clothing should be in proportion to the temperature of the climate and the season of the year; and where there are such abrupt transitions from heat to cold as in our own country, it is not safe ever to go very thinly clad, as we may in that case be exposed to a sudden chill before we can effect the proper change of dress. Very fatal effects often result to ladies from incautiously stepping out of heated rooms in the imperfect clothing which they ludicrously style *full-dress*: all such injuries might be avoided by putting on a sufficiency of shawls or cloaks, and allowing themselves a little time in the lobby to cool. The under-clothing in this country should be invariably of flannel, which is remarkably well calculated to preserve uniformity of temperature, as well as to produce a healthy irritation in the skin. While the value of comfortable clothing is fully acknowledged, we should never lose sight of the value of exercise for keeping up a kindly glow upon the surface, and for the support of a high tone of general health. Any one who, neglecting this, should live constantly in a warm apartment, or only go out of doors muffled up in a mass of clothing, would speedily suffer from a relaxed state of the system, and become so susceptible of damage from the slightest change of temperature in the atmosphere, that the most dangerous consequences might be apprehended.

Wet clothes applied to any part of the body, when it is in an inactive state, have an instantaneous effect in reducing the temperature, this being an unavoidable effect of the process of evaporation which then takes place. Hence it is extremely dangerous to sit upon damp ground, or to remain at rest for a single minute with wetted feet, or any other part of the body invested in damp garments. Dampness in the house in which we live has the same effect, and is equally dangerous. The chill produced by the evaporation from the wetted surface checks the perspiration, and sends the blood inwards to the vital parts, where it tends to produce inflammatory disease. Few persons seem to be aware of these truths. We find young men heedlessly getting their feet wet, and sitting with them in that condition, thereby incurring the most deadly peril. Young women commit a similar folly when they walk out in thin shoes in a wet or cold day. Exposure to wet, damp, or cold, is of comparatively little moment when the body, by a course of exercise or training, has been prepared to endure these conditions. Thus a person brought up delicately, or much within doors, would be killed by that which would have little or no effect on a ploughman. It is therefore worthy of being suggested as a line of policy, that no one should accustom him or herself to a pampered or too delicate mode of life. Every one should, if possible, go out daily, both in good and bad weather, with clothing corresponding to the nature of the weather, and in this way strengthen and harden the constitution to endure all ordinary and reasonable exposure. It is important, however, to note, that even the hardiest persons are never safe from the effects of wet clothes and other modes of exposure to a reduced temperature. No complaint is more common among out-of-door labourers, and also poor people in damp lodgings, than rheumatism. This is an affection produced solely by a violation of the natural law which demands that the body should not be chilled. Rheumatism is produced alike from exposure to a shower or to a draught of cold air when the body is warm, and from sitting with the feet on a cold stone or clay floor; the only difference, perhaps, being, that the rheumatism is in one case in the shoulders and in the other in the legs. Let us therefore impress on all the propriety of avoiding chills, the effects of which may be much more fatal than a simple attack of rheumatism. When rheumatism has been contracted, the best remedy for its expulsion, if adopted in time, is friction of the part; if well rubbed before a fire with flour of mustard, so as to cause a counter irritation on the surface, the internal complaint may be expelled.

Errors in Dress.

This is perhaps the most appropriate place in which to introduce some remarks upon errors in dress. The integuments which nature calls upon us to put on for the sake of warmth, are too often made the means of inflicting serious injury, either through ignorance, fashion, or caprice. It is therefore necessary, in a treatise on the preservation of health, to advert in emphatic terms to this subject.

It is scarcely too much to say that there is no part of the human frame, from the sole of the foot to the crown of the head, which has not been, and is not at this moment, mistreated by fashion. We laugh at the Chinese ladies, who have their feet constrained by iron moulds into mere bulbous appendages to the limbs; but we never reflect that, amongst ourselves, errors only inferior in degree are constantly committed. The foot naturally spreads out, fan-like, from the heel to the toes. But instead of having our shoes formed in the same triangular shape, they are made in a lozenge form, truncated at the front, the toes being thus perverted from their radiating arrangement into one exactly the opposite; so that they become crushed under one another, and deprived of a great part of that muscular power by which they were designed to propel our bodies in walking. In the greater height usually given to the heels of shoes, another important deviation from nature is committed. When the heel is raised above the level of the ball of the foot, a complete derangement takes place in the muscles of locomotion; the power of the limb is impaired; and the whole body is thrown off its equipoise. It is impossible, in such circumstances, to exercise the body as it ought to be. The foot is also forced or plugged down into the narrow front of the shoe, where the toes become liable to the grievance of corns. Thus the free healthy play of the various parts of the body is further diminished. From the uneasiness and constraint experienced in the feet, sympathetic affections of a dangerous kind often assail the stomach and chest; as hemorrhage, apoplexy, and consumption. Low-heeled shoes, with a sufficiency of room for the toes, would completely prevent all such consequences.

An improved taste in the male sex has long since abolished the coarse and self-annoying absurdity of leathern small-clothes; but it is still too common to impede the circulation and the play of the muscles by tight apparel, especially in the regions of the stomach and neck. The immediate effect of these injudicious appliances is much inconvenience: the remote result is a diminution of the general strength and health. But all the errors of the male sex sink into insignificance when compared with one to which the fair are liable. In the construction of the human chest, nature has provided ample room for several important viscera, the functions of which cannot be in any degree disturbed without a wrong being inflicted upon the whole system. Here reside the heart, the lungs, the liver, and the stomach. Fine ladies may affect to shut their mind's eye to the existence of such things; but the daintiest of their emotions depend upon the right state of those very viscera, without which they could no more think, speak, and act, than they could cast languishing looks without eyes, or melt our hearts by witching minstrelsy without a tongue and fingers. In the natural state, the external figure at this place tapers gently downwards. The waist of the Venus de Medici is of that form, and its perfect elegance was never challenged. But the women of the ordinary world have set up for themselves a different standard of beauty. A fine waist, in their estimation, is one which tapers rapidly below the arms, and is not above two-thirds of the natural girth. It must also be strictly round, although the waist of nature verges upon the oval. In order to reduce themselves to the desired shape and space, almost all the unmarried, and not a few of those who are otherwise, brace themselves in a greater or less degree with corsets, which no doubt produce the requisite roundness and slenderness, but at the expense of all the internal organs upon which health depends. The false ribs are pressed inwards; the respiratory and circulatory systems are crushed and thrust out of their proper place; the alimentary system is deranged; and even upon the exterior of the person, deformities of the most glaring kind, such as humped shoulders and curved spines, are produced. Custom to a certain extent enables the victim to endure the inconvenience; there are even some who feel so little trouble from it, as to deny that any harm ensues from tight-lacing. But a violation so excessive cannot be otherwise than mischievous. We have seen a young lady's sash which measured exactly twenty-two inches, showing that the chest to which it was applied had been reduced to a diameter (allowing for clothes) of little more than seven inches!

All who are aware of the internal organs at that part of the body, know very well that it is impossible for these to exist in their natural condition within so small a space. Bruised, impeded, and disordered, they must of course be, and accordingly cannot fail to become a source of dreadful suffering to the wretched being who outrages them. Palpitations, flushings, dyspepsia, determination of blood to the head, and consumption, are among the evils which physicians enumerate as flowing from this sacrifice to vanity. Another of a moral kind is acknowledged to be of by no means infrequent occurrence: in order to soothe the painful sensations produced by the constraint, spirituous liquors and cordials are resorted to, and thus habits of the most degrading nature are formed. Another evil still, respecting which a hint may be sufficient, is the unfitting of the system for the duties of a mother. How many domestic afflictions, which are submitted to in a spirit of resignation, as the unavoidable decrees of Providence; how many of the saddest scenes which this world ever presents—gentle and tender girls pining away under the eyes of hopeless parents—beloved wives torn from the arms of husbands and children at the very moment when prolonged life was most needful—must be owing to a cause too trivial and unworthy to be mentioned in the same sentence with its so dire effects! No doubt, it is well to submit meekly to such afflictions; but while they are ascribed in all humility to a Providence which is upon the whole only another term for Mercy and Justice, let us not be blind to the fact, that they accrue through violations committed by ourselves upon laws established by Providence for our happiness, and might have been avoided by a different course of conduct.

The fashion of tight-lacing obviously owes its origin to a desire on the part of the ladies to attract admiration. It is of little importance to point out that they are quite wrong in their calculations as to the effect; but we would press upon the guilty parties, and all interested in their welfare, that tight-lacing is a practice which cannot be long persisted in without the most disastrous consequences. It is painful to reflect that parents, so far from discouraging the practice, are so ignorant as often to force it upon their children. We have heard of a young lady whose mother stood over her every morning with the engine of torture in her hand, and notwithstanding many remonstrative tears, obliged her to submit to be laced so tightly as almost to stop the power of breathing. The result is, that the unfortunate victim is now severely afflicted with asthma, and has fallen into a state of low health. As a general rule, it cannot be too strongly impressed upon those who have the care of young persons, that all clothing should sit lightly upon the figure, so as to allow of the full play of every part of the system.

INNOCENT ENJOYMENTS.

A sufficiency of innocent enjoyments has been set down as the sixth requisite towards the preservation of health. It may seem almost superfluous to treat this part of the subject, since the disposition to take amusement is one by no means generally wanting. A regard, however, for the completeness of our little treatise, induces us to make a few remarks on it; and we are not satisfied that there is not a considerable number of persons to whom an injunction to take innocent enjoyments is needful. There may be some advantage, therefore, in seeing the matter placed on something like a philosophical basis.

No physiological doctrine seems more entitled to faith and regard, than that a harmonious exercise, in moderation, of all parts of the system, including the organs of the mental faculties, is necessary for health. It is proved by the very craving which we experience, after a long task, or a long perseverance in some particular habits, for something which will engage a different set of faculties. There is nothing which will pleasingly engage our thoughts for any considerable length of time. Something inferior will invariably be preferred, if it only be new. Now the duties by which men in general earn their subsistence, are in all cases of such a nature as only to call into exercise a part of their mental and bodily system. Something is required at once to soothe and compensate us for the drudgery of our current labours, and to bring into exercise those parts of our muscular frame and intellect which professional duty has left unoccupied. To begin with a humble illustration: how delightful to a tailor, after long exercising his fingers and arms alone at his business, to enter into some athletic sport upon the village-green, by which his limbs also will be exercised! After a lawyer has fagged for a day at a brief, how delightful to be able, by the reading of a new novel or play, to call up another set of the intellectual powers! In these changes from grave to light occupation there is at once repose given to the tasked faculty, and the gratification of employment given to others which have been pining for want of something to do. It so happens that, from the sentient nerves being mixed with those which direct the operations of all our organs, each organ has a sense of enjoyment in being rightly exercised. Even the stomach has, from this cause, a gratification when its functions are going on well, and this altogether independent of any pleasure we may have had in eating the meal upon which it is now employed. An organ left long unoccupied is thus somewhat like a child in a family which its parents have been overlooking. It craves to be noticed like the rest, and when the desired notice at length comes, it experiences a high degree of satisfaction. In short, variation of occupation and pursuit, for the purpose of keeping all the parts of the system in harmonious exercise and in healthy tone, is one of the most important principles concerned in the preservation of health.

There are several powers of the mind which must have been designed for the express purpose of creating and receiving amusement, and the existence of which therefore shows that amusement has a place in the right economy of human life. The imitative arts in general—music, fiction, drollery of all kinds—spring directly from primitive faculties of the mind; and when we see the pleasure they give in society, we cannot doubt that they are things naturally required by man, and in which it is quite legitimate for him to indulge within moderate bounds and in circumstances compatible with innocence. These things are doubtless designed to alleviate the burdens of life and beguile us of its cares. They furnish something like a different sphere of existence, into which we may enter and temporarily lose the sense of all that harasses us in the ordinary one. The *joculator*—under which name our ancestors associated the poet, tale-teller, and mimic, and which we may apply equally extensively to the poet, novelist, artist, and player—is therefore a most useful functionary in society. We say nothing on the present occasion of the refinement to be derived, in addition, from communion with the productions of the higher class of such minds.

Amongst amusements, *reading* takes a most distinguished place; for there is none which may be more readily or more innocently indulged in, and fortunately, in our own country, it is one which may now be enjoyed by all. It is unquestionably the chief of in-door amusements; and few scenes are calculated to awaken more agreeable feelings in a well-constituted mind, than a family group assembled in their parlour, to hear some one of their number reading a pleasant book. Ever honoured be the great masters of fiction, who have allowed us, by these means, to pass from common life, for a time, into 'the tale of Troy divine,' the story of 'the gentle lady married to the Moor,' the tear-compelling fate of Ravenswood, and all the other numberless suppositions of things done, and persons who spoke and acted, which we feel to be more real than much of even the life that is passing around us!

Next to reading stands *music*, a means of enjoyment of which only a few comparatively, in our country, take advantage, but which might easily be made much more extensively available, and probably will be so in the course of a few years. Connected intimately with music is *dancing*, which is not only a cheerful amusement, but a positive and direct means of bodily exercise. A family musical or dancing scene, like a family reading scene, is a thing beautiful to look upon. There is a prejudice against both in some minds, on account of their being liable to abuse; but the abuses of both arise very much from their not being extensively or freely indulged in. Were music the general accomplishment which it might easily be made, it would not only be indulged in on all occasions with simplicity and innocence, but it would supplant coarser and more clandestine amusements. Dancing is the nightly amusement of the French peasantry, and it has never been pretended that these people are less virtuous than the corresponding class in our own country. *Theatrical representations* it might be more difficult to place on such a footing as to secure the unhesitating approbation of the good; but certainly if this were done, they might prove highly serviceable in furnishing amusement.

In the class of amusements we must reckon meetings or promenades in ornamental grounds, excursions into the country, and little tours, all of which are highly commendable in those who are able to indulge in them. The entertainment of little parties of friends, and the going out to entertainments given by them in return, are other means of amusement common in society, and which may be moderately indulged in with much advantage. In short, whatever gives a pleasant variation to the monotony of life, without leading the mind away from duty or corrupting the manners, ought to be indulged in as freely as circumstances will permit. The mind returns from such diversions with renewed tone and power, and neither the time nor the expense is lost in the long-run. It is the more necessary to impress these maxims, as many well-meaning persons, alarmed perhaps at the occasional abuse of such enjoyments, repudiate them nearly altogether, and thereby lower the tone of their health, both as respects the body and the mind. It is particularly distressing to see such persons exercising a control over the young, and denying to their unfortunate protégés an element of life not much less pressingly necessary than the air they breathe. (See IN-DOOR AMUSEMENTS.)

Dr Southwood Smith, in his excellent work 'The Philosophy of Health,' has pointed out that pleasure is the ordinary, and pain in all cases an extraordinary, result of the action of our organs. 'There are,' he says, 'many cases in which pleasure is manifestly given for its own sake; but in no case is the excitement of pain gratuitous.' Pain is always a punishment; and, when it reaches a certain extreme, it is destructive of what feels it. But 'all such action of the organs as is productive of pleasure is conducive to the perpetuation of life. There is a close connection between happiness and longevity. Enjoyment is not only the end of life, but it is the only condition of life which is compatible with a protracted term of existence. The happier a human being is, the longer he lives; the more he suffers, the sooner he dies: to add to enjoyment is to lengthen life; to inflict pain is to shorten the duration of existence.' It may fairly be presumed, then, that a certain amount of enjoyment in life is necessary for health, and that when the quantity actually secured is much below that point, unhealthy conditions must ensue. If, for example, poverty or embarrassed circumstances press so severely upon a cautious and conscientious man as to leave him scarcely a moment's comfort from one year to another, he cannot fail to sink in health. If married to a female of bad temper, or who afflicts him by bad habits, and if, from these causes, he rarely enjoys a moment of happiness, so also must his health fail. In short, to be placed in any such circumstances as constitute a bar against nearly all enjoyments, must prove injurious, and tend to the shortening of life.

Enjoyments are of many kinds. Some are sensual, as the taking of agreeable food; others are intellectual, as agreeable music, reading, &c.; others are moral, as the exercise of philanthropy, the religious feelings, &c.; and some are sympathetic, and consist in the exercise of the affections, and the reflection of that gratification which we have endeavoured to impart to others. We may consider as such all things over and above the plainest unrelished fare, and the supply of water, air, and a barely sufficient temperature. These are usually considered as strictly the necessaries of life, the others being the comforts or luxuries. The distinction is not quite correct. The first class are certainly immediately necessary to the support of life; that is to say, they are hourly, daily necessary. But more or less of what are called the comforts of life are also necessary, if we would preserve health. The only difference is, that the want of them would not tell in so short a time as the want of the so-called necessaries. If a human being be shut up in a cell, and allowed only a sufficiency of unrelished and unvaried food, with air and water, the want of all the enjoyments of life, sensual, intellectual, moral, and sympathetic, will in a certain time make him utterly miserable; the health of body and mind will give way; and if the experiment be sufficiently protracted, he will perish. The ignorance which prevails on this point has led to the trial of what is called the *silent system* in prisons, which is now about to be abandoned as utterly irreconcilable with humanity. It were well if more knowledge prevailed on the subject, for, from erroneous ideas of what is necessary for healthy life, many deprive themselves or others of things which, when we take the element of time into account, are as essential to health as the supply of the air we breathe. There is, in some enthusiastic minds, a spirit of asceticism and self-mortification which would give up all the enjoyments of life together. Such persons rarely fail to reduce their own health, if they do not also exercise some unhappy control to the same effect over their fellow-creatures. While self-denial for moral purposes is always admirable, and over-indulgence of every kind saps the vigour and fortitude of the human character, it should be ever kept in view that there is great danger in reducing the allowance of comforts and indulgences too low. Very rigid views of what is necessary for the support of life usually prevail, wherever the affluent have to dictate a style of living for the poor. The tendency there is, to reduce allowances as nearly as possible to what may be called the *immediate necessaries;* for it does not seem just or right that paupers, adults or children, should enjoy any species of gratification. But these are short-sighted views. The health of these unfortunate persons requires something more, and this something would be granted by an enlightened humanity. We have a strong manifestation of this need in the eagerness with which paupers generally desire allowances of tea or tobacco, or indeed the least variation of their diet. The craving for these luxuries is not so much, what it is generally thought solely to be, the result of bad habits long indulged in, as it is the expression of a want in the personal economy—a want which, by one means or another, must be supplied, or injurious consequences will ensue.

Exemption from Harassing Cares.

It is little more than a repetition of doctrines already laid down, that, for the due preservation of health, a human being requires an exemption from acute distress of mind and harassing cares.

Mental distress and anxiety operate through the brain upon the condition of the whole body, and, when long protracted, effectually undermine the health. 'It is impossible,' says Dr S. Smith, 'to maintain the physical processes in a natural and vigorous condition if the mind be in a state of suffering. Every one must have observed the altered appearance of persons who have sustained calamity. A misfortune, that struck to the heart, happened to a person a year ago: observe him some time afterwards—he is wasted, worn, the miserable shadow of himself; inquire about him at the distance of a few months—he is no more.' It is Dr Smith's opinion that the nearest cause of many suicides is not strictly a desire to escape from a state of suffering, but some disease, probably inflammation of the brain, brought on by distress of mind. 'By a certain amount and intensity of misery, life may be suddenly destroyed; by a smaller amount and intensity, it may be slowly worn out and exhausted. The state of the mind affects the physical condition; the continuance of life is wholly dependent on the physical condition; it follows that, in the degree in which the state of the mind is capable of affecting the physical condition, it is capable of influencing the duration of life.'

Depression of mind, besides its immediate effect on the nervous system, deranges the respiration, and mars the proper oxygenation and circulation of the blood. A diminished vitality is the consequence, often leading to pulmonary consumption. An excessive agitation and alarm of the selfish feelings, such as takes place in some minds on the approach of an epidemic, affects the whole system in such a way as—to use an expressive phrase of Dr Combe—'places it on the brink of disease;' and hence the notoriously great liability of persons in this state of alarm and apprehension to fall victims to the malady when it comes. It has been remarked that an army in a high state of confidence and cheerfulness after a victory, has a much smaller proportion of sick than in the opposite circumstances, or even in its ordinary condition. The usual proportion of sick in a garrison quartered, during peace, in a healthy country, is five per cent.; during a campaign, when there is more anxiety of mind, it is ten; in the event of defeat, although the circumstances be otherwise not unfavourable, the proportion rises to a much higher amount. It is a very instructive fact, that in a large detachment of the French army cantoned in Bavaria immediately after the battle of Austerlitz, the proportion of sick was little more than one per cent.

GENERAL OBSERVATIONS.

The fundamental principle of every effort to improve and preserve health has been thus stated :—' Man, as an organised being, is subject to organic laws, as much as the inanimate bodies which surround him are to laws mechanical and chemical; and we can as little escape the consequences of neglect or violation of these natural laws, which affect organic life through the air we breathe, the food we eat, and the exercise we take, as a stone projected from the hand, or a shot from the mouth of a cannon, can place itself beyond the bounds of gravitation.' To this it may be added, that ' all human science, all the arts of civilised man, consist of discoveries made by us of the laws impressed upon nature by the Author of the universe, and the applications of these laws to the conditions—which are laws also—in which man and the particular bodies and substances around him, are placed; nor, it is manifest, should any science concern us more than that which relates to the conditions on which organic life is held by each individual.'

The preceding sections are but explanations, such as we have been able to afford, of the conditions under which the organic frame of man exists, and the agencies, internal and external, which operate upon it, for the maintenance of health or the introduction of disease. It must be evident, where there is a conviction of the truth of the fundamental doctrine, that individuals and societies have their health very much at their own disposal; that a careful avoidance, on the one hand, of what is noxious, and a judicious attention to what is beneficial, are what are chiefly necessary for the preservation of the human frame in health to old age; and that premature deaths, over and above those which result from unforeseen casualties, instead of being, as supposed by the untutored mind, a mysterious and irreversible decree of Providence, are simply the natural effect of our own violation of laws which Providence has appointed for our welfare. It might still be objected that human nature is such, that the due obedience and observance of those natural ordinances are not to be expected; so that the vast quantity of disease, and the great number of premature deaths, which afflict our present state of being, are equally to be regarded as things immutable, and therefore to be tranquilly submitted to. But this view would be not less a mistaken one; for there is no fact more clearly ascertained, than that disease and premature death are not, and never have been, fixed at any given amount, but yield constantly to the power of any new conditions which man may be able to introduce. Regarding clear views on this subject as of great importance, we shall here enter a little into detail.

The object is, we apprehend, to show that sickness and mortality vary both in place and in time, according to physical and organic conditions.

Inquiries into these subjects were not made in ancient times; but during the last two hundred years, such facts have been recorded as enable us to ascertain that in that space of time, with regard to nearly the whole of Europe, there has been a gradual improvement in health and life, in proportion to improved conditions. In Sweden, for instance, between 1756 and 1763, the annual mortality was, for males, 1 in 33½, for females, 1 in 35¾; whereas in the year 1800 it had diminished to 1 in 34¾ for males, and 1 in 37⅓ for females. From mortuary tables preserved with considerable accuracy at Geneva, it appears that at the time of the Reformation, one-half of the children born died within the sixth year; in the seventeenth century, not until the twelfth year; in the eighteenth century, not until the twenty-seventh year; consequently, in the space of about three centuries, the probability that a child born in Geneva would arrive at maturity has increased fivefold. In London, in the year 1606, the annual deaths were 1 in 14½, or 7 per cent. of the population; and in plague years during that century it reached 25 in 100, or every fourth man, woman, and child! *In 1838, it was only 1 in 35½.* Knowing that, at the former period, the city was dense, and ill-cleaned, and that the habits of the people were not then what they are now, we cannot doubt that this diminution of mortality to less than one-half is owing to the improved conditions in which human beings now live in the metropolis. Between the years 1730 and 1750, 74 of every 100 children born in London died before they were six years of age; but in more recent times, only 31 and a fraction out of every 100 die under the same age—that is to say, the deaths of children in London were then more than twice as numerous as they are now. About a century ago, the mortality of the children received into the London hospitals was of astonishing amount. Though the fact seems scarcely credible, we believe there is no good reason to doubt that, of the 2800 annually received, 2690, or *twenty-three in every twenty-four*, died before they were a year old. It was at length seen that this mortality was the effect of overcrowding, impure air, and imperfect aliment; and after an act of parliament had been procured to compel the officers to send the infants to nurse in the country, only 450 out of 2800 died in the first year. It has been ascertained that, during the last century, about a third has been added to the average expectation of life—that is to say, an individual now has as good a chance of living forty years, as he had a hundred years ago of living thirty. To what can such a fact be owing but to the diminution of the causes of disease in the improved conditions of the people?

The facts ascertained with regard to differences of mortality in different places are equally striking. A remarkable instance of the effect of marshes upon health is cited by M. Villermé. Formerly, the district of Vareggio in Tuscany was in this condition, and its few miserable inhabitants were every year visited by severe agues. In 1741, floodgates were erected to keep out the sea, the marsh was dried up, and ague appeared no more. Vareggio subsequently became a populous and healthy district. The Isle of Ely is a marshy district in the east of England, and it was ascertained that of 10,000 deaths which occurred in it between the years 1813 and 1830, no fewer than 4732 were of children under ten years of age; the proportion of deaths of children under ten in all the other agricultural districts of England being only 3505, or as about 3 to 4 of the former number. Of 10,000 deaths between ten years and extreme old age in the same period, there were, of persons between ten and forty, 3712 in the Isle of Ely, and only 3142 in drier districts. There are some remarkable discrepancies of mortality in different counties of England. While the proportion of annual deaths in every hundred persons under six years of age is, for the whole of England and Wales, about five and a-third, the proportion in Suffolk is three and a-half, in Warwick six, in Middlesex eight and a-third. Suffolk is an agricultural county; Warwick contains Birmingham and some other large towns; and the metropolis is situated in Middlesex: can we resist concluding that the pure air and constant exercise which children obtain in the country are the immediate means of prolonging their lives; while the narrow accommodations, impure air, and limited exercise to be had in large towns have exactly the contrary effect? In the general population of England, 443 in 1000 die under ten years of age; but in Manchester and Salford the number is a third larger, or 602. Here, the miserable circumstances of many of the humbler classes in Manchester—above eighteen thousand of them, for one thing, living *in cellars*—must be considered as the immediate cause of the disproportioned mortality. While the general mortality of London is, as stated, 1 annually in 35½, there are great differences with respect to different districts. In Camberwell, an open suburban district, it is 1 in 52; in Hackney, a similar district, 1 in 54; but in the huddled district of St George's, Southwark, it is 1 in 30; and in the still more dense and miserable region of Whitechapel, so much as 1 in 26, or exactly double the mortality of Camberwell.

A curious investigation has been made in London to ascertain the effect of density of population upon health. In a large district, where the population is so dense that there is only 35 square yards for each person, the annual mortality is 3428; in another district of the same population, where each individual has an allowance of 119 square yards, the mortality sinks to 2786; in a third, where there are 189 square yards to each person, the mortality is only 2289, or under two-thirds of what it is in the closest of the three districts. It was also found that in the three districts the mortality from typhus fever was, respectively—as we go from the roomiest to the most confined—131, 181, and 349. The proportion of sickness and mortality which the poor suffer in comparison with the rich is thus placed in a striking point of view. Precisely similar results have been discovered in Paris. M. Villermé has there ascertained that the deaths in some poor arrondissements are just double what they are in the rich. He states that, taking the whole of the French population, human life is protracted twelve and a-half years among the wealthy beyond its duration among the poor; consequently, in the one class, a child, newly born, has a probability of living forty-two and a-half years; in the other, only thirty years.

Taking the whole of the above facts into account, we must see that not only do health and longevity depend expressly on laws the operation of which we can understand, but man has it in his power to modify to a great extent the circumstances in which he lives, with a view to the promotion of his organic wellbeing and preservation. We see that the draining of a marsh banishes the ague, that a change from city to country air diminishes mortality, and that the greater comforts possessed by the affluent secure them longer life than the poor. It may not immediately be in the power of every one to change his circumstances from the unhealthy to the healthy; but it is a great matter to know that the object is within human power, for then at least an encouragement is held out to induce each individual to make every possible effort to put himself, and to contribute to putting society in general, into more salubrious conditions.

The object may be said to depend partly upon individual and partly upon social efforts. Every person has some control over the quantity and quality of the food he eats, the condition of the air he breathes, and the exercise, repose, and recreation which are demanded by his muscular and nervous system, according to the principles laid down in this and similar treatises; as also some power to refrain from injurious excesses, and to avoid the various external agencies of a detrimental kind which constantly beset him.* Let him act as he ought to do in these respects, and he will reap an immediate reward in that pleasurable state of consciousness which attends a healthy existence. But some of the most important requisites for health depend on public measures. The amount of the necessaries and comforts of life to be obtained by the great mass of the operative classes in all countries, depends very much upon regulations which may have been made with regard to *production* and *exchange*, as also those which may have been made for instructing and morally elevating and sustaining the bulk of the people. It unfortunately happens, in most countries, that while the bearing of certain acts upon individual happiness is fully seen and provided for, those which affect the condition of communities are imperfectly understood; so that measures destructively injurious to millions will be blindly enforced and defended by those who would severely punish the slightest wrong inflicted by one man upon another.

Measures for improving general conditions, with respect to air and exercise, are perhaps more readily practicable; yet here also the bearing of active principles upon great masses is so dimly seen, that, not to speak of more positive difficulties, it is usually long before proper sanitary regulations are made. The cleaning police of most cities is certainly improved considerably within the last fifty years; yet it is still far from being what it ought to be, while drainage continues to be extremely defective, and ventilation and means of innocent and healthful recreation can scarcely be said to be thought of. Some facts elicited by recent parliamentary inquiry, with regard to several of our principal cities, are of a most startling kind.

Dr Arnott, when examined as to the prevalence of fever in Bethnal Green, Whitechapel, Wapping, and certain other districts in the metropolis, attributed them directly to the dirty and neglected state of these localities, instancing—'Houses, courts, and alleys without privies, without covered drains, and with only open surface gutters, so ill-made, that the fluid in many cases was stagnant; large open ditches containing stagnant liquid filth; houses dirty beyond description, as if never washed or swept, and extremely crowded with inhabitants; heaps of refuse and rubbish, vegetable and animal remains, at the bottom of close courts and in corners.' [The amount of noxious matter which is allowed to collect in London is far beyond what most of its inhabitants have any conception of, as is the case with most other conditions chiefly affecting the poor.] In Manchester, 18,300 persons, or one-twelfth of the whole working population, live beneath the level of the ground, with an insufficiency of both light and air. In that town the dwellings of labourers are often situated in narrow courts, and back to back, so as to prevent ventilation; the drains are far from sufficient; and till recently there was not in the town one free space in which the people could enjoy the slightest recreation. In Liverpool, 39,000 persons live in cellars, dark, damp, confined, ill-ventilated, and dirty. The class next above, to the number of 80,000, inhabit houses built around small courts, closely pent up, back to back, with only one entrance to each, and usually a receptacle for refuse in the centre; an arrangement which appears as if it had been expressly calculated to keep health low and mortality high. In Leeds a similar style of building obtains, with a similar train of circumstances—'no effective drainage, inspection, or system of paving or cleansing.' The greater part of this town was described in 1839 as 'in a most filthy condition, demanding an immediate remedy.' It was mentioned, that in a certain dirty yard there was a house which for many years had been the seat of disease of a very malignant character: three years ago, the attention of the commissioners of police was directed to the extremely imperfect drainage of the surface-water: at that time a better escape for the refuse-water was provided; and since that period, says the reporter, 'I believe *we have not had a single case of fever from that particular locality.*'

Narrow alleys and close courts, with wet filth constantly exhaling within them, and containing a densely-huddled and extremely poor population, exist in Edinburgh, where, however, an exposure to high winds makes the evil less pestilential. In Glasgow, a comparatively level city, the same peculiarity exists to perhaps a greater extent than in any other British city. This, added to the miserably insufficient succour extended to the poor, and the influx of migratory Irish, renders Glasgow at present one of the unhealthiest cities in Europe; the mortality of the year 1837 being 1 in 24½, and the number of fever cases for the five years before 1839 at an average of 11,118 per annum. Here also we have a most notable instance (See No. 29, p. 460) of the counteractive power of a single sanitary principle; for a house containing about five hundred poor inhabitants, having been ventilated by a draught from each room in 1832, fever, which had previously never been absent from that dwelling, was nearly banished, only four cases occurring in the ensuing eight years, though fever raged during that period in all the other districts of the city occupied by the poorer classes.

FOOD—BEVERAGES.

Having shown in the preceding sheet that man is destined to subsist on a mixed diet—that is, partly on vegetable and partly on animal food—we shall now proceed to describe the specific characters of the more common alimentary substances, in as far as these have been determined by science and experience. In so doing, we shall consider their natural history and production, their chemical composition, their relative alimentary value, and the like, leaving their culinary preparation for the subject of a separate treatise. Before doing so, however, it will be necessary to establish a clear conception of the functions which food has to perform in the animal economy.

Chemical research has shown that the food of man is composed of organic matter, water, and mineral ingredients. The mineral ingredients are required to form the skeleton or solid framework; the watery fluid is necessary to the due performance of the vital functions; whilst the organic matter supplies at once the heat and nourishment of the system. Every one knows how indispensable animal heat is to the preservation of life and health; and this heat is produced, according to the researches of Liebig and others, by the consumption of a certain portion of the food, much in the same way as fuel produces heat by being burned. The elements of this portion of our food are hence termed *calorifiant or respiratory*, because it is chiefly in respiration that they, after having undergone various changes in the body, are brought in contact with the oxygen of the atmosphere in the lungs and capillary vessels all over the body; and by the chemical changes thence resulting (see Animal Physiology), heat is given out, and the warmth of the body maintained. Animal heat is thus generated by a combination of the carbon and hydrogen of a portion of the food with the oxygen of the inspired air—heat always being given out by such chemical changes, and compounds of carbonic acid and water being the result, which are given off by the lungs and skin as waste matter. The elements of the other portion of our food are termed *nutritive*, because they supply the waste and growth of the fabric. Every thought of the mind, every act of the body, produces changes in our systems, from the living and healthy particles of which they are composed, to dead and waste particles, which, being no longer of use, are either burned by the slow combustion already described, or carried off as excrementitious matter; and it is the province of these elements of nutrition, by going to form blood, to renew the parts where such waste has been produced. The leading ingredient in the nutritive portion is nitrogen or azote, hence the terms nitrogenous or azotised are equivalent to nutritive.

From the preceding statements, it must be evident that all wholesome dietary must contain both a *heat-forming* and a *flesh-forming* principle; and that, according as we live in a hot climate or cold climate, take much exercise or remain sedentary, so must we have recourse to food which will supply the elements which our bodies most stand in need of. It is the province of chemistry to determine the constituents of human food, to point out the excess or defect of the principle we are in search of; and thus attempts have recently been made to classify substances according to their capabilities of supplying heat, flesh, and bone. For example, 100 pounds of

Beans yield	31	flesh,	51½	heat,	3½	bone,	14	water.
Wheat ...	21	...	62	...	2½	...	14½	...
Oats ...	18	...	68	...	3	...	16	...
Potatoes ...	2	...	25	...	1	...	72	...
Turnips ...	1	...	9	...	1	...	89	...

If these results be correct, oats, for example, form a less flesh-forming diet than wheat; but they yield a larger amount of heating principle, at the same time that they are more favourable to the growth of bone. With a view to exhibit the relative value of substances as flesh-formers or heat-formers, chemists are also in the habit of tabulating their researches thus:—

Milk, . . .	1	of nutrition to	2	of heat.
Beans, . . .	1	...	2½	...
Oatmeal, . .	1	...	5	...
Wheat-flour,	1	...	8	...
Potatoes, . .	1	...	9	...
Turnips, . .	1	...	11	...

Or they may simply state the per centage of the principle they are in search of, as—

Beanmeal	contains	23½	per cent.	albuminous or	nutritive matter.
Oatmeal	...	23½	...	...	...
Flour	...	11¼	...	...	...
Potatoes	...	2¼	...	...	...
Turnips	...	1¼	...	...	...

In whatever way the results may be stated, it is necessary that they be obtained with accuracy; and it is equally necessary that the condition of the body as to health or disease, rest or exercise, shelter or exposure to cold, should be also ascertained, so that by the adoption of a proper diet any defect may be supplied or excess corrected. On this point man has yet made little true scientific progress. Where he has arrived at the truth, it has been chiefly by a long process of trial and error; and it is only now that he is beginning to apply the lights of science to guide and direct him. In describing the various articles of food—vegetable and animal—we can therefore only refer to very general results: accurate and detailed experiments being yet in many instances altogether wanting. To Baron Liebig, Boussingault, Mulder, and other continental chemists; to our own countrymen Sir H. Davy, Professor Johnston, Drs Thomson, Pereira, and Playfair, are we indebted for most of those researches on food which bid fair to introduce a system of dietetics, if not altogether new, at least more strictly in accordance with sound reason and economy. It must not be supposed, however, that substances which yield to the chemist the largest amount of nutritive matter, are in every case the most nutritious and wholesome. The fact is, they may contain other principles which greatly impair their digestibility, or they may be unfitted for peculiar states and conditions of health; or, what is also possible, they may be obnoxious to certain constitutions, unless administered along with the necessary correctives. Due allowance must ever be made for such exceptions; and all that we can reasonably expect of the chemist or physician, is a statement of results as applicable to healthy or normal conditions.

FOOD.

The aliment of man consists of solid and liquid substances; hence such popular distinctions as 'meats and drinks,' 'food and beverages'—the one calculated to allay the cravings of hunger, and to afford the body substantial support; the other simply to allay the sense of thirst. Such distinctions, however, are more popularly convenient than scientifically correct: milk, for example, though liquid, being the sole support of the young mammal, and affording, moreover, more substantial nourishment to every portion of the fabric than any solid substance whatever; while starch, though solid, yields little or nothing that can administer to the growth of the living tissues. Adopting, however, the common distinction of 'food and beverages,' as in some measure convenient, we shall treat the former under the three heads *vegetable*, *animal*, and *mineral*—remarking that it is chiefly the vegetable and animal kingdoms (and especially the vegetable) from which man derives the greater portion of his solid sustenance. In the dietary of tropical countries the vegetable element generally prevails over the animal; in temperate regions the proportion is more equable; while in the colder latitudes the flesh of animals may be said to be the staple of existence.

VEGETABLE FOOD.

Vegetable food, wherever employed, is consumed partly in a green and succulent state either cooked or uncooked; partly in a ripe condition—as fruits, nuts, and the like; and partly when dried and artificially prepared—as the various bread-corns. In whatever condition or form vegetable substances may be used, they consist essentially of the same elements—carbon, hydrogen, oxygen, and nitrogen, with a small proportion of solid inorganic matter. These are usually termed *ultimate* elements, from which the living vegetable elaborates certain *proximate* principles for the construction of its own peculiar fabric. These principles are—starch or fecula, gluten, vegetable albumen, sugar or the saccharine principle, gum or mucilage, lignin or woody fibre, vegetable jelly or pectin, fixed and volatile oils, wax, resin, balsams, gum-resins, camphor, tannin, colouring matter, acids, and alkalies. Of these the most abundant are starch, gluten, albumen, sugar, and gum; these constitute the principal ingredients in all esculent vegetables; and it may be remarked, that starch and gluten are the most nutritious—starch yielding carbon, or heat-forming, and gluten nitrogen, or flesh-forming principle. It may also be observed, that some of these proximate principles are convertible or nearly allied: thus starch can be converted into sugar by the processes of vitality and fermentation; and albumen differs from gluten only in containing a less amount of nitrogen. According to the prevalence of these respective principles, writers on dietetics have proposed certain classifications of vegetable food, such as the starchy or amylaceous, the saccharine, mucilaginous, oily, acid, alkaline, and so forth. Others, again, finding that many plants yield several principles in equal abundance, and that it is impossible to draw such distinctions without leading to misconceptions, abandon this classification, and merely treat of the parts consumed, as the seeds, roots, fruits, leaves, and the like. Any rigid division of this kind is also liable to objection, since the seeds of a plant may be wholesome, while its roots are poisonous; or its leaves may be worthless, while its fruit is valuable; or it may contain a deleterious principle when raw, and yet be exceedingly wholesome and agreeable when boiled or roasted. Abandoning, therefore, all such distinctions as apt to mislead, unless accompanied by more detailed explanations than our limits will allow, we shall treat of vegetables chiefly in the order of their importance.

One of the most abundant sources of vegetable food is the cereals, or bread-corns—wheat, rye, barley, oats, millet, and maize—all of which belong to the natural order *Gramineæ*, or grain-bearing plants. All of these grow in a similar manner; all yield starch, gluten, and a certain amount of phosphates; and all have been cultivated and improved by the inhabitants of different countries from time immemorial. They are commonly spoken of as *farinaceous foods*; their elements of *nutrition* being albumen, fibrine, gluten, and mucine; and their elements of *respiration*, starch (principally), sugar, and gum.

Wheat (*Triticum*), of which there are numerous varieties, justly stands at the head of the cereals. It is now grown largely in all civilised countries, and forms a principal portion of human food. The grain, freed from its bran or husk, is usually ground to a fine *flour*, and in this state is used in the manufacture of bread, pastry, maccaroni, vermicelli, semolina, and other preparations. It consists, as already stated, of starch, gluten, sugar, gum, certain phosphates, and water; and these ingredients are found to vary not only with the soil in which the corn is grown, but according to the climate or latitude—that of southern Europe yielding from two to six per cent. more gluten than that grown in the north. It is for this reason that Italian flour is so well fitted for the manufacture of maccaroni; and why bakers often prefer a mixture of wheats in the composition of their loaves. The following are given as analyses of different wheats and wheat flours:—

	French Wheat.	Odessa Hard Wheat.	Odessa Soft Wheat.	First Flour.	Second Flour.
Starch,	71·49	56·50	62·00	71·2	67·78
Gluten,	10·96	14·55	12·00	10·3	9·02
Sugar,	4·72	8·48	7·56	4·8	4·80
Gum,	3·32	4·90	5·80	3·6	4·60
Bran,	...	2·30	1·20	...	2·00
Water,	10·00	12·00	10·00	8·0	12·00

Bread is the most important article of consumption prepared from the flour of wheat, and may be fermented or unfermented:—

1. Common *fermented or loaf-bread* consists of wheat flour, salt, water, and either yeast or leaven (old dough already in a state of fermentation). To these bakers very generally add potatoes and alum—the former to assist the process of fermentation, and render the bread lighter, the latter to augment its whiteness and firmness. As to the addition of potatoes, there can be no objection beyond the substitution of an article containing less nutritive matter than pure flour; but as to alum, it is highly objectionable, and its use by bakers is accordingly prohibited by law. The rationale of the fermenting process is this:—'The yeast or leaven causes the flour to undergo the vinous fermentation, by which carbonic acid and alcohol are formed. The carbonic acid is prevented from escaping by the tenacity of the dough, which, becoming distended with gas, swells up, and acquires a vesicular structure, forming a kind of spongy mass. In this way, therefore, are produced the vesicles or eyes, which give to ordinary loaf-bread its well-known lightness and elasticity. If the vinous fermentation be not checked in due time by *baking*, the dough becomes sour; and for this purpose the mass, after being formed into loaves, is exposed in an oven to an elevated temperature, which puts a period to the fermentation, expands the carbonic acid, expels the alcohol formed, and drives off all the water capable of being removed by the degree of heat employed. On weighing bread taken from the oven, it is found to be twenty-eight or thirty per cent. heavier than the flour used in its preparation.' 'In the formation of wheaten bread,' says Sir H. Davy, 'more than one quarter of the elements of water combine with the flour; more water is consolidated in the formation of bread from barley, and still more in that from oats; but the gluten in wheat being in much larger quantity than in other grain, seems to form a combination with the starch and water, which renders wheaten bread more digestible than other species of bread.' From pretty accurate experiments, it has been found that the proportion of nutritive to the heat-forming principle in loaf-bread is as 1 to 7 and upwards: in milk, the natural food of all young mammalia, the proportion is as 1 to 2, from which it will be seen that bread alone, though popularly termed 'the staff of life,' is incapable of supporting a prolonged existence.

With regard to the other common forms of fermented bread, Dr Pereira in his valuable Treatise on Food has the following remarks:—'The *fine bread* prepared from flour only is the most nutritive and digestible. *Brown bread* made from wheaten meal, which contains bran, is laxative, and is used with effect by persons troubled with habitual constipation, as well as by those labouring under diabetes. *Hot Rolls* are indigestible, and unfit for dyspeptics and invalids; indeed all kinds of new bread are injurious. Rolls, both English and French, are made with a much larger proportion of yeast than is employed in ordinary bread. The different kinds of *fancy breads* are less adapted for the use of invalids, and of those who suffer from a tender stomach, than the common loaf-bread. *Compressed bread*—that is, bread which has been submitted to compression by the hydraulic press—becomes dry and hard, and may be kept for an almost indefinite period; it requires to be granulated before being used. *Rusks*, and *Tops and Bottoms*, are both made with wheat flour, butter, sugar, and milk, and a considerable quantity of yeast to give them lightness. Notwithstanding that they are frequently employed as infants' food, it is obvious that they are objectionable, on the double ground of containing butter and of being fermented.'

2. *Unfermented* or *unleavened bread* is prepared in two forms—either heavy and compact, or light and spongy. The former condition is that in which all the varieties of biscuits appear—the main ingredient in these being flour worked into dough with hot or cold water. *Sea biscuits*, so largely employed in the victualling of the navy, are composed of wheaten flour and a little bran: they are hard and heavy, and are difficult of mastication. *Biscuit powder* is not of course liable to this objection, and being prepared for use with hot water, is reckoned fair food for infants. The *captains' biscuits* of the ships are generally made of fine flour with a small proportion of butter; the so-called *Abernethy biscuits* are made variously by different bakers—most of whom add a little yeast, and flavour with caraway-seeds. In the numerous *fancy biscuits* now used, butter, milk, sugar, and the like, are indispensable ingredients; and for this reason little definite or favourable can be asserted of their dietetic properties.

The other form of unfermented bread is that in which, by the use of effervescing compounds, it is rendered light and spongy, and made to resemble ordinary loaf-bread. Numerous receipts have been given, and several patents taken out, for the manufacture of this species of bread, but all of them may be readily comprehended from a description of the original method. It is well understood, that if we take muriatic acid and carbonate of soda, and mingle them in due proportions, an effervescence will take place, carbonic acid is disengaged, and common salt (muriate of soda) is formed. Now if we take the soda and muriatic acid, and knead them as rapidly as possible with dough, an internal action will go on, the carbonic acid gas will raise the mass, the salt formed will season it, and if properly baked, a light, sweet, and nutritious bread will be the result. Such is the rationale of all the unfermented breads now so largely in vogue; though of course various bakers have adopted various ingredients, and hit upon different modes of applying them. Wheaten flour 7 lbs., carbonate of soda 350 to 500 grains, water $2\frac{3}{4}$ pints, and muriatic acid 420 to 560 grains, are said to form an excellent bread. A still finer and sweeter bread is said to be prepared from the following proportions:—Flour, 1 lb.; supercarbonate of soda, 40 grains; cold water, half a pint, or as much as may be sufficient; muriatic acid, 50 drops; and powdered loaf-sugar, a teaspoonful. According to Dr Robert Thomson of Glasgow, a good method of making unfermented bread is—to take of flour, 4 lbs.; supercarbonate of soda, 320 grains; muriatic acid, 6 fluid drachms; common salt, 300 grains; and 35 ounces of water by measure. The soda is first mingled with the flour very intimately; the salt is dissolved in the water and added to the acid—the whole being then rapidly mixed, as in common baking. The bread may be either baked in tins or formed like cottage loaves, and should be kept from one to two hours in the oven. Should it appear yellow, it is a proof that the soda has been in excess, and indicates the propriety of adding a little more acid—the acid varying somewhat in strength.

As to the merits of fermented and unfermented bread, medical testimony is in favour of the superior wholesomeness of the latter; at the same time that it is not so liable to become stale or sour. It has also the advantage in point of economy, there being no loss of nutritive principle through the destructive process of fermentation. 'The result of my experiments,' says Dr Thomson, 'upon the bread produced by the action of muriatic acid upon carbonate of soda, has been that in a sack of flour there was a difference in favour of the unfermented bread to the amount of 30 lbs. 13 ounces; or, in round numbers, a sack of flour would produce 107 loaves of unfermented bread, and only 100 of fermented bread of the same weight. Hence it appears that in the sack of flour by the common process of baking, 7 loaves, or $6\frac{1}{2}$ per cent. of the flour, are driven off into the air and lost. An important question now arises from the consideration of the result of this experiment: Does the loss arise entirely from the decomposition of sugar, or is any other element of the flour attacked? It appears from a mean of eight analyses of wheat flour from different parts of Europe by Vauquelin, that the quantity of sugar in flour amounts to 5·61 per cent. But it is obvious that, as the quantity lost by baking exceeded this amount by nearly one per cent., the loss cannot be accounted for by the removal merely of the ready-formed sugar in the flour. We must either ascribe this extra loss to the conversion of a portion of the gum of the flour into sugar, and its decomposition by means of the ferment—which is highly probable—or we must attribute it to the action of the yeast upon another element of the flour; and if we admit that yeast is generated during the fermentation of the dough, then the conclusion is inevitable that, besides the gum and sugar, the gluten (the nutritive principle) of the flour has also been affected.'

Among unfermented preparations from wheat flour may be classed a large variety of *cakes*, *pastry*, and *pudding*. From the amount of butter, lard, eggs, fruit, seasoning, &c. which they generally contain, they form a most indigestible kind of food, totally unfit for children, invalids, and those having a tendency to dyspepsia. 'All pastry,' remarks Dr Paris, 'is an abomination; and I verily believe that one-half at least of the cases of indigestion which occur after dinner parties may be traced to this cause.' While these remarks apply to ordinary bakers' cakes, pastry, suet pudding, and the like, there are certain light cakes, baked and boiled bread-puddings, which are not only agreeable, but wholesome and nutritious. The Italian preparations *maccaroni*, *vermicelli*, and *Cagliari paste*, consist of the finest wheat flour. The two former have their well-known forms given to them by forcing the tenacious paste through a number of holes in a metallic plate; the latter is pressed into the form of stars, rings, Maltese crosses, and the like. The nutritive qualities of all these preparations, according to Pereira, are identical with wheat; and when plainly cooked, as by boiling (maccaroni and vermicelli soup), they are easily digestible. *Semolina*, *mannacroup*, *&c.* are granular preparations of the finest wheat deprived of bran. They possess of course all the nutritious properties of wheat, and are very agreeable, light, and well fitted for children and invalids. The same remark applies to the so-called *farinaceous foods* of the druggist, which are either pure wheat flour subjected to some heating process which bursts the starch granules, or admixtures of wheat flour with that of barley or oats.

Barley (*Hordeum*), of which there are several varieties cultivated in the British islands, is one of the cereals found all over the temperate regions of the northern hemisphere—some of the varieties coming to profitable maturity even within the limits of the polar circle. As a staple of human food in northern countries, it is used in various forms: thus, freed from their husks by milling, the grains form *pot barley*, used for making broth; still more thoroughly freed from husky matter, and rounded and polished in the mill, they constitute *pearl barley*, used also in broth, and sometimes boiled in water and eaten as rice with milk; the common pot barley, ground to flour, forms the *barley-meal* of the Scotch; and from pearl barley similarly treated is obtained the *patent barley* of the shops. In any of these forms barley forms a wholesome and nutritious food; and it is much to be wished that it were consumed more in the solid state, and less in the liquid which is now so largely distilled from it.

The composition of barley has been variously stated. According to Einhof, the ripe grains yield 70 parts meal, $18\frac{3}{4}$ husky matter, and $11\frac{1}{4}$ water; and the meal so obtained consists of 67·18 starch, 4·62 gum, 5·21 sugar, 3·52 gluten, 1·15 albumen, 0·24 phosphate of lime with albumen, 7·29 fibrous matter (lignin, gluten, and starch), 9·37 moisture, and 1·42 loss. In 100 parts Norfolk barley, Sir H. Davy found 79 starch, 6 gluten, 7 saccharine matter, and 8 husk. Proust, Vauquelin, and others, have subjected this grain to analysis with very nearly the same results; and Dr Thomson adds that the gluten of barley is partially soluble in cold water, as is shown in the steeping of the grain for malting; but it coagulates in 120° or 130°, and falls down in gray-coloured flocks. He also extracted from the husks of barley a small quantity of an oily matter, of an asparagus green colour, and taste resembling that of spirits from raw grain, to which no doubt the flavour of whisky is owing. He likewise found in the specimens he analysed some nitrate of soda capable of crystallisation. From these data it will be seen that barley contains less nutritive matter than wheat, and that this matter is differently composed—that is, it has more mucilage, only about a third of the quantity of gluten, as much sugar, and nearly the same proportion of starch. On the other hand, it is lighter and less stimulating, and has the advantage of having no tendency to induce constipation; so that some persons who are habitually costive, derive advantage from the use of barley-meal cakes and porridge. We say cakes, for in consequence of the small quantity of gluten it contains, it is incapable of undergoing the panary fermentation, so as to form a light spongy loaf like flour from wheat. The barley *bannocks* or *scones* of northern countries are formed by kneading the meal thoroughly with water and a little salt, flattening the dough into cakes rather thin than otherwise, and toasting the same either on a hot iron plate or before a clear brisk fire. When new and properly made, bread of this kind is sweet and palatable; and though somewhat more difficult of digestion than wheaten bread, possesses the advantages already mentioned. *Barley water*, or a decoction of pearl barley, is reputed a soft and lubricating beverage, slightly nutritive, very easy of digestion, and recommended, with the addition of nitre, in cases of fever and inflammation. The Pharmacopœias give the following directions for its preparation:—Take two ounces and a-half of pearl barley; first wash away with water the foreign matters adhering to the seeds, then add half a pint of water, and boil for a little while. This liquid being then thrown away, pour on them four pints (imperial) of boiling water; boil down to two pints, and strain. It is frequently flavoured with sugar, and sometimes with slices of lemon-peel. *Compound barley water* is prepared by boiling together two pints of barley water, a pint of water, two ounces and a-half of sliced figs, half an ounce of liquorice root sliced and bruised, and two ounces and a-half of raisins. This composition is boiled down to two pints, and strained. It is said to be emollient, demulcent, and slightly aperient.

The Oat (*Avena*), of which there are also a number of varieties cultivated in Britain, is one of the hardiest of our cereals. It can be grown with advantage where neither wheat nor barley will ripen; and indeed thrives best under a cold climate like that of Scotland, if the soil on which it is planted be sufficiently dry. It cannot be cultivated in the south of Europe, and is altogether a staple for the inhabitants of high northern regions. The entire grain is largely used as food for horses; freed of the husk, it forms *groats* or *grits*, and these, when crushed, are termed *Embden groats*, and when ground to flour, *prepared groats*. In one or other of these forms oats are pretty extensively used as human food; but more largely as *oatmeal*, which is prepared by grinding the kiln-dried groats to various degrees of fineness, according to taste. This meal is not so white as wheaten flour, and has a peculiar agreeable odour, but somewhat bitterish taste. In various districts of the country it is used for making bread, porridge, puddings, and other preparations.

According to Sir H. Davy, 1000 parts of oats yielded 641 starch, 87 gluten, and 15 saccharine matter. Vogel found in 100 parts of the entire seeds 66 meal and 34 husky matter; and the meal so obtained to consist of 59 starch, 8·25 sugar and bitter matter, 4·30 gray albuminous matter, 2 fatty oil, 2·50 gum, and 23·95 husk, mixture, and loss. Dr Christison's analysis yielded 72·6 starch, 5·8 saccharo-mucilaginous extract, 3·2 albumen, 11·3 lignin (bran), a trace of oily-resinous matter, and 6·6 moisture. From these data it would appear that oats are inferior in point of nutrition to wheat, though, according to Boussingault, the difference is but small. Whatever may be the opinion of chemists, experience proves that they form a substantial nutritive article of diet, since many of the labouring classes in Scotland, in Lancashire, Derbyshire, Northumberland, and other parts of England and Wales, subsist chiefly upon bread, pottage, and other oaten preparations. Oaten food, according to Pereira, is apt to disagree with those having a tendency to dyspepsia: in other words, it is apt to become acescent on the stomach, and oat-bread, in particular, to occasion heartburn. With good digestive organs, however, and a proper amount of vigorous exercise, no inconveniences of the kind are experienced. *Porridge* or *stir-about*, which is composed of oatmeal, water, and a little salt, when well boiled, is one of the best forms in which oaten food can be taken, and eaten with milk, constitutes a capital breakfast. *Gruel* is described by the last-quoted authority 'a mild, nutritious, and, in most cases, an easily-digested article of food in chronic diseases, and in the convalescence from acute maladies. In some irritable conditions of the stomach, it is occasionally retained when many other foods are rejected; yet it is less demulcent than barley-water.' 'Unless gruel be very thin,' says Dr A. T. Thomson, 'it can scarcely be regarded as a diluent; and when thick, it is too heating an aliment for patients labouring under febrile symptoms.' On account of the nitrogenous principle which it contains, it is of course more nourishing than the starchy preparations (arrowroot, sago, tapioca, &c.) frequently employed in the sick chamber. It may be prepared either from oatmeal or ground groats (Robinson's, for example), and may be sweetened with sugar, acidulated with lemon-juice, or spiced. Butter should never be added in the case of the dyspeptic, or where the stomach is tender. *Oaten-cake*, unless made with scalding water, and well-fired, is apt to be heavy and heating; and as oatmeal contains too little gluten to undergo the panary fermentation, Dr R. Thomson recommends a loaf of equal parts of finely-sifted oatmeal and Canadian flour, which those who have tried it consider a great improvement on the hard dry oat-cakes, so much used by the peasantry in some parts of the country.

Rye (*Secale cereale*), though cultivated to some extent on the light sandy soils of our country, can scarcely be considered as one of the staples of British consumption. The small amount grown, however, generally meets with a ready market, partly for distillation, and partly for the making of a light spongy bread, having a peculiar but rather agreeable flavour.

According to Einhof, 100 parts of the entire seeds consist of 65·6 pure meal, 24·2 husky matter, and 10·2 moisture; and the meal so procured is composed of 3·27 albumen, 9·48 moist gluten, 11·09 mucilage, 61·09 starch, 3·27 saccharine matter, 6·38 husk, and 5·42 undetermined acid and loss. From this it would appear that rye contains more gluten than any other grain, except wheat, and therefore should be next to it as a bread-corn, were its other properties equally valuable. 'The husk,' says Webster in his 'Cyclopædia of Domestic Economy,' 'possesses an aromatic and slightly acidulous flavour, which renders it agreeable to the palate. The bran should not, therefore, be entirely separated from the flour; for if the grain be ground fine, and divested entirely of the husk, the bread will be deprived of much of its pleasant taste. Rye-bread is consequently made of coarse flour, which, together with its dark colour, has probably given rise to much of the dislike to it in this country. The quantity of gluten which it contains accounts for the facility with which it may be fermented into spongy bread, which is not the case with oats and some other grains. But bread made of it very soon becomes sour, indeed it undergoes an acetous fermentation in the process of baking, and is thought to have a gentle action on the bowels. In some farmers' families household bread is made of a mixture of one-third rye and two-thirds wheaten flour, which makes a sweeter bread than that solely of wheat, and is preferred to any other by those who are in the habit of using it. The bread is very firm and solid, and retains its juiciness and moisture long, being also very nutritious.' Though little used with us, rye-bread, under the title of black-bread, is largely consumed by the peasantry of Sweden, Germany, Russia, and other northern countries.

Rice—the *Oryza sativa* of botanists—is a plant of Asiatic origin, but is now extensively cultivated not only in China, India, and other Eastern countries, but in the West Indies and the southern states of America, as well as in the rich alluvial lands of Lombardy and in the province of Valencia in Spain. 'It is the grand material of food,' says Marsden, 'on which a hundred millions of the inhabitants of the earth subsist; and although chiefly confined by nature to the regions included between and bordering on the tropics, its cultivation is probably more extensive than that of wheat, which the Europeans are wont to consider as the universal staff of life.' Requiring a warm climate, it cannot be grown in Britain; but we import it largely—the Carolina and Patna rice being the most esteemed in the market. It is brought chiefly in the shelled or cleaned state; but of late, attempts have been made to import the *paddy*—that is, rice in the husk—with a view to obtaining the grains in a fresher condition.

Rice consists chiefly of farina or starch, 100 lbs. from Carolina yielding, according to Braconnot, not less than 85 starch, 5 fibrous matter, 4 glutinous matter, and 5 water, the remainder being sugar, gum, and phosphate of lime. It is therefore evidently much less nutritious than any of the preceding cereals, though it is light and wholesome, and altogether a very valuable food when taken along with milk or some corrective condiment. It is prepared as an article of food in various ways, either whole or ground. It may be used like barley in broth, boiled and eaten with milk, boiled and dried as a substitute for potatoes, as an accompaniment to curried dishes, or baked in puddings, which is perhaps the best mode of using it. What are called *rice-cakes* consist of about one-third of their weight of ground rice, the rest being flour, eggs, and sugar. *Rice-water*, employed like barley-water as a demulcent, is obtained by boiling well-washed rice in water. Though, on the whole, light and digestible, rice possesses a constipating quality, which somewhat detracts from its value as an article of habitual use.

Maize or *Indian Corn* is the produce of the *Zea mays* of Linnæus—a cereal found native in America, but now largely cultivated not only in the new world, but in several of the warmer regions of the old. As an article of human subsistence, it is extensively used in the countries where it is grown; but has not, till the recent failures of the potato crop, met with much attention in Britain. In America, the tender young ears, in their milky state, are roasted and eaten with butter and salt as a delicacy, or boiled with meat. When green, they are also pickled as gherkins; and dried, they keep all the year. When the grains are ripe, the skin is taken off, and the farinaceous part is boiled whole, or ground into meal, and made into cakes, puddings, &c. It is this meal which is chiefly known in Britain, and of which a variety of puddings, cakes, and loaves have been recommended.

Being extremely productive, maize can in general be cheaply procured; hence the importance in years when the staple of our own country fails. According to chemists, 100 parts of the entire corn contain upwards of 80 starch, from 5 to 9 of a peculiar fatty principle, 2 saccharine matter, 2 gum, and small proportions of various salts of lime, &c. Such data do not certainly speak highly of its nutritive qualities, and yet we find those who live chiefly upon it robust, healthy, and fond of it as an article of diet. It is somewhat laxative, and requires to be taken with caution till the system becomes habituated to its use. To make good palatable *maize-bread*, Dr R. Thomson recommends the grains to be reduced to a fine meal, and then mixed with one-third its weight of best flour, and fermented. When thus prepared, the bread is dark-coloured, and cannot be made much lighter than coarse wheaten bread. The shade, however, is of a peculiar yellow, not to be mistaken for that of wheat, besides that the taste is altogether different.

Peas and *Beans*, which belong to the leguminous order of plants, are consumed partly in a green state, and partly when ripe and dried. It is the latter state with which we have at present to do; and it may be stated generally, that their meal or farina is now but little used as an article of human food. Peas, split or whole, are used in the preparation of peas-soup; their meal, either pure or mixed, is still employed in some districts in the making of cakes; and, very finely ground and bolted, it is used as a supper diet, under the name of *Glasgow brose-meal*. With regard to the amount of nitrogenous or nutritive matter which pulse and lentils contain, it is far beyond what is found in any of the cereals, being as 44 or 50 to 100 of wheat flour. The nutritive effect, however, does not agree with this theoretical conclusion, partly from their deficiency in other wholesome constituents, and partly from the difficulty with which they are digested, the flatulence and costiveness they occasion, as well as from the acridity they are said to communicate to the blood.

Sago—Tapioca—Arrowroot.—Of a considerable number of foreign starchy or amylaceous products, these are the most extensively used, and best known in Britain. The first is the produce of the sago palm (*Sagus rumphii*), a native of the East Indies and Indian Archipelago. 'The part which affords the sago is the pith; and to procure this, the body of the tree, when it is full grown, is sawn into pieces, and the raw sago cut out and put into a trough with water, in which it is well stirred, to separate the flour from the woody fibre. This is now suffered to rest, and the flour subsides to the bottom. The water is then poured off, and the meal laid upon wicker-frames to dry. To form it into the round grains in which it is imported, the sago, when moist, is passed through a cullender, and rubbed into little balls, like shot, and then thoroughly dried. The sago-tree requires to be seven years old before being fit for felling; and a full-grown specimen will yield about 600 lbs. of sago. The best sago is of a slightly pinkish hue, and readily dissolves to a jelly in hot water. Several other trees beside that above-mentioned yield sago, but neither so abundantly nor of so excellent a quality.' The sago of commerce is imported either as sago-meal, pearl-sago, or common brown sago, which states have reference more to its form than composition. In all, the main constituent is starch, which, being light and easily digestible, renders sago an eligible substance for the dyspeptic and invalid. *Sago-puddings* (made like tapioca) are by no means uncommon; but the common mode of use is *sago-milk*. This is prepared by soaking the sago in cold water for an hour, pouring off this water, and then either boiling slowly in milk, or in a little water to which milk is afterwards added. This mixture may be taken plain, or sweetened and seasoned to taste.

Tapioca is obtained from the tuberous root of the *Janipha manihot* by grating and washing. It is usually met with in small irregular lumps, a form it has acquired by being dried on hot plates. The heat breaks the starch globules, and renders them partially soluble in cold water. In boiling water tapioca becomes gelatiniform, transparent, and viscous. 'In its nutritive qualities,' says Pereira, 'it agrees with sago, than which it is much purer, being free from colouring matter. It also yields a more consistent jelly than some other kinds of starch. It is principally employed as an agreeable light nourishment for invalids, as well as for children.' 'No amylaceous substance,' says Christison, 'is so much relished by infants about the time of weaning; and in them it is less apt to become sour during digestion than any other farinaceous food, arrowroot not excepted.' Tapioca-milk is made in the same way as sago-milk; but tapioca being more soluble than sago, requires only half the time for its preparation.

The pure white amylaceous powder known as arrowroot, is obtained from the tubers of the West Indian plant *Maranta arundinacea*. It makes a tolerably strong jelly, stronger than that of wheat starch, and is free from colouring matter, and also from any unpleasant taste or odour. It is used either in the preparation of puddings, gruel, or milk, like sago and tapioca. 'The best arrowroot we have,' says Webster, 'is from Antigua, Jamaica, and Bermuda; but a great deal of what is sold in London is adulterated with potato-starch, which, though a substance not very different, has not precisely the same properties. Arrowroot, like every kind of starch, boils to a jelly, but it differs from potato-starch in this respect: the jelly formed from arrowroot will remain firm for three or four days without turning thin or sour, whereas the jelly from potato flour, in the course of ten or twelve hours, becomes thin as milk and acescent; hence it is not so well calculated for food, and particularly infants.' The proper value of all these starchy substances, however, is now much better known; and as starch can only supply heat-forming matter, the purer they are, the less fitted are they for the purposes of nutrition. As food for the young, they are by far too largely employed, as are all those so-called 'farinaceous compounds' of the quack and medicine-vender. 'The best American wheat flour, good Scotch oatmeal, and barley-meal,' says Dr R. Thomson, in his Experimental Researches, 'may all be employed at different times, by way of variety, and repeated according to their agreement with the child's organs of digestion. The digestion of all these forms of food containing starch is greatly promoted by long boiling either with water or milk, as this process is just so much saved to the intestinal organs. It is thus obvious that we have a great variety of food fitted for children, of which we know the composition, and that we should prefer it to any species of compounded stuff of the constitution of which we are ignorant.'

The Potato (*Solanum tuberosum*) is one of our most abundant amylaceous or starchy vegetables, and next to the cereals, is one of the most common articles of human food. Originally discovered in South America, it is now introduced into almost every quarter of the globe, where it seems to thrive, and to break into innumerable varieties, differing in shape, size, colour, flavour, and quality. Without noticing minutely the peculiarities of the numerous varieties, we may remark that those of middling size, and which become white, mealy, and void of any especial flavour when boiled, are in general the most esteemed, as they are the most wholesome and nutritious. As they are an easily-raised crop, producing twice as much food from the same extent of land as wheat, potatoes are very largely grown in the British islands, and notwithstanding the recent failures, are likely still to be so. The disease to which we allude having drawn much attention both to their natural history and economical importance, there is perhaps no object of culture or article of diet which has elicited so many and contradictory opinions. Some would apparently have the potato altogether eradicated from our soil; others, taking a more modified view, would 'never allow it under any circumstances to occupy, as the staple aliment of any class of our population, the place of the grain-bearing plants;' while a third party see in it 'a cheap and available source of subsistence to the poor, which has had, in addition, much effect in lessening the prevalence of scorbutic, calculous, and arthritic disorders.' Without pronouncing dogmatically on the subject, we shall merely present the leading dietetic properties of the potato, as set down by Liebig, Pereira, and Webster. The most correct opinion respecting the nutritive properties of potatoes will be obtained from the consideration of their constituent principles. They have been analysed by various chemists. The analysis of Einhof, which is generally considered the best, is in 100 parts—water 72·6, starch 15, fibrous matter 7, albumen 1·4, and mucilage 4. Here it is essential to observe the large proportion of water, and it is only the remainder that is to be considered as farinaceous. Like all the *Solanaceæ*, or Nightshade family, the potato contains a poisonous principle (solanine); but this is wholly destroyed by cooking. Citric and tartaric acids are also said to be present in various parts of the growing plant, and to these are likely to be ascribed the reputed antiscorbutic properties of the tuber. The fibrous matter in Einhof's analysis appears to be a peculiar modification of starch, which, as well as that substance, may be employed for food; but it is to be noticed that there is no gluten, except the albumen may be considered as nearly the same thing. Various kinds of potatoes afford these constituents in proportions a little different; but the preceding may be considered as the average of the best mealy potatoes—the alimentary part being about 27 per cent., of which starch is the principal ingredient. No doubt can be entertained of their wholesome nature, when we consider the numerous hardy peasantry of Ireland, many of whom subsist entirely upon this useful vegetable. It must not, however, be imagined that potatoes contain the same nutritive powers as bread, weight for weight. It has been estimated, as the result of experiments made by Percy and Vauquelin, that one pound of good bread is equal to two and a-half or three pounds of potatoes, and that seventy-five pounds of bread and thirty of meat are equal to three hundred pounds of potatoes.

In Britain, potatoes are generally brought to table boiled plain; but in France they are cooked in a great variety of ways, and furnish very agreeable dishes. *Potato soup* (see PREPARATION OF FOOD) is a very palatable and thrifty mode of cooking; and *mashing* them with various ingredients, though it produces a more savoury dish, does not certainly contribute to their digestibility. 'It is of little signification, as affecting the digestibility,' writes Dr Robertson, 'whether the potato be roasted or baked, or boiled, provided the quality and the cookery be unimpeachable. They are probably more nutritive—that is, contain more azotised matter, if boiled with their skins on, than if peeled before boiling; but it is equally probable that they are more easily digested if peeled before they are boiled. The new or immature potato is much less easily digested than the fully-ripened tuber, and should certainly be forbidden to the majority of dyspeptics. Early and forced potatoes must be less easily digested than those which have been grown with the advantages of free exposure to the air and the sunshine.' As already stated, potatoes are used in the manufacture of loaf-bread; and *potato starch*, which is nothing more than dry starch powder, is used not only in fine bread and pastry, but as a substitute and adulterant of arrowroot. *Bright's nutritious farina* is said to be a carefully-prepared potato starch, slightly scented; and we believe several of the 'farinaceous foods' of the shops are of similar origin. The most that can be said of them is, that they are sufficiently light, and not unwholesome, but by no means nutritious.

The *Cabbage tribe* (*Brassica*), which includes the common white and red cabbages, the savoy, greens, cauliflower, broccoli, &c. is pretty extensively cultivated in Britain (See KITCHEN GARDEN) for the purposes of human food. The parts used are the leaves which *heart* or gather together; and in the case of the cauliflower and broccoli, it is the young and compact flowering heads. As nutritive products, they rank high theoretically—dried cabbage being set down by Boussingault as 83 to 100 of wheat flour; but as they contain upwards of 90 per cent. water, a larger quantity requires to be consumed for the purposes of nutrition than would be either wholesome or agreeable. For healthy constitutions they supply a valuable mixture with animal food; but for the dyspeptic, they are apt to prove indigestible, and productive of flatulency. They are usually recommended to be well boiled; and like all the Cruciferous order, to which they belong, possess valuable antiscorbutic qualities.

The Turnip (*Brassica rapa*), which belongs to the same family, is perhaps still more largely consumed. The varieties best adapted for human food are the Swedish, yellow, and Dutch—all of which contain a considerable quantity of sugar and mucilage, but little or no gluten. 'A hundred parts of turnip bulb yielded Boussingault 92·5 water, and 7·5 solid matter; and this, when dried, only 1·7 of nitrogen—being but a third of the amount found in dried cabbage. Sir H. Davy estimates the nutritious matter of turnips at about 4 per cent.; but though thus slightly nutritive, they form an excellent culinary vegetable, and are either eaten alone, mashed, or cooked in soups or stews. Pereira regards them as of easy digestion, and has never seen them produce flatulence when well boiled. Turnip tops, or the young leaves gathered in spring, are occasionally used in England as greens, but are very apt to disorder the bowels.

The Carrot and *Parsnip* are two well-known umbelliferous roots, possessing highly-nutritive properties, if chemical composition is to be taken as the test of alimentary value. They contain vegetable fibrine, albumen, sugar, and a volatile oil; 1000 parts yielding 95 sugar and 3 starch, or about six times the amount of sugar found in potatoes. They are valuable culinary vegetables in soups and stews, and ought to be much more largely used. The fibrous matter they contain renders them somewhat difficult of digestion if not well boiled—a matter admitting of very easy remedy.

Beet-root, though largely made use of on the continent, is chiefly employed in England as a garnish for salads and other dishes, and as pickle. According to the experiments of M. Achard, 14 lbs. of beet yield 1 lb. of sugar; hence the manufacture of sugar from this root, and hence also its value in a culinary point of view. During the recent potato failures, various preparations of beet were recommended as a food for the poor; and among others, *beet-bread* from an admixture of finely-rasped beet and wheaten flour, fermented and baked in the usual form. 'We have had the experiment tried,' says Dr Lindley, 'by rasping down a red beet-root, and mixing with it an equal quantity of flour; and we find that the dough rises well, and forms a loaf very similar to good brown bread in taste and appearance. We regard this,' he continues, 'as an important discovery, because no crop is so readily cultivated, or will yield so large a return as beet, and likewise because of its great value in point of nutrition. In its relation to potatoes it stands as 1020 to 433, if its nutritive quality is considered; and as 6630 to 3480 in regard to utilisable produce of all kinds.' We may add, that either the red beet, the white sugar beet, or the carrot, may be used with success in this manner.

Of the vast variety of garden vegetables used as salads, pickles, garnishes, and so forth, none of them are consumed in such abundance as to entitle them to especial notice. Many of them are no doubt useful, others are useless, and not a few positively hurtful, though fashion and caprice may give them a place on our tables. Some notice of the more prominent—as lettuce, radish, spinach, celery, asparagus, artichoke, parsley, cress, onion, and the like—will be found under KITCHEN GARDEN, COOKERY, and MEDICINE.

Sugar.—As already mentioned, sugar exists both in vegetable and animal substances, but more abundantly in the former. In many of the products already noticed, the saccharine principle forms no unimportant item, though not in such proportion as to be considered characteristic. We now come to consider it as a distinct principle, and as an article of vast dietetic importance. Sugar, as a vegetable product, is found in considerable quantity in such dried fruits as the currant, raisin, fig, date, tamarind, and so forth; and these are now pretty largely consumed in Britain. Thus figs yield about 60 per cent. of sugar, tamarinds 12, prunes 16, and dates 35; and there can be no doubt that these, as well as many of our ripe fleshy fruits, owe their chief alimentary value to its presence. It is, however, as a separate and prepared article that we have now to do with it—as a substance obtained by art from the sugar-cane, the maple, the beet, the palm, and other plants yielding it in abundance. Though procured from the maple in America, from the beet on the continent, and from the palm in the East Indies, it is solely from the sugar-cane of the tropics that Britain obtains her supply, amounting annually to upwards of 5,000,000 hundredweights. When the canes, of which there are several varieties, have attained a certain height and age (about twelve or thirteen months), the cuticle having become smooth, dry, and brittle, they are cut, stripped of their leaves, and crushed between rollers to express the juice, which is mixed with lime, to saponify, and render more liquid and separable the uncrystallisable portion, known as molasses or treacle. The juice is now heated to the temperature of 140°, and separated from the scum, and again heated several times, and at length allowed to drain, for the separation of the *molasses* and the crystallisation of the sugar. The *raw* or *brown sugar* thus formed is again purified, by being dissolved in lime water mixed with bullock's blood: the one serving still more to separate the molasses, the other, by the coagulation of the albumen, effecting the clarification and mechanical separation of any foreign insoluble matters. Reduced to a certain syrupy consistence, the sugar is poured into moulds, and agitated for a certain time, to prevent the formation of large crystals, and secure a compact mass of closely-adherent, small, and glistening grains. This constitutes *loaf-sugar*, the quality of which depends greatly on the lowness of the temperature at which the boiling has been effected. When sugar thus refined has been again dissolved, and left to crystallise slowly at a somewhat elevated temperature, in boxes crossed with threads, to form centres of crystallisation, *sugar-candy* is formed; or if sugar so dissolved is made to cool more quickly, a transparent solid is obtained, known as *barley-sugar*. Sugar in one or other of these states constitutes the basis of almost all *confectionary*, as acidulated drops (sugar and tartaric acid), toffee, hardbake, comfits, lozenges, and the like. It forms also an excellent antiseptic, and for this purpose is used as a *syrup* for preserving fruits, roots, &c., as well as for the curing of meat and fishes.

In whatever form sugar or the saccharine principle may be made to appear in commerce or in diet, its ultimate composition, when pure, is carbon, oxygen, and hydrogen; or more simply, carbon and water. It contains no azotised principle, and thus its function in the animal economy is to supply heat, and not nutrition. Thus 100 parts of pure sugar-candy yield 42·85 carbon, and 57·15 water; refined sugar 41·5 carbon, 58·5 water; and raw sugar 40·75 carbon, and 59·15 water. According to the quantity of water which any sugar contains, so it is denominated *high* or *low;* that from the cane being a higher or stronger variety than that from the grape, and sugar-candy a higher form than that of raw sugar. Theoretically, therefore, sugar is merely an element of respiration—a result at variance with the common notion that it is nutritious. 'During the sugar season of the West India islands,' says Dr Wright, 'every negro on the plantations, and every animal, even the dogs, grow fat.' But the accumulation of fat is a diseased rather than a healthy condition; and though sugar, as furnishing the respiratory carbon and the fatty tissue, may be termed nutritious, it is certainly insufficient to sustain existence without the addition of some nitrogenous article of diet. 'The fondness of children for saccharine substances'—we quote Pereira—'may be regarded as a natural instinct; since nature, by placing it in milk (woman's milk contains upwards of 6 per cent. sugar), evidently intended it to form part of their nourishment during the first period of their existence. Instead, therefore, of repressing this appetite for sugar, it ought rather to be gratified in moderation. The popular notion of its having a tendency to injure the teeth is totally unfounded; Dr Wright informs us that no people on the earth have finer teeth than the negroes of Jamaica. Sugar is readily digested by the healthy stomach; though in some dyspeptic individuals it is apt to give rise to flatulency and preternatural acidity of the stomach. In some diseases—as diabetes, for example—it should be altogether excluded from the diet.' Contrary to this opinion as to the digestibility of sugar, Dr Robertson pronounces pure sugar to be 'by no means easily digested,' and that it only becomes so when sufficiently mixed and diluted with other juices. Molasses, on the other hand, from containing more component water, is more easily digested, at the same time that it is usually laxative in its effects. It is still, nevertheless, saccharine matter, and is still apt to irritate the digestive organs, and by so much to interfere with and derange the processes of ultimate assimilation.

Honey, though, strictly speaking, obtained through the medium of the animal kingdom, may with little impropriety be considered in this place. It is but a weaker form of sugar, and although elaborated by the bee, is still found ready-made, if we may so speak, in the flowering apparatus of many plants. It consists chiefly of cane and grape sugar, or, in other words, of crystallisable and uncrystallisable sugar, and according as the former predominates, so is its quality superior. Besides these two sugars, honey also contains a free acid matter not yet well understood, mucilage, sometimes a little wax, together with colouring and aromatic matter. These adjuncts differ, according to the kind of flowers on which the bees feed; and occasionally honey has been known to possess narcotic and poisonous properties. Its dietetic properties are thus spoken of: —Like treacle, honey often acts as a laxative, and to a greater degree. But, like all other concentrated forms of saccharine matter, the digestibility of honey is only a comparative question; and although honey may be much less apt to derange the functions of assimilation than cane-sugar or treacle, it is nevertheless by no means easily digested when the stomach is either weakened or otherwise less equal to its duties; and should always be used cautiously by the dyspeptic, if used at all by them. With some constitutions it by no means agrees, and has to be carefully avoided.

The fleshy fruits, as the apple, pear, plum, peach, and the like, though generally consumed during their seasons, cannot be regarded as a staple of food. Excluding water, which enters largely into their composition, they consist of sugar and mucilage, with peculiar acids. Any alimentary value they therefore possess, may be estimated from what has been already stated of sugar: some, as the pear and apple, are employed in the manufacture of BEVERAGES; and as to their acid properties, these will be fully considered under the principles of MEDICINE.

ANIMAL FOOD.

Animal, like vegetable substances, are resolvable into ultimate and proximate principles. The *ultimate elements* of 100 parts ox blood, for example, are—51·95 carbon, 7·17 hydrogen, 21·39 oxygen, 15·07 nitrogen, and 4·42 insoluble mineral matter. Again, 100 parts beef yield 52·59 carbon, 7·89 hydrogen, 19· oxygen, 15·22 nitrogen, and 3·30 insoluble ingredients. Comparing this with what has been said of vegetables, the vast preponderance of nitrogenous or nutritive matter will be readily perceived—thus giving to animal food a theoretical more than a practical superiority, inasmuch as nature seems to have intended our food to be used in a form rather coarse—requiring full mastication, insalivation, and a longer retention in the stomach. The *proximate principles* of animal food are—fibrin, or the fleshy fibre of meat when boiled to rags; gelatine, or animal jelly; albumen, as white of eggs; oil and fat; osmazome, which gives to meat its peculiar flavour; kreatine, a peculiar crystallisable juice; casein, such as the curd of milk or cheese, which is nearly allied to albumen; and, we may add, sugar, as in the case of milk. Of these principles are all animal bodies composed; always bearing in mind the large percentage of water which they contain. These principles vary considerably in ultimate composition—thus 100 parts of fibrin yield 53·36 carbon, 7·02 hydrogen, 19·68 oxygen, and 19·93 nitrogen; while albumen yields 50·00 carbon, 7·78 hydrogen, 26·67 oxygen, and only 15·55 nitrogen. Of course their relative values in point of nutrition depend upon the ultimate constitution; and this must be obtained with accuracy before any comparison can be instituted between fibrin and gelatine, gelatine and albumen, or albumen and casein.

In treating of animal food, some writers attempt to classify it according as it may be derived from the flesh, blood, viscera, bones, cartilages, ligaments, cellular tissue, milk, &c. As our limits, however, prevent any such minute consideration, we shall merely remark, that all these portions of the animal body are less or more prized and made use of; and that they differ in nutritiousness not only according to the kind or species of the animal, but according to the age, sex, food, and mode of life of the individual. Thus the flesh of young animals is more tender than that of old; that of the entire male adult coarser and tougher than that of the female; while the flesh of castrated animals is more delicate, tender, and better flavoured than that of animals left entire. Again, feeding and exercise are not without their influence; and just as the fibres of flesh are loose, tender, and minute, so are they the more easy of digestion. With these preliminary remarks, we shall proceed to notice in detail the leading articles of animal food made use of in Britain:—

Beef, or the flesh of the full-grown ox, is largely consumed in Britain, perhaps more largely than a due regard to health and economy would allow. The quality of this article depends upon a variety of circumstances, such as the breed, sex, and age of the animal, and likewise the kind of food with which it has been supplied. 'Bull beef,' says a leading authority on cuisine, 'has a strong disagreeable flavour, and is dry, tough, and difficult of solution. The flesh of the ox is more soluble; the fat is better mixed, the meat more sapid, and highly nourishing and digestible if the animal is not too old. The flesh of the cow is sufficiently fit for nourishment, but is inferior to ox beef; *heifer* beef, or that of the young cow, is much esteemed, but that of an old fatted cow is bad. The beef of the larger varieties of the ox is inferior to that of the smaller breeds; the former is in perfection from five to seven years old; the latter may be taken a year or two sooner. Grass-fed beef, or that produced from good farm produce, is always better-flavoured and more digestible than that reared from oil-cake, brewers' wash, and the like.' Beef is consumed both in a fresh and salted state; it is also pickled, smoked, and otherwise prepared. Salted, it is more difficult of digestion, while the salt, moreover, destroys a considerable portion of its albumen. Preserving it fresh in hermetically-sealed vessels, from which the air has been expelled, is now extensively adopted, with the best results. For various modes of pickling and preserving, as well as for an estimate of the comparative merits of boiling, broiling, and roasting, the reader is referred to the following article on the PREPARATION OF FOOD.

Veal, or the flesh of the calf, is tender and nourishing, but not so easy of digestion as the prime parts of beef and mutton. Veal, particularly if it be young, contains much gelatine, as is the case with all young animals, and therefore yields a great deal of soluble extract when boiled long in water. This fact has led to the idea of its being more nourishing than meat which is less soluble; but this does not follow, for the gastric juice acts differently from water, and can digest what that fluid cannot. Veal contains less nitrogenised matter than beef, as well as a smaller proportion of proteinaceous compounds.

Besides beef and veal, strictly so called, the intestines (tripe), heart, lungs, bones, marrow, cartilage, &c. of the ox are variously made use of; none of them, however, possessing the same amount of nutritious matter as the true flesh, nor being so digestible and wholesome. 'Animal flesh being identical with our own flesh and blood, say chemists, it requires neither addition nor subtraction to render it nourishing;' but in order that it may reach the different organs, it is necessary that it should be reduced to a liquid form (blood). It is for this reason that true flesh is preferable to liver, for example, which contains a peculiar oily matter; to kidney, in which urea has been detected; to heart, which is densely muscular and indivisible; or to tripe, which, though light and easily digested, consists chiefly of fibrine and albumen.

Mutton, or the flesh of the full-grown sheep, is also extensively consumed in Britain, and that almost wholly in a fresh state. Compared with beef, it is lighter, and more easily digested, owing very probably to the greater fineness of the fibres. 'The quality of mutton,' says the authority already quoted, 'varies much in the different breeds. In the large long-haired sheep (see No. 38) it is coarse-grained, but disposed to be fat. In the smaller and short-wooled breed the flesh is closest grained and highest flavoured; but the quality is probably most affected by the food on which the flocks are fed. Those which range over the mountainous districts of Wales and Scotland, or the chalk downs of England, and feed upon the wild herbage, possess a flavour very superior to those kept on rich pastures and marsh land. Marsh-fed mutton often becomes extremely fat, but the meat has a rank taste. Turnips, hay, chaff, bean, corn, and other vegetables, as likewise oil-cake and grains, are employed for fattening sheep; but such mutton is never so good as that produced where the animals range at freedom. *Tup* mutton, or the flesh of the ram, has a strong disagreeable flavour, and is usually tough; ewe mutton, if under two years old, is good, but after that, it becomes hard and tough; wedder mutton is the most esteemed. Mutton is in perfection at five years old, being then sapid, full-flavoured, and firm, without being tough; and the fat has become hard. Mutton under three years old is deficient in flavour, and is of a pale colour. *Lamb*, as the flesh of the young sheep is termed, is more tender and less exciting than mutton, but is not readily digested; nor is it improved in this respect by the mint sauce, sliced lemon, and other absurdities with which it is usually accompanied. It receives the name of lamb from the time it comes into season, in April or May, till the ensuing Christmas.

Pork, or the flesh of the pig, is invariably set down by writers on dietetics as difficult of digestion, but less so when pickled and cured than when fresh. 'The fat is so intimately mixed with the lean, and the tissue between the fibres contains so much of it,' say they, 'that it is utterly impossible to separate the one from the other. A man must therefore have unimpaired powers of digestion to render it nourishing, and a stomach that is not easily irritated to render it wholesome.' Notwithstanding, it is largely consumed, and forms a useful and economical diet for those leading an active and laborious life, chiefly, however, in a cured state—the preparation of the salted article for home consumption or exportation forming a large and flourishing business. Those who pursue the occupation cut the carcass in pieces, and pack it in kits formed to hold from one to two hundred pounds' weight. A brine is then made by dissolving salt in water, until the mixture is so thick that an egg will swim in it. This is boiled, and poured upon the pork after it has cooled. Russian pork, always much esteemed, is steeped in a brine containing 2 lbs. of loaf sugar and 3 ounces of saltpetre, to 6 lbs. of salt, the whole being boiled in six gallons of water. After brine is added to pork in kits, the end of the receptacle is fixed in, and the article is usually sufficiently cured in a few days.

Hams are the cured hind-legs of the pig, and are considered the finest parts of the animal. They are generally in great request, and form an article of extensive consumption in Britain. The following are general directions for curing them:—In the first place, the legs require to be cut in a neat rounded form, and it is usual to prepare a number at a time. Being properly prepared, pack them with rock-salt in a suitable tub or cask, being careful not to lay the flat sides of the large pieces upon each other, and filling the intervals with hocks, jowls, &c. To every 200 lbs. of meat, then take 20 lbs. of rock-salt, or Onondago coarse salt, 1 lb. of saltpetre, and 14 lbs. of brown sugar, or half a gallon of good molasses, and as much water (pure spring water is the best) as will cover the meat; put the whole in a clean vessel; boil and scum; then set it aside to cool, and pour it on the meat till the whole is covered some three or four inches. Hams weighing from 12 to 15 lbs. must lie in the pickle about five weeks; from 15 to 25 lbs., six weeks; from 25 to 45 lbs., seven weeks. On taking them out, soak them in cold water two or three hours, to remove the surface salt, then wipe and dry them. It is a good plan, in cutting up, to take off feet and hocks with a saw instead of an axe, as it leaves a smooth surface, and no fractures for the lodgment of the fly. Some make only six pieces of a trimmed hog for salting, but it is more convenient, when intended for domestic use, to have the side pork, as it is called, cut in small pieces. The goodness of hams and shoulders, and their preservation, depend greatly on their smoking, as well as salting. The requisites of a smoke-house are, that it should be perfectly dry; not warmed by the fire that makes the smoke; so far from the fire, that any vapour thrown off in the smoke may be condensed before reaching the meat; so close as to exclude all flies, mice, &c. and yet capable of ventilation.

Bacon is the whole side of a pig cured. The method of preparation is as follows:—After being killed, the carcass should not be scalded to remove the bristles, as in the case of pork, but singed off by being covered lightly with straw, to which fire is applied. When the burning straw has cleared one side, the other side may be cleared in the like manner. By this means all the hair is to be singed clean off, but without scorching the flesh, and then the skin is to be well scraped as a finish. This singeing process gives a fine firmness to the bacon, which scalded bacon never possesses. In Hampshire, as Mr Cobbett informs us in his 'Cottage Economy,' the plan of singeing is universally followed; and pig-keepers could not have a better example. The next steps in the process are related as follows by this writer:—'The inwards are next taken out, and if the wife be not a slattern, here, in the mere offal, in the mere garbage, there is food, and delicate food too, for a large family for a week, and hog's puddings for the children. The butcher the next day cuts the hog up, and then the house is filled with meat; souse, griskins, blade-bones, thigh-bones, spare-ribs, chines, belly-pieces, cheeks, all coming into use one after the other, and the last of the latter not before the end of about four or five weeks. All the other parts taken away, the two sides that remain, and that are called *flitches*, are to be cured for bacon. They are first rubbed with salt on their insides, or flesh sides, then placed one on the other, the flesh sides uppermost, in a salting trough, which has a gutter round its edges to drain away the brine; for, to have sweet and fine bacon, the flitches must not lie sopping in brine, which gives it that sort of taste which barrel-pork and sea-junk have, and than which nothing is more villanous. Every one knows how different is the taste of fresh dry salt from that of salt in a dissolved state; the one is savoury, the other nauseous; therefore change the salt often; once in four or five days. As to the time required for making the flitches sufficiently salt, it depends on circumstances—the thickness of the flitch, the state of the weather, the place wherein the salting is going on. It takes a longer time for a thick than for a thin flitch; it takes longer in dry than in damp weather; it takes longer in a dry than in a damp place. But for the flitches of a hog of twelve score, in weather not very dry or very damp, about six weeks may do; and as yours is to be fat, which receives little injury from over-salting, give time enough, for you are to have bacon till Christmas comes again. The place for salting should, like a dairy, always be cool, but always admit a free circulation of air; confined air, though cool, will taint meat sooner than the mid-day sun, accompanied with a breeze. The flitches of bacon are now to be smoked, for smoking is a great deal better than merely drying, as is the fashion in the dairy counties in the west of England. Great attention should be paid to this matter: the flitch ought not to be dried up to the hardness of a board, and yet it ought to be perfectly dry. Before you hang it up, lay it on the floor, scatter the flesh side pretty thick over with bran, rub it on the flesh, and put it well down upon it. This keeps the smoke from getting into the little openings, and makes a sort of crust to be dried on, and, in short, keeps the flesh cleaner than it would otherwise be.'

Bacon has been much vaunted by some as a remedy for indigestion, while by others a totally different opinion is entertained. 'In the large majority of cases,' says Dr Robertson, 'it cannot be so; but, on the contrary, must tax still further the powers of the stomach, or irritate still further its tissues, which under such circumstances may be already in a state of morbid sensitiveness. Bacon is obtained from the most difficultly-digested of the meats, the fleshy fibres of which are toughened by the salt and by the drying. That fat is rendered more digestible by being impregnated with salt, is an admitted fact; and this must of course qualify these strictures on the use of bacon. But the lean of bacon is rendered more difficult of digestion by the same process that has increased the digestibility of the fat; and the fat is not by any means so altered in character, as no longer to irritate the debilitated stomach. I have no hesitation in saying, that in the greater number of cases of dyspepsia bacon does harm.'

Brawn.—Boars are also fattened for the purpose of procuring an article of food under this name. Male pigs of all ages are put into feeding with this view, but those experienced in such matters prefer them of the age of two years. They are kept separately, in pens which will not permit of their turning round, perfect inactivity being held to conduce to their fattening. Their food is beans, with water, into which a small quantity of sulphur has been put. The collar of the animal is the part prepared for brawn, by the process of pickling and drying. A large collar will weigh about thirty pounds, and is valued at about £3 in the market.

Lard is that part of the fat of the pig which melts easily, and forms a fine, soft, white grease. It is extensively used not only in household economy, but by the pastry-cook, apothecary, and perfumer. It should be, according to Martin Doyle, of *two* qualities: the finest and whitest (that taken from the sides) should be chopped into small pieces in a pan, over a slow fire, and kept constantly stirred, lest it should stick to the sides of the boiler; then strained, and put into bladders turned inside out, and thoroughly purified by having all the fat cut out, and being well blown and dried in the open air. That of the first quality, when well made, is far better than any salt butter for cookery, and, from the delicacy of its colour, is used by confectioners for the finest kinds of cake and pastry. The inferior lard is obtained from the intestines, and is treated as the finer lard in every particular. The *blood* of the pig, we may also observe, furnishes a distinct article of food—being used in the preparation of the black-puddings of the shops.

Venison—Hare—Rabbit.—The flesh of the deer, hare, rabbit, and other game found in the British islands, can never be considered as an article of general consumption. The comparative scarcity of these animals, and the fact that they are in season or fit for food only during the colder months of the year, when they become objects of fashionable capture, render them more as luxuries for the middle and higher classes, than a staple of food for the bulk of the population. The ultimate analysis of their flesh is much the same as that of the domestic animals, differing, however, in proximate character, and also in containing certain flavouring principles of a bitter or acid nature. From their constant motion and exercise, wild animals acquire a drier and harder flesh than that of the tame; and those parts which have the least motion, as the back of a hare, for example, are most juicy and palatable. From the same cause, the fluids of these animals are more heating, and much more apt to putrefy than the fluids of the domestic kinds.

The term *venison*, though applicable to the flesh of all animals which are caught by way of hunting, is generally restricted to that of the deer kind, as the buck, the doe, the hart, and the hind. When well fed, killed at the right season, and properly dressed, venison forms a palatable as well as a wholesome and readily digested food. 'Chymification,' says our highest authority on this subject, 'is most easily effected on a soft solid, which is easily divisible into shreds or small particles. Such is particularly the character of venison, which is ascertained to be one of the most digestative substances.' To the injury of health, however, it is generally eaten when half putrefied, notwithstanding its natural tendency to putrescence. Cooked in this state, it forms highly objectionable food for those predisposed to scurvy or putrid diseases, and should never be partaken of unless with the addition of vinegar, acid of lemons, or some other corrective. The flesh of *hares* was in high repute among the ancients both in dietary and in medicine. 'Inter quadrupedes gloria prima lepus,' says the Latin epigram; 'but the poet,' quaintly remarks a surgeon of the last generation, 'knew little of diet; for the flesh of the hare is hard, and is neither good nor wholesome nourishment.' The youngest and fattest are the best; and those bred on plains and mountains are preferable to those which live in moist places—the former feeding on aromatic herbs, which gives to their flesh a peculiar flavour. *Rabbits* are in more common use than hares; and in certain districts of the country no man who has tenpence or a shilling to spare need be in want of a pair to furnish himself and family with a nice Sunday dinner. Rabbits are either found wild in warrens, or are reared in sheds and hutches as directed in No. 40. The former furnish the most dainty and agreeable food—having a greater opportunity of feeding on sweet aromatic herbs, such as thyme, juniper, and the like, which imparts to their flesh a rich and more pleasant flavour. Though a rabbit is in many respects similar to a hare, yet the flesh of the former is more tender as well as more juicy than that of the latter, and after boiling, becomes pale, and may be termed *white meat*. On the whole, it affords a good and nourishing diet, if taken at a middling age and size: when too young, it is not esteemed wholesome; and when old, it becomes dry, hard, and difficult of digestion. Rabbits are in prime season from the middle of October till the end of January.

Poultry—Game-Birds.—So far as experience goes, the flesh of all birds is edible, though that of some tribes is less palatable and wholesome than that of others. As an article of food, it is pretty largely consumed in this country—the domestic fowl, turkey, goose, duck, pigeon, partridge, grouse, and pheasant, being the species which afford the chief supply. According to Brande, 100 parts of chicken flesh yield 73 water, 20 albumen or fibrine, and 7 gelatine—that is, a total of 27 per cent. nutritive matter. Schlossberger's estimate is somewhat less; but of course chemical analysis will differ according to the condition, age, and other particulars of the specimen examined. 'The flesh of birds,' says Dr Duncan, 'differs very much in its sensible properties, not only in different kinds, but even in the different muscles of the same bird. The pectoral muscles which move the wings are drier and more tender than those which move the legs. The tendons of the legs are also very strong, and at a certain age become bony; but the flesh of the legs, when sufficiently tender, either from the bird being young, or from long keeping, or sufficient cookery, is more juicy and savoury than that of the wings. Of a few birds, especially the woodcock and snipe, the legs are at all times preferred to the breast. In the black-cock, the outer layer of the pectoral muscle is of a dark-brown colour, while the inner is white. A similar difference is observed in many other birds, and perhaps it is general in a slight degree. The muscular organs of birds differ from those of quadrupeds in their flesh never being marbled, or having fat mixed with the muscular fibres.' This is so far advantageous, as the fat of most birds, the aquatic in particular, is extremely difficult of digestion and assimilation.

It is usual for writers on dietetics to classify the flesh of feathered animals according to its colour, or according to the leading habits of the birds as regards their food and mode of life. Adopting some such distinction, Dr Pereira makes the following generalisations:—'The meat of the common fowl, turkey, and the like, is *white-coloured*, contains but little osmazome, when good, is generally liked, and when young, is exceedingly tender. Dr Beaumont states that it is more difficult of digestion than beef: he says that the texture of the chicken being closer than that of beef, the gastric juice does not insinuate itself into the interstices of the muscular fibre so readily as into beef, but operates entirely upon the outer surface, which it dissolves as a piece of gum-arabic is dissolved in the mouth, until the last particle is dissolved. Chicken flesh, however, is nutritious, and when young, is perhaps the least stimulating of animal foods. It is often retained on the stomach of invalids when other meats would be immediately rejected. Chicken broth is well adapted for irritable stomachs. The flesh of the wild gallinaceous birds, as the grouse, blackcock, &c., is *darker coloured*, firmer, richer in osmazome, somewhat less digestible, and more stimulating than that of the chicken. When sufficiently kept, it acquires a peculiar odour, called *fumet*, and an aromatic bitter taste, most sensible in the back. In this condition it is said to be *ripe* or *high*, and is much esteemed by epicures as a luxury. The flesh of aquatic fowl, as the goose and the duck, is mostly firm, penetrated with fat (which often acquires a rancid and fishy taste), and is more difficult of digestion. It forms, therefore, a less appropriate aliment for invalids.' On the whole, it may be remarked that the younger and smaller the bird, the more delicate and tender the flesh; but the female is generally more tender and delicate than the male; that domestication renders birds more fleshy and tender; and that the more cleanly and carefully the animals are reared, the more wholesome and palatable their flesh becomes. It may be also added, as the result both of experience and experiment, that poultry is more easily digested when broiled; is somewhat less digestible when roasted; and is least easily digested when boiled. The less it is mixed and qualified by sauces, stuffings, and other abominations, the better.

The eggs of birds—the hen, duck, goose, and turkey—are largely consumed in Britain, partly as a direct article of diet, and partly in puddings, pastry, and fancy breads. It is scarcely necessary to observe that the egg of the common fowl is that most extensively used, both on account of its superior flavour and digestibility. Both the white and yolk consist chiefly of albumen, the former almost entirely so. Thus 100 parts of white of egg yield about 80 water, 16 albumen, and 4 incoagulable mucilaginous matter; the yolk about 54 parts water, 18 albumen, and 28 a peculiar yellow oil. The white, upon an average, is about twice the weight of the yolk; and deducting from the weight of the whole egg one-tenth for the weight of the shell, and the half of the remaining nine-tenths for water, and less than a fourth of the further remainder for the oily portion of the yolk, about a third of the entire egg appears to consist of azotised or nutritious matter.

With respect to the eligibility of eggs as an article of diet, much depends upon the mode of preparation. 'If lightly boiled,' says Dr Robertson, 'the digestion of the yolk of egg is hardly ever felt. Not so the white: when boiled, this almost always irritates the disordered stomach, and by the dyspeptic and invalid it should not be eaten. The same observations apply to some extent to eggs when made to form part of a pudding: the yolk is still the part which is most easily digested—the white that which is the more likely to disagree; but the latter is not so likely to prove injurious as when eaten alone, and unmixed with other things. The probable reason of this is the same as that assigned for the increased digestibility of milk when mixed with flour or oatmeal; the albumen being prevented from coagulating into large masses, is offered to the action of the gastric secretions in smaller portions, which are therefore more readily acted upon by it. It is an important fact, that either the white or the yolk of egg, if eaten raw, and therefore uncoagulated, is much more easily digested than when it has been previously boiled. The albumen is of course, in this case, coagulated by the acid secretion of the stomach, as the first step to its digestion; but this coagulation is different from the coagulation by heat, and does not offer the same degree of resistance to the solvent powers of the stomach. A raw egg is not, then, liable to the objections, on account of its degree of digestibility, that a boiled egg may deserve; and on the contrary, it would seem that there are few articles of diet which are so quickly or so easily digested as uncoagulated albumen. Lightly-poached egg is probably more digestible than egg boiled in the shell; and this may be owing to the more rapid coagulation of the albumen, and the shorter time it is necessary to expose the albumen to the heat, in order to render it sufficiently cooked for palatibility. It is hardly necessary to say, that fried eggs, involving the addition of fat, part of which is necessarily browned, and by so much burned or converted into empyreumatic oil, and likewise involving the exposure of the albumen to a much higher temperature than that of boiling water, must be much less easily digested than boiled eggs. The digestibility of egg is much influenced by its having been recently laid. Containing so much azotised matter, and the usual proportion of sulphur and phosphorus, egg soon undergoes the changes of decomposition; and probably to a considerable extent before these are to be detected by the sense of smell.'

Turtle.—Of the reptiles, which rank next in the descending scale of animated life, none can be regarded as a staple of food in this country. We leave the edible frog to our continental neighbours, and the turtle to the inhabitants of those regions of which it is a native. As a luxury, however, turtle is consumed by the wealthy and great, and is yearly becoming more common, as the facilities of steam navigation bring it in much better condition, and much more abundantly. When cooked, the flesh of the green or edible turtle somewhat resembles that of chicken or veal; is pale, watery, soft, rich in gelatine, poor in fibrine, and contains little or no osmazome. It is said to be of easy digestion, and nutritive; and by decoction yields highly-restorative soups. The eggs of several of the turtle family are eaten as a palatable article of food.

Fish—Crustacea and Shell-fish.—This division embraces a large amount of the food of our countrymen, and is steadily, though slowly, on the increase. In the articles ANGLING and SEA-FISHERIES, the natural history and modes of capture of the fishes chiefly consumed in Britain are sufficiently detailed; we shall here restrict ourselves to their dietetic condition and importance. Unlike the flesh of birds, that of fish is not always to be eaten with impunity. Many, indeed, are highly poisonous; and even the best are not always in season. They are said to be in season after full recovery from the operation of spawning, up to the time when the roe and milt are ripe, and about to be shed—and the nearer this point the better. Almost every portion of the common edible fishes is available as food; but the muscular, fleshy, or flaky part is that which forms the staple. It differs little in composition in the various kinds, being composed mainly of water, albumen, and gelatine. Thus 100 parts of cod-flesh yield 79 water, 14 albumen or fibrine, and 7 gelatine; and that of the sole 79 water, 15 albumen, and 6 gelatine. In many fishes this flesh is mixed or covered with fat or oil, as in the salmon, herring, pilchard, &c.; but after the spawning season this fat is greatly diminished: in others, as the cod, skate, &c. the fat seems concentrated in the liver, leaving the flesh devoid of it. Fish-flesh contains, theoretically, a fair amount of nutritive matter; but this is greatly depreciated in many instances by its indigestibility. Taken in the aggregate, Dr Robertson arranges their relative indigestibility thus:—1. white-fleshed fish; 2. flat-fish; 3. shell-fish; 4. fresh-water fish; 5. red-fleshed fish; and lastly, the more oleaginous fish. From the quantity of water which the flesh of fish contains, it is less satisfying to the appetite than butcher-meat or poultry, at the same time that it is less substantial and nourishing. Besides the albumen, gelatine, mucus, and oil usually found in the substance of fishes, there are phosphates, chlorides and iodides of lime, magnesia, soda, &c. which may give to it peculiar dietetic and medicinal properties.

For dietetical purposes, fishes have frequently to undergo some sort of preparation, varying according to the situation, the necessities, or the tastes of the consumers. 'When circumstances permit,' says Dr Fleming, 'they are in general used in a *fresh* state; and in large cities, where the supply must be brought from a distance, various expedients are resorted to, to prevent the progress of putrefaction. By far the best contrivance for this purpose is the well-boat, in which fish may be brought to the place of sale even in a live state. Placing the fish in boxes, and packing with ice, is another method, and has been extensively employed, particularly in the supply of the metropolis with salmon. In many maritime districts where fish can be got in abundance, a species of refinement in taste, or at least a departure from the simplicity of nature, prevails, to gratify which the fish are kept for some days until they begin to putrefy. When used in this state, they are far from disagreeable, unless to the organs of smell. Where fish are to be procured only at certain seasons of the year, various methods have been devised to preserve them during the periods of scarcity. The simplest of these processes is to *dry* them in the sun. They are then used either raw or boiled, and not unfrequently, in some of the poorer districts of the north of Europe, they are ground into powder, to be afterwards formed into bread. But by far the most successful method of preserving fish, and the one in daily use, is by means of salt. For this purpose they are packed with salt in barrels, as soon after being taken as possible. In this manner are herrings, pilchards, cod, and salmon, as well as many other kinds of esculent fish, preserved. The fish, in many instances, after having been salted in vessels constructed for the purpose, are exposed to the air on a gravelly beach, or in a house, and dried. Cod, ling, and tusk so prepared are termed in Scotland *salt-fish*. Salmon in this state is called *kipper*; and haddocks are usually denominated by the name of the place where they have been cured. After being steeped in salt, herrings are in many places hung up in houses made for the purpose, and dried with the smoke of wood. In this state they are sent to market under the name of *red-herrings*. Although salt is generally employed in the preservation of fish, whether intended to be kept moist or to be dried, vinegar in certain cases is added. It can only, however, be employed in the preservation of those fish to which this acid is served as a sauce.' By the above processes of salting, drying, and smoking, the digestibility of fish is greatly impaired; though, in some cases, they may thereby be rendered more palatable and nutritious.

But though salting may thus impair the digestibility of fish, by hardening the fibres of the flesh, yet fresh fish are recommended by physicians to be eaten with a considerable quantity of salt. When salt is eaten with fresh fish, according to Dr Robertson, 'the fibres are not hardened by the salt; and the only effect of the salt is to stimulate the stomach so far as to promote or produce its speedy digestion. The more greasy the fish, the more salt should be eaten with it, and vinegar is usually a palatable and advisable addition. It answers the same end as salt, in correcting the effect of the fat, &c.; but this remark, it must be observed, applies only to such stomachs as can bear a moderate degree of acid without inconvenience. Broiling and boiling, especially the latter, are undoubtedly the most wholesome and easily-digested ways of cooking fish. Fried fish, from being cooked in butter or fat, is much less digestible. If the fish be not of greasy character, broiling is the most digestible mode of cooking it; if greasy, the fat is rendered more or less empyreumatic, and by so much less wholesome, by broiling—and boiling is then the way of cooking it. With the exception of salt—and in the case of oily fish, of sugar—all addition to fish, in the form of sauce or condiment, of necessity renders its digestion more difficult. The melted butter with which fish is almost invariably eaten, must render it less digestible; and the dyspeptic who will eat fish, should not add to it butter in any form.

The same observation, as to difficulty of digestion, is applicable to all the different kinds of shell-fish and crustacea. Mussels, cockles, &c. are less easily digested than oysters, and it is quite a mistaken notion that these are comparatively harmless in this respect. Prawns, shrimps, &c. like the lobster and crab, have hard, dense fibres, that are not readily dissolved by the gastric secretions. The character of the fibres, indeed, will afford a trustworthy guide (other circumstances being equal) to the digestibility of the different kinds of fish. Thus the denser fibres of the skate render this fish less digestible than the turbot; and the same circumstance makes the halibut less digestible than the salmon.' As to the nutritive properties of crustacea and shell-fish, they are in general greatly overrated. In the oyster, for example, 100 parts of the flesh yield about 88 water, and only 12 of solid or nutritive matter; while 100 parts of butcher-meat yield on an average from 25 to 28.

Milk—Butter—Cheese.—These are indirect animal products, all largely consumed in every country, whether savage or civilised. Milk, which is obtained only from the class Mammalia, and intended by nature for the nourishment of their young, is the basis of the whole—furnishing, according to certain changes, which it readily undergoes, cream, butter, curd, cheese, whey, and so forth. Intended by nature as the sole food of the young mammal, it necessarily contains all the elements of respiration and nutrition. Blood, flesh, bones, and every other tissue, are formed from its elements: it is, in fact, a perfect food; that is, perfect in its kind, up to a certain stage of animal development. Its proximate constituents are casein, butter, sugar of milk, various salts, and water; and these differ not only in various animals, as the following analyses will show, but also according to the food, the age, and the period after parturition. Thus 100 parts of

	Casein.	Butter.	Sugar.	Salts.	Water.
Cow's Milk yield	4·48	3·13	4·77	0·60	87·02
Ass's do. . .	1·82	0·11	6·08	0·34	91·65
Woman's do. .	1·52	3·55	6·50	0·45	87·98
Goat's do. . .	4·02	3·32	5·28	0·58	86·80
Ewe's do. .	4·50	4·20	5·00	0·68	85·62

Such analyses, however, are to be regarded only as approximations, for the food, age, &c. must ever be taken into account. A cow fed on carrots, for example, yields a milk differing from that which she produces when fed on beet-root:—

	Casein.	Butter.	Sugar of Milk.	Salts.	Water.
Carrots, .	4·20	3·08	5·30	0·75	86·67
Beet, . .	3·75	2·75	5·98	0·65	86·87

Notwithstanding these differences, there is always in the milk of a healthy mother sufficient nutriment for the young; the cream and butter yielding fat, which, along with the sugar, subserves the purposes of respiration or heat; the casein the elements of nutrition and growth; and the salts (chiefly phosphates of lime, magnesia, soda, and iron) matter for the construction of the solid skeleton. Milk as an article of diet for adults, is obtained in Britain almost solely from the cow; goat and ewe-milk being only occasionally used in the preparation of cheese; and that of the ass solely as a remedy in cases of consumption.

Referring the reader to the article DAIRY for the management and preparation of milk, cream, butter, cheese, and the like, we shall here merely advert to the respective dietetic peculiarities of these preparations. Cows' milk, when obtained from healthy, well-fed, and properly-kept animals, is a very useful and valuable article of food, as well for adults as for children. Its principal drawback, according to Pereira, is the difficult digestibility of its fatty constituent, or butter—an objection, however, which can be got rid of by using it in the *skimmed* state. Under the name of *milk diet*, it is extensively employed in conjunction with bread, oatmeal, rice, sago, potatoes, and other farinaceous substances, and forms in every case a readily assimilated and nutritive aliment. *Cream* consists of butter, curd, and serum or whey, and though less digestible than milk, properly so called, is not so liable to this objection as butter. *Fresh butter* is more easily digested than salt; and whether salted or fresh, preference is always to be given to that most recently prepared. *Whey* is chiefly composed of water and lactic acid, with a slight proportion of casein, butter, and sugar. It is therefore very slightly nutrient, but forms an excellent diluent in inflammatory complaints, and also gently promotes the secretions. *Buttermilk*, as containing the casein, the sugar, and the salts of milk, must possess nutritive properties. It is deserving of wider adoption, both as an article of diet, and as a cooling and agreeable beverage. *Curd* is less easily digested than cream; but more so than butter. It consists mainly of casein, and this from fresh milk yields 54·82 carbon, 7·15 hydrogen, 15·63 nitrogen, and 22·39 oxygen and sulphur. *Cheese*, or casein dried, and having probably undergone some chemical change during the process of 'ripening,' is generally very difficult of digestion. It almost always contains a considerable proportion of the fatty part of the milk, and in some cases is made almost entirely from cream. The impunity with which many persons can eat toasted cheese may be partly attributed to the mustard, &c. eaten along with it, although the cooking has much to do with the greater digestibility. Cheese made from cows' milk is more easily digested than that from goats' milk; and the richer or more oleaginous the cheese, the more easily is it digested. Ripe cheese is preferable to that which is green or immature, and also to that which is partially decayed. In whatever stage, cheese should be eaten with caution, as apt to produce not only indigestion, but crudity and consequent irritation in the intestines. It will thus be observed that none of the artificial or secondary preparations from milk possess its own bland and generally unobjectionable character; and this arises from the fact of their being concentrated forms of certain principles, while in milk these principles are mingled and diluted in right and natural proportion.

Animal fat, like the oil of vegetables, consists essentially of carbon, hydrogen, and oxygen; and therefore, when taken as food, can supply only respiratory or heat-forming matter. Containing about 80 per cent. of carbon, *heat* is its proper function, and thus is explained the fact why the inhabitants of cold climates can consume with impunity so much of this aliment. All fatty matters are digested with difficulty, and are apt to irritate and derange the stomach and its functions. The fat of different animals, however, differs in point of digestibility; and what is more curious still, differs also according to the part of the animal from which it is taken. The digestibility of fat is much affected by modes of cooking; it is also greatly modified by the action of vegetable acids, and of common culinary salt.

MINERAL FOOD.

It has been already mentioned that man derives little of his food directly from the mineral world. No doubt all plants and animals contain a certain amount of saline and earthy ingredients, which are indispensable to healthy aliment; but these are indirect products, and are always taken into account when estimating the relative dietetic value of vegetable and animal compounds. In fact, the only substances obtained directly from the inorganic kingdom, and consumed in large quantities, are water and salt—two substances as necessary to existence as the air we breathe. The former, as has been seen, enters largely into the composition of every species of food; it acts as a solvent and diluent in all cases, and permeates everywhere the tissues to whose subsistence and growth it administers. The latter, though usually taken as a palatable condiment, is really essential to the maintenance of health and vitality, and accordingly appears as a constituent of the blood and the tissues elaborated therefrom.

Water, as consumed by man either as a beverage or as a constituent of his food, is generally in a fresh state; that is, contaminated as little as possible by foreign ingredients. The nature and constitution of water has been already detailed under the heads CHEMISTRY and SUPPLY OF WATER: all that is necessary to be here observed is, that the supply for dietetic uses should be freed from all mechanical impurities, and from all chemical impregnations, which may render it unpalatable, unsuitable for culinary purposes, or detrimental to the system of the consumer. Absolutely pure water is not found in nature, nor does it indeed seem to be required by the animal economy. It is only pure when distilled, and in this state it is neither pleasant to the taste nor nourishing. The purest waters always contain some amount, however small, of lime, clay, iron, or other mineral; and what is more curious still, analysis always detects some trace or per centage of organic matter. It is only when these foreign substances exist to any amount that water becomes objectionable. Good water is generally known by its softness, its limpid and somewhat sparkling appearance, its agreeable flavour, and its non-liability to become putrid. Its softness it acquires from the absence of saline or mineral ingredients, its sparkling aspect and agreeable flavour from the carbonic acid which it absorbs from the atmosphere, and its resistance to putrescence from the comparative absence of animal or vegetable matter. By filtration, which is now generally practised, all mechanical impurities can be got rid of; but for the removal of chemical impregnations, boiling, or the admixture of chemical reagents, is required.

The ordinary sources of fresh water are rains, springs, rivers, lakes, and wells; and according as it is obtained from one or other of these sources, so is it characterised by peculiar properties. *Rain water*, if collected in mountain districts, far from human dwellings, is perhaps the purest of all; but if collected in the neighbourhood of towns, it is found to be largely impregnated with soot, and other extraneous substances; and the rapidity with which it putrefies, demonstrates the presence likewise of organic matter. Being soft, it is valued by the housewife for washing; but is unfit for internal or culinary purposes without undergoing rigid filtration. Unimpregnated with mineral substances, its action on lead is more rapid than that of other waters, and it should never therefore be kept in lead cisterns. All *spring water* is less or more impregnated with the substances through which it has percolated to the surface; but with the exception of those commonly termed 'saline' or 'mineral'—and which are noticed under MEDICINE—most springs yield water of sufficient purity for domestic purposes. Those issuing from the primitive and igneous rocks, or from extensive beds of sand and gravel, are generally the purest; those from the carboniferous and other secondary strata always hold in solution compounds of iron, lime, sulphur, salt, and magnesia. *River water*, which is a combination of rain and spring water, is often well fitted for human purposes. Its impurities are more of a mechanical than of a chemical kind, and may be removed by careful filtration. Much, however, depends upon the soil and district through which the river flows; meadows, morasses, and forests yielding organic matter, and factories and towns bequeathing heterogeneous impurities, not to be got rid of by any ordinary process. Water drawn from fresh *lakes* is less turbid than that from rivers; but is always (unless from deep mountain tarns) more largely impregnated with vegetable and animal matter. *Well or pump water* is that obtained by boring or by sinking shafts into the rocky strata. It must of necessity, like spring water, partake more or less of the mineral ingredients through which it percolates; and not unfrequently is injured by the pumps, pipes, and other apparatus by which it is raised. Such are the ordinary sources from which man derives his dietetic waters; and it were greatly to be desired that more efficient modes of purification, as well as abundance of supply, were more generally adopted in reference to our towns and cities, which, with few exceptions, have neither quantity nor quality to boast of.

Respecting the alimentary functions of water, Dr Pereira, after remarking that it is the natural drink of all adults, observes—'It serves several important purposes in the animal economy: *firstly*, it repairs the loss of the aqueous part of the blood, caused by evaporation and the action of the secreting and exhaling organs; *secondly*, it is a solvent of various alimentary substances, and therefore assists the stomach in the act of digestion, though if taken in very large quantities, it may have an opposite effect, by diluting the gastric juice; *thirdly*, it is probably a nutritive agent—assisting in the formation of the solid parts of the body. It has not, indeed, been actually demonstrated that water is decomposed in the animal system; or, in other words, that it yields up its elements to assist in the formation of organised tissues; yet such an occurrence is by no means improbable. It appears from Liebig's observations, that the hydrogen of vegetable tissues is derived from water; and it is not probable that the higher orders of the organised kingdom should be deficient in a power possessed by the lower orders. Dr Prout appears to admit the existence of this power, but thinks that it is rarely exercised by animals. The water which constitutes an essential part of the blood and of the living tissues, assists in several ways in carrying on the vital processes. "In the blood," says Prout, "the solid organised particles are transported from one place to another; are arranged in the place desired; and are again finally removed and expelled from the body, chiefly by the agency of the water present." It is from water that the tissues derive their properties of extensibility and flexibility. *Lastly*, this fluid contributes to most of the transformations which occur within the body. As a solvent it serves not only to aid digestion, but also to effect other changes, as, for example, the conversion of uric acid into urea, and sugar or starch into sugar of milk and diabetic sugar. So also the hydrochloric acid of the gastric juice, and the soda of the blood and bile, are derived from common salt (chloride of sodium) by the aid of water.'

Salt.—Referring the reader to our article on MINING AND MINERALS, p. 363, for an account of the modes of procuring and preparing this indispensable article, we shall here strictly confine our remarks to its dietetic or alimentary importance. 'By virtue of its chlorine,' says a popular authority, 'salt largely promotes the functions of the stomach and bowels in assimilating the food; by virtue of its soda, it greatly subserves the uses of the bile in the economy; and in its every action—whether by means of its separated constituents, or in its combined state, serving probably to maintain the blood in its singularly compound and yet homogeneous condition—is shown to be great on all the functions and conditions of the body. There can be no question, however, that even salt may be too much or too little used in the food: that in the one case, the tissues and the expending organs are too much stimulated; in the other case, the system is unduly, and not without serious risk, deprived of that agent, by which so large a share is performed in the nutrition of the body; and which in itself, by its ultimate elimination from the body in the several excretions, probably serves to keep up the action of the excreting organs, and promotes the disintegration and throwing off of the effete matters, no longer fitted for the purposes of the economy, and which could not be retained without injury. The less readily assimilated the articles may be, and the less of saline matter contained in them, the more essential is salt as a part of the food; hence the oily articles of food, and the purer forms of the starchy principle, when largely used as means of nutrition, require usually more salt to be eaten with them than the more ordinary and less pure forms of vegetable or even animal diet. And yet animal diet of any kind, probably from its putrescent tendency, if not mixed with vegetable food in sufficient proportion, is found to require a large mixture of salt with it, for the maintenance of health and strength.' The amount of salt consumed by a full-grown person has been estimated at 16 lbs. a year, or about 5 ounces a week; but of course this estimate will vary exceedingly, according to the tastes and habits of individuals.

All the varieties of salt, whether small-grained, like the *basket or table salt*, or in large crystals, like the *bay* and *fishery salts*, consist essentially of chloride of sodium, which is composed of 60 per cent. chlorine and 40 sodium. The salt of commerce, however, is never found absolutely pure, being less or more contaminated with salts of lime and magnesia, as well as insoluble matter. Thus an average of foreign bay salts yielded to analysis 3½ per cent. of such impurities; British salt from sea-water upwards of 4 per cent.; and that from English rock-salt somewhat more than 1½ per cent. The purer salt is, of course the more wholesome will it be as an article of diet, and the more effectual for the purposes of pickling and curing provisions.

BEVERAGES.

Writers on dietetics are in the habit of classifying drinks or beverages according to their sensible, chemical, or medicinal properties. Thus we have—1. Mucilaginous, farinaceous, or saccharine drinks; 2. Emulsive or milky drinks; 3. Animal broths, or drinks containing gelatine and osmazome; 4. Aromatic or astringent drinks; 5. Acidulous drinks; and, 6. Alcoholic and other intoxicating drinks. Water, however, is the only true natural beverage: it forms the basis of the whole of the above—the other constituents being but infusions, decoctions, and solutions of solid elementary substances already described. Being reduced to a liquid form, the alimentary action or effect of these substances is much facilitated, and thus, in point of easy assimilation, beverages are immensely superior to solid food. In certain cases, therefore, it is advisable that diet should be taken in this form; not only on account of its ready assimilation, but from the accuracy with which it can be reduced to the necessary strength. In all cases, however, of healthy existence, food in a solid form is indispensable, and beverages are to be regarded simply as diluents, demulcents, and correctives. Setting out with this view, and following the above distinctions, we shall now briefly allude to the more abundant and familiar beverages—adopting as authorities Liebig, Pereira, and Robertson:—

1. The mucilaginous, farinaceous, and saccharine drinks are perhaps the simplest, next to water. They are merely solutions, infusions, or decoctions of substances already described, and are known by such terms as *gum-water*, *toast-water*, *sugar-water*, *barley-water*, *mucilage of rice*, and *gruel* from oats, sago, arrowroot, or tapioca. They are all very slightly nutritive; and are used chiefly in the sick-chamber as demulcents and diluents. Toast and barley-waters are placed by the faculty at the head of this division.

2. Emulsive or milky drinks are such as hold in suspension any oily or fatty substance in a finely-divided state. *Animal milk* (already described) is at the head of this section; others, as *milk* and *syrup of almonds*, fall more properly to be noticed under MEDICINAL PREPARATIONS.

3. Broths and soups, or drinks containing gelatine and osmazome, are usually prepared from beef, mutton, veal, and chicken. A number of receipts are given for their preparation in the following article (COOKERY); the rationale of their aliment has been already described. Boiled meat of good quality yields kreatine and osmazome, coagulated albumen, gelatinous cellular tissue, fatty matter, saccharine matter, some salts and water; and to prepare a soup so that none of these may be dissipated and lost, is the chief point requiring attention. When pot vegetables, as turnips, carrots, onions, barley, &c. are used, of course these communicate new principles to the liquid—as mucilage, sugar, azotised products, volatile oil, and salts. Extract of the pure or lean meat is always preferable for invalids and convalescents—*beef tea* and *chicken broth* being the most highly recommended.

4. Of the aromatic and astringent drinks, tea, coffee, and chocolate are pre-eminently the most familiar. 'We shall never, certainly, be able to discover,' writes Baron Liebig, 'how men were led to the use of the hot infusion of the leaves of a certain shrub (tea), or of a decoction of certain roasted berries (coffee). Some cause there must be, which would explain how the practice has become a necessary of life to whole nations. But it is surely still more remarkable that the beneficial effects of both plants on the health must be ascribed to one and the same substance, the presence of which in two vegetables belonging to different natural families, and the produce of different quarters of the globe, could hardly have presented itself to the boldest imagination. Yet recent researches have shown, in such a manner as to exclude all doubt, that *caffeine*, the peculiar principle of coffee, and *theine* that of tea, are in all respects identical.' The fact is certainly striking enough, and all the more so that cocoa or chocolate also yields a principle (*theobromine*) identical, or all but identical with theine and caffeine. These principles furnish elements precisely the same as those of the bile; hence their effect on the processes of secretion, on nutrition, and vitality.

Tea is usually distinguished as *black* or *green*; the former including such marketable varieties as Bohea, Congou, Souchong, Caper, and Pekoe; the latter Twankay, Hyson, Imperial, and Gunpowder. Of the black teas, Pekoe is one of the best; of the green, Gunpowder. When subjected to analysis, they all yield less or more volatile oil, chlorophyle or colouring matter, wax, resin, gum, tannin, theine, albumen, lignin, and extractive matter. The dietetic and medicinal properties of tea are thus detailed, throwing out of view the qualities usually imparted by the addition of sugar, milk or cream:—It acts on the system as a stimulus or a sedative, according to the strength of the infusion that is taken. When taken in smaller quantity, its effect is, in general, simply and in a small degree sedative, even in the first instance; when used in larger quantity, its primary action is decidedly that of a stimulus. Its well-known effect of inducing wakefulness illustrates this. To many people, when taken late in the evening—and in some when taken strong at almost any time—it produces a very sensible degree of stimulation, and a state of sleepless excitability. Besides inducing wakefulness, tea seems to sharpen the mental faculties, and perhaps, in an especial degree, the imagination. Green tea has, generally speaking, more stimulating, black tea more sedative properties. The stimulating effects are, however, always and necessarily followed by sedative effects, which may amount in extreme cases to depression, or even to a degree of narcotism; and in most cases it acts as a narcotic on the organs of excretion, producing more or less visceral torpidity and sluggishness. To the man who has a sufficiency of nourishing and wholesome food, the use of tea in moderate quantities, and at proper times, cannot be said to be ever followed by unpleasant or unsatisfactory consequences. If taken in excessive quantities, tea becomes decidedly debilitating to the nervous system, affecting it much in the same way as any other stimulant and narcotic. But though tea, when used in moderation, is serviceable to the individual who takes a sufficient quantity of nutritious food, unquestionably serving some important purpose, in completing and perfecting the last stages of digestion; and although, under such circumstances, the use of tea is not injurious, this is by no means the case when the aliment that is taken is deficient in quantity, or of too poor a quality. Under such circumstances, tea acts on the nervous system to a degree that is often productive of disorder, and which probably sometimes leads to disease. The effect of tea on the second stage of digestion, and probably on the secretion of the bile, points out and explains its value when taken about three or four hours after the principal meal of the day, and illustrates the well-known anxiety of the dyspeptic for tea-time, and the comparative comfort he enjoys after this beverage, which is aptly said 'to cheer, but not inebriate.' Taken at the same time as a heavy meal of food, or such a meal as contains a large proportion of the day's alimentary supply, tea may prove to be too much of a diluent, or too directly narcotic; and in some cases may rather retard the primary digestion than otherwise. This, however, depends very much on the quantity and the strength of the infusion made use of. Green tea, although said to be used almost exclusively in some countries, is found to be much too narcotic and stimulating for exclusive use in this country, and is necessarily forbidden to most invalids, from its evidently enervating effects.

The *Coffee* of commerce is the seed of a berry-bearing tree or shrub, found originally in Arabia, but now extensively cultivated in all tropical countries. It is usually distinguished by the place of its growth—as Mocha, Jamaica, Mountain-Jamaica, Demerara, Ceylon. Raw coffee can be kept for any length of time without deterioration—indeed the older the better; but on being roasted, it developes a fragrant and aromatic principle, which is extremely volatile. Roasted coffee should therefore be ground and used as speedily as possible. Coffee yields to analysis caffeic acid, tannic acid, caffeine, wax, resin, gum, albumen, lignin, extractive matter, and salts of lime, magnesia, and iron. Its dietetic properties and peculiarities are thus detailed by the preceding authority:—Used in infusion or decoction, coffee is more nutritious than tea, but is more difficult of digestion. Whether owing to the tannin, which the roasted coffee is said to contain, or to the aromatic oil, or the mucilage, or the bitter extract, or to the combination of these different constituents, coffee deranges considerably the stomachs of some people, and is usually somewhat difficult of digestion to invalids, and to those who are more seriously dyspeptic. It is probable that this is not referable to the aromatic principle, as the best coffee, which contains more aroma, is less likely to disagree than the commoner sorts. The infusion is usually less apt to disagree than the decoction, unless the latter have been most carefully clarified. The consequence of coffee proving to be of difficult digestion is rather to produce considerable acidity than to give rise to any other marked dyspeptic symptom. Supposing that coffee does not disagree, which in the healthy and strong is seldom does, it is a peculiar and decided stimulus, quickening the circulation, promoting the secretions and excretions, very perceptibly warming the system and elevating the spirits. Supposing that the powers of the digestive organs are adequate to its complete assimilation, coffee, from being much more nutritious, and more decidedly restorative to the system, forms a better addition to other articles of food that are taken at breakfast than tea. If its ready digestibility be suspected, the question of its being mixed with sugar, and the known difficulty with which sugar is digested, should be considered, before coffee is pronounced to be unsuited to the individual. The addition of milk to coffee adds much to its nutritiousness, diminishes in some degree its directly stimulating effects, and seldom makes its digestion more difficult. As to the addition of *chicory* (the roots of the wild succory, or endive, dried and ground), now so commonly practised, medical authorities are rather in favour of a moderate admixture than otherwise. The chicory root is perfectly wholesome, contains no alkaloid or oil, and only a small amount of resinous and narcotic matter. When added in small quantities, it rather improves the flavour of coffee, apparently combines with, or neutralises its oil, and altogether renders it less difficult of digestion.

Cocoa is derived from the seeds or nuts of the chocolate-tree (*Theobroma cacao*), a native of tropical regions. The seeds grow in pods, and are prepared for use by being roasted, deprived of their husks, and ground. Cocoa is either used in the form of the ground seeds, simply made into a decoction; or these are ground into a paste mixed with cloves, cinnamon, vanilla, &c. forming *chocolate*. In either form, cocoa is described as oleaginous, and somewhat acrid, and is in general by no means so easily digested as tea or coffee. Still, there are many people, both dyspeptic and sedentary, with whom it invariably agrees; and this much can be said in its favour, that it is devoid of the disagreeable qualities of disturbing the nervous functions. The ground seeds are preferable to the paste or cakes, of whose composition, or, we should rather say, adulteration, we are ignorant.

5. The acidulous beverages in common use are *lemonade, ginger-beer, soda-water, effervescing saline draughts, Seidlitz powders*, and the like. Their action being medicinal and corrective, rather than alimentary, their consideration properly belongs to a subsequent number. When prepared from the acid juices of fruits—as lemon, raspberry, apple, &c.—they form cooling refreshing antiscorbutic drinks, and are well adapted for hot seasons, and for febrile and inflammatory cases. When compounded of some alkali and acid, like the common effervescing draughts, they are also slightly aperient.

6. Beverages which are the products of fermentation are usually classed as *spirits*—brandy, gin, whisky, and rum; *wines*—port, sherry, claret, champagne, &c.; *liqueurs*—embracing all the sweet or home-made wines; and *malt liquors*—ale, porter, and beer.

Referring the reader to APPLIED CHEMISTRY, p. 363, for the theory and principles of fermentation, we shall here merely allude to the alimentary or dietetic effects of these well-known, and, in many cases, too largely-consumed beverages. *Alcohol*, or the leading principle in spirits, consists of carbon, hydrogen, and oxygen; it contains no nitrogen, sulphur, phosphorus, or other ingredient capable of administering to growth or nutrition. Its function is that of a heat-former; it is merely an element of respiration serving to support the temperature of the body. But in subserving this purpose, it stimulates, excites, and, if taken in any quantity, intoxicates; and the question for those in search of animal heat simply resolves itself into this—Can we not gain our end by means more simple, natural, and less dangerous? It has been well remarked, that 'though alcohol evolves heat in burning, it is an obnoxious fuel. Its volatility, and the facility with which it permeates membranes and tissues, enable it to be rapidly absorbed, and when it gets into the blood, it exerts a most injurious operation, before it is burnt in the lungs, on the brain and the liver. Though, by its combustion, heat is evolved, yet, under ordinary circumstances, there are other better, safer, and less injurious combustibles to be burned in the vital lamp.' It is only, indeed, as a restorative and corrective that its use is at all admissible; and there can be no doubt that, in cases of extreme exertion and privation of food, the cautious and moderate dietetic use of spirits has on many occasions proved invaluable. *Brandy*, derived from the distillation of wine, is perhaps the least objectionable form in which alcohol is administered. Its constituents are alcohol, water, volatile oil, a minute quantity of acetic acid, œnanthic ether, and colouring matter. It is distinguished from other ardent spirits by its cordial and stomachic properties. *Rum*, distilled from molasses and sugar skimmings, is very similar to brandy in its effects, but more heating, and more disposed to cause sweatings. *Gin*, obtained from corn spirit, and flavoured with juniper, sweet flag, &c. is, owing to the oil of juniper it contains, more powerfully diuretic than either brandy or rum. *Whisky*, also a corn spirit, agrees in most of its properties with gin, but is somewhat lighter, and more stomachic.

Wine is the general term applied to liquors prepared by the vinous fermentation of the juice of the grape. 'The peculiar qualities of the different kinds of wine depend on several circumstances; such as the variety and place of growth of the vine from which the wine is prepared; the time of year when the vintage is collected; the preparation of the grapes previously to their being trodden and pressed, and the various manipulations and processes adopted in their fermentation.' Though thus varying, and known by a thousand names, the general constituents of all wines are—water, alcohol, volatile oil, sugar, gum, tannin, tartrate, and bitartrate of potash, acetic acid, extractive and colouring matters, and carbonic acid in the effervescing varieties. The amount of alcohol in wines is exceedingly varied; in claret, for example, it seldom exceeds 7 or 8 per cent. by weight; while in ports and sherries it ranges from 12 to 18 per cent. As to the dietetic properties of wine, Dr Paris asserts 'that there exists no evidence to prove that the *temperate* use of good wine, when taken at *seasonable* hours, has ever proved injurious to *healthy* adults.' Dr Pereira is by no means disposed to question this assertion, qualified as it is; but maintains, on the other hand, that 'for healthy individuals wine is an unnecessary article of diet. It may prove,' he continues, 'a valuable restorative when the powers of the body and mind have been enfeebled by fatigue; but, on the other hand, it cannot be denied that the most perfect health is compatible with total abstinence from wine; and that the habitual employment of it, especially by the indolent and sedentary, is calculated in many instances to prove injurious. Disorders of the digestive organs, and of the brain, gout, gravel, and dropsy, are the maladies most likely to be induced or aggravated by the use of wine. Intoxication, in its varied and lamentable forms, is the effect of the excessive use of it.'

Malt liquor is the generic term for all fermented infusions of malt flavoured with the bitter principle of hops. Normally, they ought to contain less or more of alcohol, starch, sugar, dextrine or starch gum, extractive and bitter matters, fatty, aromatic, and glutinous matters, lactic acid, carbonic acid, salts, and water. They are, however, often largely adulterated; molasses and other wash being used for malt, quassia substituted for hops, flavours imparted by capsicum, ginger, and coriander; and intoxicating qualities conferred by cocculus Indicus, nux vomica, and opium. Keeping out of view these adulterations, the genuine liquors are fitted by their constitution to quench thirst and act as diluents, to yield heat and nutrition, and to operate as tonics and stimulants. The only drawback to their use in large quantities is the intoxicating effect of their alcohol—common beer containing about 1 per cent. by measure of this spirit, porter from 4 to 6, and strong ale from 6 to 8.

PREPARATION OF FOOD—COOKERY.

COOKERY, or the preparation of food, is an art upon which so much of our daily comfort and health depends, that it is of the highest importance that it be well performed. Every housewife may not be able to procure the finest kinds of food, but every one has it in her power to make the most of that which she does procure. By a certain degree of skill and attention, very humble fare may be dressed in such a manner that it will almost rival the most expensive dishes, both in savouriness and nutritiousness. A good housewife suffers nothing to be lost or spoiled. Mere scraps, which a careless individual would perhaps throw away, are put to a proper use; and, by means of certain auxiliary *seasoning*, brought to table in a new and attractive guise. Even if little or nothing be absolutely saved by these economical arrangements, the dressing of food in a tasteful manner is a point of some importance. When a dish has a slovenly appearance, is smoked, underdone, or prepared with rancid or unclean seasoning, both the eye and the appetite are offended, which is a serious evil in itself, independently of the injury which may possibly be done to the stomach of the eater. In every respect, therefore, it is consistent with good judgment to prepare food for the table in the most tasteful and agreeable manner.

One of the chief points to be attended to in cookery is *cleanliness*—scrupulous cleanliness in every department of the business of the kitchen. The hands of the cook, in particular, should be always clean; that is, washed every time after doing any kind of work which has soiled them, or before proceeding to handle meat for dressing. She should also be careful in having her hair always neatly trimmed up, so that no loose hairs may drop into the dishes. The next point of regulation is to keep all the saucepans and other utensils perfectly clean in their inner parts, and also in the insides of the lids; carefully washing with hot water, and scouring and rinsing when necessary. If the cooking utensils are not kept thoroughly clean, they will be very apt to taint the food prepared in them, and will certainly detract from the agreeable taste of the dishes. It is the duty of every housewife, either in her own person or by her deputy, the housekeeper, to see that these and all other rules affecting the cleanliness of the kitchen are attended to by servants, for she is understood to be responsible both for the wholesomeness and the tidy appearance of the dishes presented at table.

Another essential point in cookery is *attention*. Many persons think they have done all that is necessary, when they have fairly commenced or set agoing any particular process in cooking. They seem to imagine that they may safely leave a joint to be roasted, or leave a pot of soup or broth to be boiled, and that they have only to go back to the fire at a certain time, and they will find the things ready for dishing. Now this kind of inattention is certain to spoil the best meat ever put to a fire. Some processes require less attention than others, but none can be properly performed if left long to itself. A good cook is frequent in her visits to the fire, and seizes the right moment in giving her assistance.

Perfection in the culinary art is only attainable by lengthened experience, and a careful study of the qualities of meats, and the application of sauces and seasonings. It is chiefly in knowing how to make and apply these adjuncts that a cook shows her skill.

KITCHEN ARRANGEMENTS.

A young and thriftily-disposed housewife will, if possible, proceed to market herself, in order to lay in butcher-meat and other fresh provisions for her family. By this plan she will possess two advantages—that of selecting the best pieces, and of getting them at the lowest price. The frequency of her visits to the market will of course depend on the number of her family, and their taste as to the staleness or freshness of the meat to be purchased. If circumstances permit, it is advisable to purchase a whole week's provisions at a time, at least the chief things which will be required for the ensuing eight days. We would recommend a housewife to act upon a system in varying the kinds of meat which she buys, not only as they may be suitable to the seasons, but as calculated (see No. 45) to promote the health of a family. Let the housewife, therefore, exercise a little ingenuity and judgment in her marketing expeditions, contriving to present at table a succession of different descriptions of animal and vegetable food: as, for example, sometimes meat roasted, and sometimes boiled or stewed; sometimes fresh meat, at other times salted; sometimes butcher-meat, and other times fish; and so on, according to taste and other circumstances. It does not necessarily follow that, in thus varying the bill of fare, greater expense is incurred than if the same kind of articles were continually purchased.

The best meat is that which is moderately fat. If it be lean, or almost free of fat, it is an indication that the animal has been ill fed, and that the meat will prove tough and tasteless. Avoid lean beef—it forms wretched fare, and will be dear at any price. The fat of good beef is slightly yellowish; the fat of good mutton is pure white. The flesh of both beef and mutton should be of a clear red colour. The mutton of well-fed black-faced or of Southdown sheep is the most tender or sweet, and may be known by the shortness of the shank. Mutton is in perfection at between four and five years (wether-mutton), but is seldom to be had older than three years. Cow and bull beef are considerably inferior to ox beef; and even this depends much upon the kind of animal and mode of feeding—grass-fed being sweeter than stall-fed, and that fed on farm produce being finer than that reared upon oil-cake, brewers' wash, and the like.

In choosing lamb, select that which has a delicate appearance, and is perfectly fresh. Young veal has a dark and flabby look, and is tasteless when dressed. Veal is best when the animal is between four and six months old. The flesh is then white and delicate, and is firm in the fibre. Pork should be white and delicate like veal, and thin in the skin. Lamb, veal, pork, and all other young or white meat should be fresh, and not bought long before being used.

Fowls, ducks, and other feathered animals should be purchased young, and should all be firm and fleshy to the touch. If the thin bone which projects over the belly feel hard on being handled, the animal is old; if it feel softish like gristle, the animal is young. This is the safest rule for choosing in the poultry market. The age of game is of little consequence, as it is hung for a considerable length of time before dressing.

All kinds of fish should be purchased as fresh as possible. Freshness in cod, haddock, and generally all fish, is indicated by stiffness in all parts of the body, and a clear glittering appearance in the scales. Freshness is likewise known by the smell. If there be the least staleness, the fish has an offensive odour. As tricks are sometimes performed with the eyes and gills, freshness of appearance in these is not to be trusted.

It is very difficult to ascertain when eggs are perfectly fresh. There are different rules on the subject, but they are all liable to failure. One mode of judging is to hold the egg between the eye and the light of a candle, shadowing the eye with the hand; if the appearance is universally luminous, without any cloudiness, the egg is fresh; if cloudy, or not uniformly luminous, it is probable that the egg is unfit for use.

Butter may be easily selected by the taste and the smell; but in buying both eggs and butter, it is best to deal with a person on whom you can rely, as it is troublesome to be continually seeking out and examining these articles to determine their freshness.

Good ham and bacon have a fresh savoury smell; the fat is white, and free from any yellowness. If it be yellow, reject it, as it will soon become rank.

Flour for culinary purposes should be new and fresh. Old flour is liable to spoil and become full of animal life, in which condition it is unfit for pastry and other dishes. The best kind of salt for the kitchen is that which is purchased in lumps and cut down. All condiments and spices should be sought for fresh, full-flavoured, and as little exposed to the air as possible.

Cutting up Meat.—Butcher-meat is not cut up in the same manner in all parts of the country. There are two chief plans of cutting followed—the English and the Scotch plan, and consequently the pieces of meat in a carcass differ in number, size, and name, in England and Scotland. This circumstance creates a certain degree of difficulty in giving directions for cooking; and to obviate this as much as possible, we subjoin the following drawings and explanations:—

Figure 1 represents a bullock marked for cutting up on the English plan. No. 1 is the loin or sirloin, 2 the

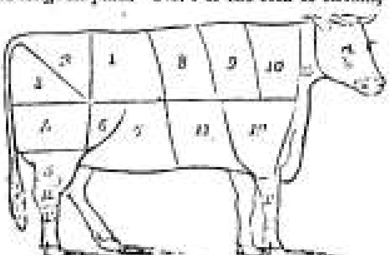


Fig. 1.

rump, 3 the itch or edge bone, 4 buttock, 5 hock, 6 thick flank, 7 thin flank, 8 fore rib, 9 middle rib, 10 chuck rib, 11 brisket, 12 leg of mutton piece, 13 clod, sticking, and neck pieces, 14 shin, and 15 the leg. From 1 to 7 is the hind quarter, and from 8 to 15 is the fore-quarter. Nos. 1 and 2 on both sides united constitute what is called a *baron of beef.*—Figure 2 represents a bullock marked for cutting up on the Scotch plan.

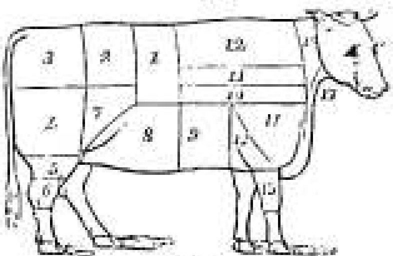


Fig. 2.

No. 1 is the sirloin or back sye, 2 the hook bone, 3 buttock, 4 large round (3 and 4 together make the rump), 5 small round, 6 hough, 7 thick flank, 8 thin flank, 9 nineholes, 10 and 11 large and small runner, 12 spare rib or fore sye, 13 brisket, 14 shoulder lyer, 15 nap or shin, 16 neck, and 17 the sticking piece. From 1 to 8 is the hind quarter, and from 9 to 17 the fore.

According to the English plan, the meat is cut up more advantageously for roasting and broiling than by the Scotch plan. For instance, the rump and itch bone, Nos. 2 and 3, figure 1, are cut in such a manner that the meat affords a much better steak than when cut as in figure 2. The Scotch plan, on the other hand, gives more pieces for boiling; and thus each way seems suitable to the taste of the people who have respectively adopted them.

Figure 3 represents the English plan of cutting up mutton. No. 1, extending across and marked as a circle, is the shoulder, 2 is the scrag end of the neck, 3 breast, 4 loin, 5 leg, 6 best end of neck. The slanting line betwixt 4 and 5 is the division of the fore and hind quarter. The dotted line across the shoulder shows where the neck is separated from the breast after the shoulder is off. Two loins united form a *saddle*

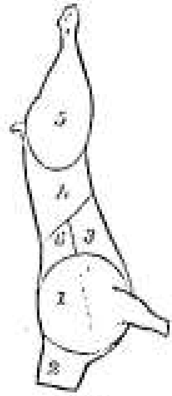


Fig. 3.

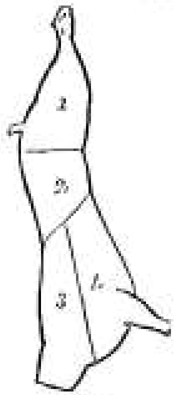


Fig. 4.

of mutton. Fig. 4 represents a side of mutton marked for cutting on the Scotch plan. No. 1 is the gigot, 2 the loin, and both together form the hind quarter; 3 is the back ribs, and 4 the breast, both forming the fore quarter. Lamb is cut up in the same manner, when not sold in quarters.

Veal is usually cut up both in England and Scotland in a manner somewhat uniting the plans for cutting beef and mutton. A fillet, which is believed to be the most elegant joint, is cut from the upper part of the hind-leg, being partly of the buttock and flank. The piece at the extremity of the loin is called the *chump.*

The larder is a place where fresh meat is kept till it is in a fit place for being cooked, and where cold meat or any other kind of food may be set aside. The larder should be cool and dry, with the outer air playing freely through it. It should also be impervious to vermin or insects, particularly flies. Two or three shelves (of slate or stone where the larder is a built apartment), and a few strong iron hooks for hanging the meat, are the only furniture.

Beef and mutton are always improved by hanging some time after being killed before they are cooked. The length of time which they may be kept depends on the state of the weather. The best weather for the purpose is when the atmosphere is cool, clear, and dry; in such circumstances beef and mutton may hang from four to eight days; mutton, if well managed, may hang for a fortnight. A moist thick atmosphere is the worst for keeping meat; and when it occurs, great care must be taken with the contents of the larder. The meat should be wiped daily with a cloth, to free it as much as possible from the moisture that gathers upon all meat when kept for many days. In all cases fresh meat should hang from a hook, and not be laid on a plate.

In most instances, fresh meat is cooked too soon after being killed, a circumstance perhaps arising from the general deficiency of proper larders, and the dread of the meat being spoiled. The consequence is, that instead of being tender and palatable, the meat is tough and disagreeable, and not so nutritious or so easily digested as it ought to be. But while beef and mutton may with great propriety be kept some days to become tender, veal, lamb, and pork (being young or white meat) will not endure keeping more than a day, or two days at the utmost. Game may be kept for two or three weeks, that which is feathered being kept with the feathers on, and hares being embowelled or paunched. A fowl will keep a week, and a turkey a fortnight. A goose will not keep above eight or ten days. Great care should be taken in picking feathered animals which have been kept, for their skin will in such a case be easily torn.

When newly-cooked meat is brought from table, and has to be set aside for after use, put it on a clean dry dish; if any liquor or gravy be left about it, the meat is apt to become sour. The drier and more cool that cold meat is kept the better. Cold meat is always best when it has not been cut while warm, as in that case the juices have not escaped.

Green vegetables of all kinds should be used as soon after gathering as possible. They begin to ferment, and to lose both their flavour and their wholesomeness, very shortly after being taken from the ground. When they have necessarily to be kept for a day or two, place them in a perfectly dry and cool situation, but not exposed to currents of wind. Keep also each kind of vegetable separate from another, to prevent contamination of flavour. They should never be washed or placed in water till immediately before being used.

The Kitchen Range or Grate is the most important part of culinary apparatus; and in general too little care is bestowed by young persons, when setting up housekeeping, in making a proper choice of this article. A common error consists in buying ranges which are too large, and which consume a great deal more fuel than is necessary, either for cooking or giving forth heat. One of the chief points in housekeeping, is to cook victuals with the smallest possible quantity of coal. To effect this desirable object, let the range be of a small size, consisting of a fireplace in the centre, large enough for only one vessel, with an oven upon the one side and a boiler on the other; the boiler also going round the back of the fireplace; the top of the whole to be flat. The fire in the grate will thus heat the water in the boiler without any trouble, and will in a great measure render the use of a kitchen kettle unnecessary. The fire will also assist greatly in heating the oven, which at least will at all times heat dinner plates; and if required for baking, a very small quantity of live coal put into the furnace beneath will be sufficient. A range of this description, which will cost about £4, 10s., will at once roast meat in front, boil water, bake a dish in the oven, though not so well as by a separate or large oven, and keep boiling or simmering at least three vessels on the fire and top of the boiler and oven. Care should be taken to have the range set in such a manner that the smoke from the oven may pass upwards behind to the chimney. By being altogether of iron, this kind of range requires very little building, and is not apt to get out of order.

The main advantage of such a range is the constant and large supply of hot water which it affords. Every one experienced in family arrangements knows that a *house should never be without hot water*, as it may be wanted at a single moment's notice for various purposes besides those of cooking; among others, for hot fomentations, bathing of infants, and so forth. A life may be saved by the ready supply of this article alone.

Boiling and Stewing Vessels are now to be had of every size and description; and the choice of these will depend on the taste and judgment of the purchaser. The best kind (called goblets in Scotland, and saucepans in England) are those made of iron, well tinned inside, and these may be had of all sizes. It is convenient to have one or two of the very smallest dimensions, made of block tin; and also to have several to be kept for delicate stews or preparations, for which purposes those lined with delft are preferable. It is likewise advantageous to have a few shallow saucepans to be used for stews, or where little liquor is required. Also one large fish kettle, with a flat drainer to place below the fish in boiling, and for lifting to the dish when done. All the vessels should have tightly-fitting tin or iron covers; and one or two should be fitted with perforated apparatus for steaming.

Roasting and other Utensils.—Roasting is always best performed with a twirling hook and bottle-jack. A spit spoils a small piece of meat, and is an instrument which, with the jack that moves it, should never gain an entrance into the kitchen of a family in the lower or middle ranks of life. The bottle-jack, which is in every respect preferable, should be attached to the top of a tin screen of the usual semicircular form. This screen reflects the heat upon the meat, and aids the roasting. Sometimes the screen has the effect of drawing out the smoke from the chimney; when this is the case, have the upper part of the screen taken away, and suspend the jack from a projecting arm or rack on the chimney-piece. This arm, which may be folded back when not used, is made of brass, and may be had for about eighteenpence from any London or other ironmonger. A tin box with an open side, called a Despatch, and resembling a bachelor's oven, is a most useful utensil for baking small puddings or potatoes. Two other indispensable utensils are a gridiron and frying-pan.

ROASTING.

Meat is roasted by being exposed to the direct influence of fire. This is done by placing the meat before a fire, and keeping it constantly in motion, to prevent scorching on any particular part. According to Liebig, beef or mutton cannot be said to be sufficiently roasted until it has acquired throughout the whole mass a temperature of from 150 to 158 degrees; but poultry may be well-cooked when the inner parts have attained a temperature of from 130 to 140 degrees. This depends on the greater amount of blood which beef and mutton contain—the colouring matter of blood not being coagulable under 150 degrees or thereby. Roasting is generally considered to be the least thrifty mode of dressing meat; but much of the loss may be avoided by care and cleanliness in saving the dripping for other processes of cookery.

Dripping.—Roast beef yields a dripping, which is a valuable article in the economy of the kitchen. It should be removed from the pan beneath the meat before it becomes overheated, or scorched by the fire, leaving sufficient for basting. Dripping is prepared for future use in the following manner:—As taken hot from the dripping-pan, pour it into boiling water, when all particles of cinder or other improper matter will fall to the bottom, and leave the pure fat on the surface. Collect these cakes of fat, and by heating them in a jar, placed in a saucepan of boiling water, the whole will become a solid mass, and may be thus put aside for use. This process not only purifies dripping, but gives it a clear white colour. A little salt must be added, to assist in preserving it. The dripping from mutton, being tallowy, is little used in cookery, as is also that from most other kinds of meat and poultry. The dripping from lamb may be preserved for use in frying fish, or in making pie-crust.

To roast Beef.—The best piece of beef for roasting is the sirloin. If the suet be not required, it may be ordered to be cut off before purchasing the joint; a small piece of suet is all that is requisite for the purpose of basting. Do not wash the meat, unless when it is musty, as already directed. Wipe it quite dry, and hang it on the hook of the jack, in the way most advantageous for being operated upon uniformly by the fire. Handle it as little as possible. At first, place it at such a distance from the fire that it may be warmed thoroughly before being scorched on the outside. The fire must be quite clear and brisk. It is customary to allow a quarter of an hour for every pound of the meat. While roasting, baste it very frequently with its own dripping. In dishing, pour a little boiling water and salt over it for a gravy. A well-roasted joint ought to have a nice rich brown tinge, and this is to be obtained only by careful basting, attention to the fire, and removing at the proper time, when experience tells that the joint is 'done.' Garnish with scraped horse-radish.

To roast Mutton.—The best parts of mutton for roasting are the leg, the shoulder, and the loin. The pieces may be kept longer than would be desirable for mutton for boiling. It should have a clear and brisk fire. A leg will take two hours to roast; but this, as well as the time for roasting the other parts, must be regulated by the fire and the weight of the meat, and can be learned only by attention. The joint of mutton should be basted the same as beef, with its own dripping. A gravy for roast mutton, as in the case of beef, may be made by pouring a little hot water and salt over it; if wanted of a richer quality, a gravy sauce may be made from beef, as directed under the head SAUCES. Most persons prefer mutton 'well done.' In roasting the loin, take away the fat surrounding the kidney, otherwise the dish, on being brought to table, will, when cut up, be floured with oil. The back-ribs and loin of mutton ought to be well jointed or cut before being put to the fire.

To roast Venison.—Venison is roasted in the same manner as mutton, but requires longer time at the fire. It is such a dry meat, and the fat is so easily melted, that it should be covered with buttered paper, and well basted. Serve with a good gravy and currant jelly.

To roast Veal.—The best parts of veal for roasting are the fillet, the breast, the loin, and the shoulder. The fillet and the breast should be stuffed, particularly the fillet; the stuffing to be composed of crumbs of bread, chopped suet and parsley, a little lemon peel, and pepper and salt, wet with an egg and a little milk. The piece should have a slow fire at first, and will require longer time to dress than beef or mutton. Let it be well basted with butter when there is not sufficient dripping from the joint. The gravy for roast veal is either the usual hot water and salt, or thin melted butter, poured over the meat.

To roast Fillet of Veal.—The fillet of veal, which is the thick fleshy part of the hind-leg, requires care in the preparation for roasting. The knuckle or bone must be cut out neatly, without disfiguring the joint; then stuff the flap, as above; roll it up firmly, and bind it with tape or string. Allow the stuffing in this, as in all other cases, room to expand in dressing. Cover the ends with buttered paper, and baste the piece frequently with butter. Take off the paper a short time before the meat is done. Gravy as above. This dish may be garnished with sliced lemon.

To roast Lamb.—Lamb also requires to be well roasted. It is usually dressed in quarters; all parts, particularly the spinal bone, should be well jointed or cut by the butcher or cook; and the ribs of the fore quarter broken across the centre, in order to accommodate the carver. In roasting, baste, as already described, with its own dripping. The gravy for lamb may be the same as for beef or mutton—namely, hot water and salt poured over it: it is also customary to serve it up with mint sauce in a small tureen.

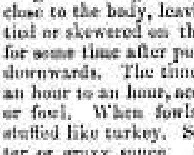
To roast Pork.—Pork requires a longer time in roasting than any of the preceding meats. When stuffing is to be used, it must be composed of chopped sage and onion, pepper and salt. The pieces should be neatly and well scored in regular stripes on the outer skin, to enable the carver to cut slices easily. Before putting to the fire, rub the skin with salad oil, to prevent its blistering, and baste very frequently. The basting may be done by rubbing it with a piece of butter in a muslin bag, where there is not enough of dripping. The gravy for pork may be the same as for other joints, hot water and salt poured over it on the dish. It is considered an improvement to have apple sauce served in a small tureen, as it assists in overcoming the richness or lusciousness of the meat, and imparts an agreeable acidulous flavour.

To roast Bullock's Heart.—Wash the heart well, freeing it completely from blood. Then fill all the openings at the top or broad end with a stuffing composed of crumbs of bread, chopped suet, parsley, pepper and salt, moistened with an egg and a little milk. Suspend with the pointed end downwards. An hour and a-half or two hours, according to the degree of heat, will cook the dish. It should, however, be well done. Send to table with beef gravy.

To roast Pigeons.—Pick and draw them well, and truss, keeping on the feet. Make a stuffing of the liver chopped, crumbs of bread, minced parsley, pepper, salt, and a little butter; put this inside. Make a slit in one of the legs, and slip the other leg through it. Skewer and roast them for half an hour, basting them well with butter. Serve with brown gravy in a small tureen. Some serve roast pigeons and game with toast bread beneath them, and bread sauce.

To roast Fowls.—Pick, draw, and singe them. A fowl should be so cleanly or well drawn as to require no washing. Take care not to break the gall-bag in drawing; if the gall be spilled, it will communicate a bitter taste to every part it touches. Press down the breast-bone. Break the legs by the middle of the first joint, drawing out the sinews, and cutting off the parts at the break. It being proper that roast fowls should have a neat appearance at table, it is customary to *truss* them—that is, to fix their legs and wings in a particular position. This is done by fixing down the knees of the animal close to the tail by a skewer or piece of string, leaving the stumps of the legs projecting. The pinion ends of the wings are then turned round on the back, the liver being placed as an ornament in one wing and the gizzard in the other. Cut the head off close to the body, leaving a sufficiency of the skin to be tied or skewered on the back. Baste well with butter for some time after putting to the fire. Suspend neck downwards. The time of roasting will vary from half an hour to an hour, according to the size of the chicken or fowl. When fowls are large, they are frequently stuffed like turkey. Serve roast fowls with melted butter or gravy sauce. Before sending to table, remove all skewers and strings which may have been used in trussing. This, which should be done in all cases of serving dishes to table, is too frequently neglected, and shows slovenliness in cookery. Fowls and all other feathered animals are served with the breast upwards.

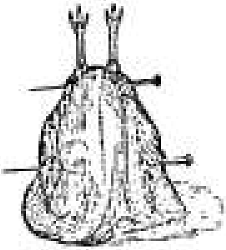
To roast Turkey.—Pick, draw, and singe the turkey well. Press down the breast-bone, and follow all the directions given for trussing fowls. The breast should be stuffed with crumbs of bread, minced beef suet or marrow, minced parsley, a little nutmeg, pepper and salt; wet it with milk and egg; a little sausage meat may also be added. On finishing, sew up the orifice or neck. Before putting to the fire, cover the breast with a sheet of writing-paper well buttered, to preserve it from scorching, and which may be removed a short time before taking from the fire, to allow the breast to be browned. Baste well with butter. A turkey will take from an hour and a-half to two hours. Serve with gravy sauce and bread sauce.



To roast Partridges and other Game.—Pick, draw, singe, and clean these birds the same as fowls. Leave the head on. Make a slit in the neck, and draw out the craw. Twist the neck round the wing, and bring the head round to the side of the breast. The legs and wings may be trussed in much the same manner as fowls. The feet are left on, and crossed over one into the other, as seen in the annexed figure. Baste well with butter before a clear fire. When about half done, dust a little flour over them to be browned. A partridge will take from twenty minutes to half an hour, and a pheasant three-quarters of an hour. Serve on toasted bread, with gravy and bread sauce; the toasted bread may be dipped in the gravy. Grouse and black-cock should be dressed and served in the same manner; the head being trussed under the wing. Snipes and woodcocks are not drawn.

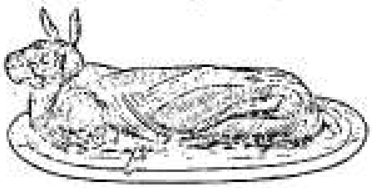
To roast Goose.—Pick, draw, and singe the goose well. Cut off its head and neck. Take off the legs and wings at the first joint. The portions of the legs and wings that are left are skewered to the sides. Stuff with chopped sage and onion, and crumbs of bread, with pepper and salt. The skin of the neck must be tied securely, to prevent the gravy from running out. Paper the breast for a short time. A goose does not require so much basting as fowl or turkey, for it is naturally greasy. It will require from two hours to two hours and a-half in roasting. It ought to be thoroughly done. Serve with gravy sauce and apple sauce. The liver, gizzard, head, neck, feet, and the pinions of the goose, form what is termed the *giblets*, and compose a good stew or pie.

To roast Ducks.—Pick, draw, and singe them well. Take off the head. Dip the feet in boiling water to take off the outer yellow skin. Truss them neatly, turning the feet flat upon the back. Stuff as in the case of goose, and serve with the same sauces. A duck requires about an hour in roasting.



To roast Pheasants.—Pick, singe, and draw them, the same as fowls. Truss them by twisting the head round one of the wings, and turning both wings on the back. The legs are fixed on each side, much in the same manner as in a roast fowl, the feet being left on, as here represented. Serve with beef gravy and bread sauce.

To roast Hare.—A hare will keep with the skin on it, and paunched, for about three weeks in cold weather. It is then fit for roasting. First cut off the feet, and commence drawing off the skin at the hind-legs, proceeding along the body to the head. Be careful not to tear the ears in skinning them. Soak and wash well in several waters, and then wipe quite dry. Stuff with crumbs of bread, chopped parsley, a bit of beef or veal suet chopped finely, a little grated



lemon-peel and nutmeg, a piece of liver boiled and finely chopped or grated, and pepper and salt; the whole moistened with an egg, a little milk, and a spoonful of ketchup. The skin of the belly afterwards to be sewed. Commence trussing, by placing the hind and fore-legs flat against the sides. To make the hind-legs lie flat, the under sinews must be cut. Fix the head between the two shoulders, on the back, by running a skewer through it into the body. In roasting, suspend head downwards. It may be basted first with milk, afterwards with butter, flouring it lightly. It will require from an hour and a-half to two hours. The hare is dished back upwards, as represented above, and served with a dish of rich beef gravy, and a dish of currant jelly.

BAKING.

Meat is prepared for baking in the same manner as for roasting. It should be placed in a deep dish for receiving the fat which flows from it; not laid, however, on the sole of the dish, but raised on a stand, to prevent the grease soaking into it. Small iron stands are made and sold for this purpose. Few dishes are so good when baked as when roasted, the meat being so liable to be shrivelled for lack of basting; and being liable, moreover, if done in a baker's oven, to partake of the flavour of the multifarious articles which are there prepared. Perhaps the only dishes which are better baked than roasted are bullock's heart and leg of pork, because in roasting they are liable to be scorched on the outside before they are thoroughly cooked in the inner parts. In baking a heart, place it in a stand in a dish with the point downwards; a piece of writing-paper, buttered, may be placed over it to keep the stuffing from drying. The sauce used is beef gravy.

BROILING.

Broiling is the rapid cooking of any kind of animal food by the influence of fire. The apparatus required in broiling is very simple, and consists only of a gridiron; which should have small bars, and be kept thoroughly clean, not only on the tops, but on the sides of the bars. An improved form of gridiron consists of channeled bars leading to a trough or receptacle for the exuded juices. Before placing the meat on the iron, let it be heated for a few minutes; and if the bars, when warm, be rubbed with a piece of brown paper, the meat will be prevented from sticking to them. The operation of broiling requires a clear strong fire, with no smoke. In almost all cases, the meat ought to be frequently turned, which may be best done by a pair of small tongs; a fork should on no account be used in turning, for it breaks the skin of the meat, and allows the gravy to run out. Broiling possesses the peculiarity of being applicable only to meat which is to be eaten immediately on being dressed. This is an advantage when expeditious cooking is required, but a disadvantage when there is any uncertainty as to the time at which the meat is to be eaten. It is by no means an economical method, as a great proportion of the nutritious juices is discharged from the flesh beyond the means of recovery.

To broil Beef-Steak.—A beef-steak is the most suitable of all kinds of meat for broiling, and is a dish universally relished. There are several parts of beef used for steaks, but in every case it should not be too newly killed. The best steak is that cut from the rump (called in Scotland the *heuk-bone*), because it is the most juicy and well flavoured. Steaks should be cut in slices of from three-quarters of an inch to an inch in thickness, and into pieces of a convenient size for turning. Some persons dust the steaks with pepper before putting them to the fire, by which means the flavour of the pepper is infused through the mass. When placed on the gridiron, turn them very frequently; it is said indeed that the steaks should never be at rest, but this is carrying matters to an extremity. It is impossible to state any exact length of time to be employed in cooking a steak, for much depends on the tenderness and thickness of the meat, and the strength of the fire. The taste of the individual who is to eat the steak must also regulate the length of time; because, while some prefer steaks in a half-raw state, others wish them to be well done; that is, to have the colouring matter of the blood fully coagulated. When cooked to the extent which is required, place the steak on a hot dish, and after rubbing the steak with a little good fresh butter, sprinkle it with a little fine salt. Beef-steaks should be carried to table immediately on being dressed, and eaten forthwith, in order to be in perfection. Every moment they stand they lose a portion of their flavour and juice. When sauce is required, either mushroom or oyster sauce may be used.

To broil Mutton Chops.—Mutton chops should be cut from the middle of the hind loin, and about the same thickness as steaks. They are broiled in the same manner as steaks, and require equal attention. No butter is to be used on dishing, as the chop is sufficiently fat of itself. Sprinkle a little salt on it, and carry to the table immediately. Mushroom sauce may be used as an adjunct.

To broil Fowls and Pigeons.—Clean and prepare them as for roasting; then split them down the back, laying them quite flat. Dust with pepper. They should be broiled more slowly than steaks or chops, being thicker, and requiring to be more thoroughly dressed. Rub occasionally with a little butter, to prevent the skin from cracking. In no case should the skin be taken off before broiling. On dishing, sprinkle with salt. Various sauces are used—parsley and butter, melted butter, beef gravy, or mushroom sauce.

FRYING.

Frying is as expeditious a mode of cooking as broiling, requires less activity and care, and is more thrifty. The thriftiness of frying is a point of material consequence, and may be thus explained. It affords a ready means of dressing in a savoury manner many odd pieces of uncooked or cold meat, thereby saving that which might otherwise have been thrown away as useless. A skilful housewife, with the aid of a frying-pan and some unexpensive vegetables, such as onions and potatoes, along with a slight seasoning, will make a small portion of meat dine a large family. A frying-pan should be of malleable, not of cast iron. It should also be thick in the bottom, and of an oval form. It should always be kept clean, by being washed with boiling water, but not scoured. In all cases of using, a small piece of dripping, butter, or lard, must be put into it and melted, to prevent the meat from adhering. In frying all meats, excepting those which are sufficiently fat in themselves, it is necessary to use some kind of grease or fat. The best fat for this purpose is lard, which is more economical, and less likely to get burnt than butter. When lard is not employed, the best substitute for it is dripping.

To fry Beef-Steaks.—Cut the steaks as for broiling, and, on being put into the pan, shift and turn them frequently. Let them be done brown all over, and placed in a hot dish when finished. Gravy may be made by pouring a little hot water into the pan after the steaks are out, and the fat poured away, with a little pepper, salt, ketchup, and flour. The gravy so formed is to be poured into the dish with the steaks. Serve to table immediately. If onions be required along with the dish, cut them in thin slices, and fry them till they are soft. They should be fried after the steaks, and merely with part of the fat in which the beef has been fried.

To fry Mutton Chops.—They require to be cut in the same manner as for broiling, and may be dressed according to the preceding directions for steaks. None of the grease which flows from the chops is to be used along with them, and the whole must be poured away before preparing the gravy.

To fry Veal Cutlets.—Veal cutlets form a delicate dish, and should be fried with butter. The best cutlets are from the fillet, because they are free from bone; the fore or hind loin—that is, the back-ribs or loin—may be used, but the bone must be cut away, which causes a waste. Cut them half an inch in thickness. They require to be dressed slowly and thoroughly, and should be of a light-brown tinge when finished.—Another and more tasteful way of dressing cutlets, is first to dip them in a beat egg and then strew them with crumbs of bread, and parsley chopped very fine, along with pepper and salt, after which put them in the pan. They will require more lard or dripping this way than when fried plain. Gravy may be made for cutlets the same as for fried steaks, but add a little juice of a lemon, and skim the gravy before pouring it over the cutlets.

To fry Lamb Chops.—Lamb chops may be either simply fried in the same manner as mutton chops, or dressed with egg and crumbs of bread (but with no parsley), as in the case of cutlets. Gravy made in the pan, as for fried steaks.

To fry Pork Chops.—Pork chops should be cut rather thin, and be thoroughly dressed. They may be either simply fried in the same manner as chops, or fried after being dipped in egg, and sprinkled with crumbs of bread, and sage and onion finely chopped. No gravy is expected with pork chops. If any sauce be used, it must be apple sauce.

To fry Beef or Pork Sausages.—All sausages are fried alike, and require to be dressed very slowly. Before being put into the pan, they should be pricked in several places with a fine fork, to prevent their bursting by the expansion of the air within. It is common in England to bring fried sausages to table neatly laid out on a flat dish of mashed potatoes. The sausages and potatoes are helped, together. They may also be laid in links on toasted bread, and garnished with poached eggs round the dish. Fried sausages are sometimes used for garnishing roast turkey.

To fry Tripe.—The tripe must be washed well, and boiled till tender. Take the thickest parts, and dry them well with a cloth. Make a thick batter of egg, flour, and milk, seasoned with salt, and for those who wish it, a little minced onion. Dip the tripe into the batter so formed, after which fry in lard or good fresh dripping, of which there must be a sufficiency in the pan almost to cover the tripe. Let it be done to a light-brown. Garnish with fried parsley.

To fry Bacon, or Ham and Eggs.—The bacon should be cut very thinly in slices not more than a quarter of an inch in thickness. The best bacon is that which is alternately streaked with fat and lean. No butter or dripping is required in the pan in frying bacon, which does not need much dressing, and is soon prepared. When done, take the slices from the pan, and place them in a hot dish before the fire. Have the number of eggs required previously broken, each in a separate cup, and place them gently in the pan, so as to preserve them in a round flat shape. Let them remain in the pan till the white is set, and take them out carefully with a slice, and place them on the bacon. The tasteful appearance of this dish is spoiled if the eggs be either broken or ragged, which is very apt to be the case if they are not previously put into cups.

To fry Collops.—The difference betwixt this dish and fried steaks is, that the collops or pieces of meat are partially stewed, as well as fried. It is consequently a more economical process, as retaining a larger proportion of the nutritious juices of the flesh. In preparing, cut the meat thinner than for broiling, and put the slices in a pan along with a large piece of butter and sliced onions. Cover it close, and when the meat is sufficiently dressed, add a little hot water and ketchup to the liquor already in the pan.

BOILING.

Boiling is the preparation of meat in water, and it is necessary that the vessel employed be large enough to allow the meat perfect freedom; if it be cramped, and have only a little water, it will be stewed, not boiled. In all cases of boiling, there must be a sufficiency of water to cover the meat. In boiling meat there is less waste than in roasting; and in some cases soup may be made of the liquor. It is the general direction for boiling, 'that all meat, poultry excepted, should be put into *cold* water, and not boiled too fast; and as the water decreases from evaporation, it ought to be replenished with *hot* or *boiling* water, so as to keep the meat always covered.' Now, according to Liebig, our greatest and most scientific authority, cold water can dissolve the most important ingredients of flesh, so that if meat is put into cold water, and slowly boiled up, the water will have carried off all the albumen and several other substances, and the remaining beef will be a kind of husk, insufficient to nourish the system, unless the water it has been boiled in is taken at the same time in the form of soup. To boil beef without losing the nutritious and savoury elements, he accordingly gives the following directions:—The water is, in the first place, to be put into a brisk boiling state; into this boiling water the meat should be plunged, and allowed to lie for a few minutes; it is then taken out, and cold water is to be poured into the boiler till the heat be reduced far below boiling, or to about 160 degrees; the meat is then put in again, and kept in the water at this temperature for two or three hours. Everything is in this way effected that can render the flesh pleasant and wholesome as food. The contact with the boiling water at the outset coagulates the albumen of the flesh all round the surface of the meat, and closes up its pores with a solid wall, that none of the internal juices can pass through, and the meat is preserved in all its integrity while undergoing the action of the heat.*

* Mr Leach of Vernon House (a retreat for mental invalids), Briton Ferry, near Neath, South Wales, has adopted Liebig's directions for preparing meat, soups, &c. for the inmates (150 in number) of his establishment, and finds that he thereby effects a saving of fifty per cent., while the quality of the food is greatly improved.

When meat of any kind is done, and has to be lifted from the pot, take care not to put a fork into any part where there are juices; if this be not attended to, a portion of the juices will escape, and the marks of the fork will produce an unsightly appearance in the meat. All parts of mutton and lamb may be roasted, but it is only the leg, neck, and head that are boiled.

To boil a salted Round of Beef.—If large, cut out the bone, roll it up firmly, and bind it with a tape; then put it into the pot, and keep the lid close. Boil it slowly and equally, allowing, as above-mentioned, a quarter of an hour for each pound of the beef. The appropriate garnishing for this and other pieces of boiled salt beef, is carrot and small greens; some add turnips. Put a little of the liquor in which it has been boiled in the dish.

To boil a Leg of Mutton.—A leg of mutton should be kept four or five days before boiling. Before putting it into the pot, bend round the shank, cutting the tendon at the joint if necessary, so as to shorten the leg. Two hours of slow equal boiling will be sufficient for a good-sized leg of mutton. Some persons, to make the leg look white and tasteful, wrap it tightly in a cloth in boiling; but this spoils the liquor for broth. It is not safe to boil vegetables with a leg of mutton, as they are apt to flavour the meat. Dish the leg with a little of the liquor, placing the lower side uppermost, conveniently for carving. A good leg of mutton will soon yield sufficient gravy. Sauce, finely-chopped capers in melted butter. Turnips mashed or whole form the appropriate vegetable to be eaten with this dish.

To boil a Leg of Lamb.—A leg of lamb, when well boiled, is a delicate and excellent dish. It requires about an hour and a-half. When whiteness is desirable, it is wrapt in cloth, the same as mutton. When dished, garnish with the loin cut into chops, and fried, to lay round it. The sauce used is plain melted butter, or parsley and butter.

To boil Veal.—Veal is seldom boiled, being too insipid by that mode of dressing. The only part boiled is the knuckle, which requires much boiling, in order to soften the sinews. It is eaten with boiled ham or bacon. The sauce used is parsley and butter. The liquor from veal is the best of any for making soup.

To boil a Turkey.—Boiled turkey is one of the most delicate and excellent dishes which can be brought to table, and should be dressed with as much care as possible. Clean the turkey from all feathers, and singe the hair with burning paper, being careful not to blacken the skin. Clean it well inside by drawing and wiping. Cut off the legs at the first joints, and draw out the sinews; then pull down the skin, and push the legs inside. Cut off the head close to the body, leaving the skin long, and draw out the craw. Make a stuffing of chopped suet, crumbs of bread, chopped parsley, pepper, salt, and a little nutmeg, which wet with an egg and milk. Put this stuffing into the breast, leaving room for the stuffing to swell; after which draw the skin of the breast over the opening, and sew it neatly across the back; by which means, when the turkey is brought to table with its breast uppermost, no sewing will be seen. Place the liver in one wing, and the gizzard in the other, turning the wing on the back, and fixing the wings to the sides with a skewer. The turkey being now ready for the pot, put it into a cloth and boil it for a length of time according to the size and age. A small young turkey will not require more than an hour and a-half; an old and larger one perhaps two and a-half or three hours. Let the water be warm in putting in, and of sufficient quantity to keep the turkey always covered. When done, and placed in a hot dish, pour a little sauce over the breast, and put the remainder in a sauce tureen. The sauce used is various—as parsley and butter, celery, or oyster sauce. One of the most delicate and agreeable sauces is that which is made of melted butter, boiled maccaroni, and milk.

To boil a Fowl.—A fowl is to be prepared for boiling in the same manner as a turkey, except that no stuffing is used. It may be boiled with or without a cloth. Small fowls will require from half an hour to three-quarters of an hour; large fowls will require from an hour to an hour and a-half. Sauce, parsley, and butter.

To boil Rabbits whole.—Wash them well in warm water. They may be either stuffed or not stuffed, according to taste. When stuffing is required, make it of crumbs of bread, suet, parsley, and onions—all chopped—and pepper and salt; moisten with milk and egg. Sew this neatly into the belly. Truss in the same manner as roast hare, and boil slowly for an hour. The sauce to be made of boiled onions, milk, melted butter, and flour, with pepper and salt, which pour over the rabbits when dished. This is called *rabbits smothered in onions*. When two rabbits are dished together, always lay the head of one in a contrary direction to that of the other.

To boil a Ham.—If the ham has been cured long, it may require soaking in cold water to soften it, from twelve to twenty-four hours before dressing. Put it in a large boiling vessel, with plenty of cold water, and let it simmer slowly from two to four hours, according to the size. Skim it frequently, to remove the grease which is constantly rising to the top. When done, skin it, and strew bread raspings over the upper side; then place it before the fire to dry and brown. Garnish with greens or cabbage.

To boil Leg of Pork.—Pork requires to be particularly well boiled. Place it in the pot with the skin side uppermost, with a plate below it, for pork is very apt to stick to the bottom of the pot. Peas pudding is generally served separately with this dish.

To boil a Tongue.—If hard, soak the tongue in water all night before using. Boil it from two hours and a-half to three hours. Skin it before dishing. Garnish with greens or cabbage.

To boil Tripe.—When tripe is purchased from the butcher in a raw state, it requires to be boiled a very long time, to be thoroughly soft and tender. The length of time will depend on the age of the animal from which it has been taken. Sometimes, for young tripe six or seven hours will be sufficient, while old tripe will perhaps take ten or twelve. In all cases, boil, or rather simmer it very slowly, for quick boiling hardens it. It should be cut into moderately-sized pieces for helping at table. When to be served plain, carry to table in a hash dish, in some of the water with which it has been boiled, with boiled onions in it. A tasteful way of serving is to take it from its liquor after boiling, and stew it for about ten minutes in a saucepan with milk, which thicken with a little arrowroot, or flour and butter, and season with pepper and salt. This makes a delicious and cheap dish.

To boil Cow-heel.—Cow-heel should be boiled for five or six hours, or till the bones will slip out. Serve with a sauce of chopped parsley and butter.

To boil Eggs.—The boiling of eggs is a very simple operation, but is frequently ill performed. The following is the best mode:—Put the egg into a pan of hot water just off the boil. When you put in the egg, lift the pan from the fire and hold it in your hand for an instant or two. This will allow the air to escape from the shell, and so the egg will not be cracked in boiling. Set the pan on the fire again, and boil for three minutes or more, if the egg be quite fresh, or two minutes and a-half, if the egg has been kept any time.

STEWS, HASHES, AND MADE DISHES.

Stewing is the preparing of meat by slow simmering or boiling, and by which all the liquor is to be used along with the meat at table. This is a much more savoury and nutritious mode of cookery than boiling, because the substance of the meat is partly in the liquor, and is seasoned to have a high relish or flavour. Generally, much more can be made of meat by stewing than by roasting, boiling, or frying, because nothing is lost in the process of dressing. It also possesses the decided advantage of being a way by which meat may be dressed for a person whose time of dining is uncertain. A stewed steak, for instance, will keep warm and in good condition for an hour, but a broiled or fried steak cannot keep a minute after dressing.

To stew a piece of Beef, or make Beef Bouilli.—Take a piece of beef—the brisket or rump, or any other piece that will become tender. Put a little butter in the bottom of the stew-pan, and then putting in the meat, partially fry or brown it all over. Then take it out, and lay two or three skewers in the bottom of the pan; after which replace the meat, which will be prevented from sticking to the pan by means of the skewers. Next, put in as much water as will half cover the meat. Stew it slowly, with the pan closely covered, till done, with a few onions, if required. Two hours are considered enough for a piece of six or eight pounds. When ready, take out the meat, and thicken the gravy with a little butter and flour. Cut down into handsome shapes a boiled carrot and turnip, and add them to the liquor; season with pepper, salt, and ketchup. Boil all together for a few minutes, and serve in a hash dish.

To stew a Shoulder of Mutton.—Take a shoulder of mutton, and cut out the blade bone without injuring the form of the meat. Make a stuffing of crumbs of bread, chopped suet, and parsley, a little green or dried sweet herbs, chopped onion, and pepper and salt, moistened with egg and milk. Lay this stuffing in the place from which the bone was cut out; then roll it up, and skewer or bind it firmly with tape. Rub the bottom of a stew-pan with suet or butter, and brown the mutton. When sufficiently brown, lay two skewers in the bottom of the pan; add a little stock or boiling water, and let it stew for an hour and a-half; the gravy drawn from itself will be sufficiently rich for sauce, seasoned with pepper and salt. Skim it before serving.

To stew Steaks and Chops.—Cut the beef in slices rather thinner than for broiling or frying. Put them in a stew-pan, with water sufficient to make gravy. Add grated carrot, turnip cut in small squares, and pepper and salt. Stew for an hour, or till tender. Skim if necessary. When done, thicken the gravy with a little arrowroot or flour, and flavour with ketchup. Some persons add a little maccaroni or vermicelli, which requires from ten to twenty minutes' boiling along with the stew. Mutton chops are stewed in the same manner, but require to be trimmed of the superfluous fat, and more carefully skimmed. This is called *haricot of mutton* when the chops have been previously browned. The same directions will serve for stewing slices or pieces of any other kind of meat.

To stew Veal.—The best parts of veal for stewing are the fillet, the breast, and the shoulder. The shoulder must be stuffed when the knuckle is cut out, which must be done neatly, without disfiguring the meat; the stuffing should consist of bread-crumbs, minced suet, chopped parsley, grated lemon-peel, white pepper and salt, moistened with egg and milk; fill the shoulder, and sew it up. Rub the bottom of a large stew-pan with butter, lay in the veal, and brown it on both sides. When sufficiently brown, put in a pint of cold water, and stew it slowly for two hours, or, if large, two hours and a-half. Before it is to be dished, draw off the gravy, and if not thick enough, brown a little butter, and dust in a little flour; put it amongst the gravy, and season with Cayenne, salt, and the squeeze of a lemon (a glass of sherry will be an improvement); skim the sauce, and pour it over the meat.

To stew Kidneys.—Cut the kidneys into slices; wash them, and dry them with a clean cloth; dust them with flour, and fry them with butter until they are brown. Pour some hot water or beef gravy into the pan, a few minced onions, pepper and salt, according to taste; let them stew slowly for an hour, and add a spoonful or two of mushroom ketchup before dishing.

To stew Pigeons.—Pick and wash the pigeons well, trussing them as fowls for boiling. Put a piece of butter and some pepper inside; dust them with flour, and brown them in a covered stew-pan with a good piece of butter; put in a little flour; add some gravy or hot water. Season them highly, and let them stew slowly for twenty minutes or half an hour. Before dishing, add half a glass of port wine, if the flavour be approved.

To stew Rabbits.—Wash the rabbits well; cut them in pieces, and put them in to scald for a few minutes. Melt a piece of butter, in which fry or brown the rabbits for a short time. When slightly browned, dust in some flour; then add as much gravy or hot water as will make sufficient sauce. Put in onions, ketchup, pepper and salt, according to taste. Stew for an hour slowly. When required, flavour the gravy with a small quantity of curry powder.

To make Irish Stew.—Take a piece of loin or back-ribs of mutton, and cut it into chops. Put it in a stew-pan with pared raw potatoes, sliced onions, pepper, salt, and a little water. Put this on to stew slowly for an hour, covered very close; and shake it occasionally, to prevent it from sticking to the bottom.

To make English Stew.—English stew is the name given to the following excellent preparation of cold meat:—Cut the meat in slices; pepper, salt, and flour them, and lay them in a dish. Take a few pickles of any kind, or a small quantity of pickled cabbage, and sprinkle them over the meat. Then take a teacup half full of water; add to it a small quantity of the vinegar belonging to the pickles, a small quantity of ketchup, if approved of, and any gravy that may be set by for use. Stir all together, and pour it over the meat. Set the meat before the fire with a tin behind it, or put it in a despatch, or in the oven of the kitchen range, as may be most convenient, for about half an hour before dinner-time. This is a cheap and simple way of dressing cold meat.

To hash Cold Beef or Mutton.—Cold roast beef, or cold roast or boiled mutton, may be dressed as a hash in the following manner:—Cut the meat from the bones into small pieces, and lay them aside; then put the bones in a stew-pan, with a little water and sliced onion. After stewing for a short time, take out the bones and put in the meat. When the meat is perfectly hot, thicken with a little flour and butter, and season with pepper and salt, and a little ketchup. Dish the hash, and stick small triangular pieces of dry toasted bread round the inner edge of the dish.

To dress Cold Boiled Beef, or make Bubble and Squeak.—Cut the beef in slices of about the third of an inch in thickness. Fry the slices till lightly browned and heated through. Then take them from the pan, and place them on a warm plate before the fire, to keep hot. Fry some cabbage which has been previously boiled and chopped; stir this about a short time in the pan, and season with pepper and salt. Spread the cabbage in a dish, and place the slices of meat upon it; or heap the cabbage in the dish, and place the meat around it.

To mince Cold Veal.—Cut the veal from the bones, and mince it in small square bits, and lay them aside. Then put the bones in a stew-pan with a little warm water, to make a gravy. After stewing for a short time, take out the bones and put in the bits of veal, with a small piece of lemon-peel, chopped very fine. When perfectly heated, thicken with a little flour and butter, and season with pepper and salt, and a little lemon-juice. Dish with small pieces of toasted bread, as in hashed mutton.

To dress a Lamb's Head and Pluck.—Lambs' heads are procured skinned. Take the head with the neck attached; split up the forehead, and take out the brains, which lay aside. Wash the head carefully, cleaning out the slime from the nose by rubbing it with salt, and take out the eyes. The head being thus cleaned, put it on to boil, along with the heart, and the lungs or lights. Let the whole boil for an hour and a-quarter; then take them out, and dry the head and neck with a cloth. Rub it over with an egg well beaten; strew crumbs of bread, pepper and salt, over it; also stick small pieces of butter over it, and lay it in a dish before a clear fire, to be browned lightly. Mince the lungs and heart, and part of the liver, with some onion, parsley, pepper, salt, a little flour, grated nutmeg, and a tablespoonful of ketchup; mix all together, and add some of the liquor in which the head was boiled to form a gravy; let it simmer by the side of the fire for half an hour. Take the brains and beat them well with two eggs, two tablespoonfuls of flour, and a sprig of fine chopped parsley, also a little pepper and salt, and two or three tablespoonfuls of milk—the whole forming a batter. Have a frying-pan with a little lard or dripping, and fry the batter in small round cakes, which turn and brown lightly on both sides. Cut the remainder of the liver in slices, and dust it with flour, and fry it. Now lay the head upon a dish; place the hash round it, and lay a slice of liver and a brain cake alternately on the hash all round. This forms a handsome and a savoury dish, but requires great attention on the part of the cook, to have all the various parts hot and equally ready at the time of dishing.

To make Potted-Head.—This is a dish to be eaten cold as a jelly. Take the half of a bullock's head and clean it; soak it in warm water, with a cow-heel, for two or three hours. Then boil it with the heel till tender. When done, cut them in small pieces, and lay them aside; after which strain the liquor in which they have been boiled, and let it stand till it is cold, so that the fat may be easily skimmed. Put the whole into a sauce-pan, and boil for half an hour, and season with pepper and salt according to taste. Pour it into basins, or tin or earthenware shapes, which stand in a cool place. When quite cold, it forms a jelly, and is ready for being turned out on a dish for use. If it do not come out easily, dip the basin or shape in hot water, and the heat will immediately loosen it. Garnish with sprigs of fresh parsley.

SOUPS AND BROTHS.

Soups are the substance of meat infused in water by boiling, and are of many different kinds, but may be divided into two classes—namely, *brown* and *white*. The basis of brown soups is always beef, while the basis of white soups is generally veal. Broths are preparations of soup, but more simple in their nature, and usually containing some kind of vegetables or matter for thickening—as rice, barley, &c. Soups of every description should be made of sound fresh meat and soft water. It is a general rule to allow a quart of water for every pound of meat; also to boil quickly at first, to make the scum rise, which is assisted by adding a little salt; and after skimming, to simmer gently.

To make Brown or Gravy Soup.—Take a shin or piece of the rump of beef, and break it in several places. Cut the beef from the bones; take out part of the marrow, and lay it on the bottom of the pot. If there be no marrow, use butter. Then lay in the meat and bones to brown. Turn the whole, when browned, on one side, and take care that it does not burn. When it is thoroughly browned, add a pint of cold water to draw the juice from the meat, also a little salt; and in a quarter of an hour after, fill in the quantity of cold water which may be requisite. Now add the vegetables, as, for instance, two carrots, a turnip, and three or four onions, all sliced; also a stalk of celery, some sweet herbs, with some whole black and Jamaica pepper. Let the soup boil slowly for from four to five hours, after which take it off, and let it stand a little to settle. Then skim off the fat, and put it through a hair sieve to clear it. The soup, if cleared, may now be either served or set aside for after use. It should have a clear bright look, with a brownish tinge. Frequently, it is made the day before using, in order that it may be effectually skimmed of fat. In such a case it is heated again before serving. On some occasions it is served with a separate dish of toasted bread cut in small squares. The meat which has made the soup is supposed to be divested of nearly all its nourishing qualities; but where thriftiness is consulted, it may form an agreeable stew, with vegetables, a little ketchup, and pepper and salt.

Brown soup, made as above directed, forms what is called *stock*—that is, a foundation for every other soup of the brown kind, also a gravy for stews where richness is required. It likewise forms any kind of vegetable soup, by merely adding to it, when just finished boiling and clearing, the particular vegetable which may be required. Thus are formed *carrot soup*, the carrots being cut into small stripes or straws; *leek soup*, by adding leeks cut into short pieces, and boiling an hour; *vermicelli soup*, by adding boiled vermicelli; and so on with other vegetables.

Liebig's Brown Soup.—The following plan is that proposed by Baron Liebig for obtaining a soup which shall contain the whole, or nearly the whole, of the nutritious elements of the flesh employed:—'When one pound of lean beef, free of fat, and separated from the bones, in the finely-chopped state in which it is used for beef-sausages or mince-meat, is uniformly mixed with its own weight of cold water, slowly heated to boiling, and the liquid, after boiling briskly for a minute or two, is strained through a cloth or sieve from the coagulated albumen and the fibrine, now become hard and horny, we obtain an equal weight of the most aromatic soup, of such strength as can be obtained even by boiling for hours from a piece of flesh. When mixed with salt, and the other usual additions by which soup is usually seasoned, and tinged somewhat darker by means of roasted onions or burnt sugar, it forms the very best soup that can be prepared from one pound of flesh.' An extract of meat thus prepared is found to be an invaluable provision for an army in active service. Administered along with a little wine to wounded soldiers, it immediately restores their strength, exhausted by loss of blood, and enables them to sustain the fatigue of removal to the nearest hospital. Of course what is so useful in this extreme case must be useful in thousands of minor occasions of bodily prostration. The loss of strength means the loss of the substances that support vitality, such as these very ingredients of fleshy juice. The fleshy fibre itself is wasted more slowly than the substances that float in the liquid that invests it; so that, in fact, a supply of these matters has a more instantaneous action than any other refreshment. We can thus explain the effect of soups upon convalescent patients.

Beef Tea.—This is but another name for the pure extract of beef, as above recommended by Liebig. The common plan is merely to cut the meat into thin slices; but of course mincing is to be preferred, as a much more effective method of obtaining the essential juices. After boiling, skim, and season with salt.

Kidney Soup.—Make a stock or gravy soup as above directed. Cut two beef kidneys in slices; wash them well, and stew them in water or soup for an hour. Take out the kidneys and strain the soup. Then return the kidneys to the soup so strained, and add as much stock or gravy soup as is required. Let the whole boil for a few minutes, and serve in a tureen.

Ox-tail Soup.—Make a quantity of brown soup, as previously directed. Take two or three tails, and separate them at the joints into pieces. Put the whole in the soup, and boil till the meat is tender, but not till it comes from the bones. Add a little ketchup, and serve with the pieces of tail in the soup.

Hare Soup.—Take a fresh hare, and, when skinned, wipe it well with a cloth. Cut it open, and take out the entrails, taking great care not to lose any of the blood. Then cut the body into separate pieces, and put them in a pot with two or three quarts of water, along with any blood that may have run out. Put into the pot also two or three pounds of beef cut into pieces, likewise a sliced carrot, turnip, and onion, a few sprigs of thyme, a few Jamaica peppercorns, and four tablespoonfuls of flour mixed with cold water. Keep stirring till it boil, and let it boil for an hour and a-half. When this is done, take the best pieces of the hare, which are the back and upper joints of the hind-legs. Lay these aside. Let the soup boil for other two hours. Then take out the remainder of the meat, and cut it off the bones, and pound it in a mortar, or otherwise mash it well. Put the meat thus pounded back into the soup, and strain the whole through a hair sieve. Put the soup so purified into the pot, along with the best pieces of the hare which were laid aside, also two tablespoonfuls of ketchup. Boil this for half an hour; then add pepper and salt, and serve with the pieces of hare in the tureen.

Jugged Hare.—After having skinned, drawn, and washed the hare, cut it into pieces, and put the pieces into a jar with an onion, a bunch of sweet herbs, and a little water. Cover the top of the jar so close that very little of the steam can escape from it; the cover may be tied down to the jar. Place it in a saucepan of water, the water not to cover the top of the jar. Keep the water constantly boiling. Boil between three and four hours. When done, skim off any fat, thicken the sauce with flour and butter, season with salt and pepper, and serve altogether in a hash dish.

Mock-Turtle Soup.—This is made with a calf's head. It is best to get the head ready scraped and cleaned from the butcher, but with the skin on. If it be got in an uncleaned state, wash it, and put it into a pot with cold water, and boil it for a short time till the hair is loosened. Then scrape off the hair, split the head, clean it thoroughly, and take out the brains. The head is now supposed to be clean, and ready for making the soup. Put it into a pot with considerably more water than will cover it. Skim it frequently as it warms, and let it boil gently for an hour. Take out the head, and when it has cooled, cut the meat off into handsome pieces of about an inch square. Scrape and cut the tongue in the same manner. Lay all these pieces aside. Then put into the water in which the head was boiled about three or four pounds of hock of beef and a knuckle of veal, with the bones broken. Add to this four or five onions, a carrot and turnip sliced, a small bunch of sweet herbs, and some black and Jamaica pepper, whole. Add also the brains, after you have boiled them separately in a cloth, and pounded them. With all these additions let the soup boil slowly for four or five hours, after which strain it, and when cool, take off the fat. Take a quarter of a pound of fresh butter, and melt it in a stew-pan; when melted, put in two handfuls of flour and let it brown, stirring it all the time; add a little of the soup, a sprig or two of sweet basil, and a few heads of parsley. Boil this for a quarter of an hour; strain it through a sieve; then put this, the pieces of meat, and the soup, all together, and boil it for an hour. Add two tablespoonfuls of ketchup, the juice of a lemon, Cayenne pepper, and salt to taste. It is usual to put in at the same time four glasses of sherry wine. When dished in a tureen, put in two dozen of egg-balls.

Egg-balls for mock-turtle soup are made as follows:—Boil four or five eggs till they are quite hard. Take out the yolks, and beat them in a mortar, with salt and Cayenne pepper. Make this into a paste with the white of one or two raw eggs. Roll the paste into balls the size of small marbles. Roll them in a little flour, and either fry them in butter or brown them before the fire, being careful to keep them whole and separate. They are now ready for being put into the soup.

Peas Soup.—This is an excellent soup, if well made, and is one of the cheapest dishes that can be put on the table, for it may be formed of cold meat or marrow-bone, or, what is cheaper still, merely water, or the liquor in which any piece of mutton, lamb, or veal has been boiled. We give the following recipes:—

Peas Soup with meat or bones.—Take a good marrow-bone, or the bones of cold roast beef; a slice or shank of ham may be added, if the flavour be liked. Break the bones, and put them in the pot with four quarts of cold water. According to the thickness and quantity required, take two or three pounds of the best split peas, and put them among the cold water and bones; add to this two carrots, two turnips, half-a-dozen small onions, a stalk of celery cut in pieces, a bunch of thyme, and some whole black and Jamaica pepper. Let all this boil for two hours, stirring frequently, as the soup is very apt to burn. When the peas are quite soft and broken down, take the soup off, and put it through a sieve, into another pot; rub it well through until the pulp be mixed with the soup. Add salt melted amongst a little water, and boil the soup again for a few minutes. When to be served, cut a slice of toasted bread into small square pieces, and put in the tureen with the soup.

Peas Soup without meat or bones.—Put two pounds or pints of peas in five quarts of water. Boil for four hours; then add three or four large onions, two heads of celery, a carrot and a turnip, all cut up; and season with salt to taste. Boil for two hours longer. If the soup become too thick, add a little water. The peas may be boiled the evening before being used, and the longer they boil, the smoother and more mellow the soup will be; but do not put in the vegetables until the day the soup is to be used. By this plan the soup does not require straining.

Mutton Broth.—This is a broth of a mild nature, being intended chiefly for invalids. Take a scrag or thick end of a loin of mutton, and put it into a pot with cold water; the proportion being a quart of water to a pound of meat, which will allow for loss in boiling. Turnip and onion may be added when not considered injurious. Let this boil slowly for three hours, and skim off all the fat before serving. The meat is supposed to be useless.

SCOTCH DISHES.

Sheep's Haggis.—There are different ways of making a haggis, as far as the exact composition of the materials is concerned. Some put minced tripe in it, others put no tripe. The following is the more common, and, we believe, the best manner of making it:—Procure the large stomach bag of a sheep, also one of the smaller bags called the king's hood, together with the pluck, which is the lights, the liver, and the heart. The bags must be well washed first in cold water, then plunged in boiling water, and scraped. Great care must be taken of the large bag; let it lie and soak in cold water, with a little salt, all night. Wash also the pluck. You will now boil the small bag along with the pluck; in boiling, leave the windpipe attached, and let the end of it hang over the edge of the pot, so that impurities may pass freely out. Boil for an hour and a-half, and take the whole from the pot. When cold, cut away the windpipe, and any bits of skin or gristle that seem improper. Grate the quarter of the liver (not using the remainder for the haggis), and mince the heart, lights, and small bag very small, along with half a pound of beef suet. Mix all this mince with two small tea-cupfuls of oatmeal, previously dried before the fire, black and Jamaica pepper, and salt; also add half a pint of the liquor in which the pluck was boiled, or beef gravy. Stir all together into a consistency. Then take the large bag, which has been thoroughly cleansed, and put the mince into it. Fill it only a little more than half full, in order to leave room for the meal and meat to expand. If crammed too full, it will burst in boiling. Sew up the bag with a needle and thread. The haggis is now complete. Put it in a pot with boiling water, and prick it occasionally with a large needle, as it swells, to allow the air to escape. If the bag appears thin, tie a cloth outside the skin. There should be a plate placed beneath it, to prevent its sticking to the bottom of the pot. Boil it for three hours. It is served on a dish without garnish, and requires no gravy, as it is sufficiently rich in itself.

Lamb's Haggis.—This is a much more delicate dish, and less frequently made than a sheep's haggis. Procure the large bag, pluck, and fry of a lamb. The fry is composed of the small bowels, sweetbreads, and kernels. Prepare the bag, as in a sheep's haggis. Clean thoroughly the small bowels and other parts; parboil them, and chop them finely along with a quarter of a pound of suet. Mix with dried oatmeal, salt, and pepper, and sew the mixture in the bag. Boil it, and attend to it in the same manner as a sheep's haggis.

Broth or 'Kail.'—Broth is made of beef or mutton, but mutton is preferable, and is generally employed. The best broth is made as follows:—Put into a pot three quarts of cold water, along with a cupful of pearl barley, and let it boil. As soon as it boils, put in two pounds of the best part of the neck or back ribs of mutton. Allow it to boil gently for an hour, skimming occasionally, and watching to prevent boiling over. Then add one carrot grated, two small turnips cut in squares, a few small onions shred; also two or three pieces of carrot and turnip uncut. Instead of part of these vegetables, according to taste put in the half of a small cabbage chopped in moderately-sized pieces, or if cabbage cannot be procured, a similar quantity of greens. Leeks are also used instead of onions. Boil the whole for an hour longer, adding, if necessary, a small quantity of hot water to compensate the loss in boiling. The broth is now supposed to be done. Season with salt only, and serve in a tureen. The meat, which is not expected to be over-boiled, is served in a separate dish, garnished with the uncut pieces of turnip and carrot. By this preparation both the broth and meat are used, so that a small quantity of meat produces food for a large number.

Hotch-Potch.—This is a dish only to be obtained in perfection in summer, when green peas are in season. Put on two quarts of water, and when it boils, put in three pounds of the back ribs of mutton or lamb, paring off the fat if there be too much. Put in with the meat two or three carrots cut into squares, and two grated, also three or four sweet young turnips in squares, a cauliflower and a lettuce cut down, a few young onions shred, a little parsley, and about a pint of sweet young peas. Boil this for an hour and a-half, then take out the meat and cut it in chops, laying it aside. Add another pint of young peas, seasoning with pepper and salt; and when these peas are done, put in the chops. A few minutes afterwards, serve up in a tureen.

Sheep's Head.—Procure as good a sheep's head as possible. The first thing done is to singe it with a hot iron, so as to free it completely from every particle of wool. This process is always performed in Scotland by a blacksmith, or some other person who makes a business of singeing heads. The horns should have been previously sawed off by the butcher. When singed and ready for the cook, soak the head for some time in warm water, and then scrape it till it is perfectly clean, and as nearly white as possible. The head must now be split, and the brains removed. Take out the eyes, and scrape and clean out the nose; after which wash the head again, and let it lie in warm water for a short time. It is usual to procure the trotters along with the head, and to subject them to a similar treatment as regards singeing, cleaning, and washing. The head and trotters being now ready for the pot, put them in with a sufficiency of water, and let them boil till the skin is soft and tender, which may be in three hours. When ready, serve with the trotters round the dish, and garnish with boiled carrot and turnip.

Minced Collops.—Take a pound of good juicy beef, and a proportionate quantity of suet. Mince the whole very fine, as if for sausages, taking away any bits of gristle or skin. Melt a piece of butter in a frying-pan, and then put in the collops. Stir them well, adding a little flour, a little hot water or gravy, and season with pepper and salt, and a little ketchup. Onion may be chopped, and put in along with the meat, if required. Ten minutes will dress a pound, which will form a dish for four or five persons. Serve in a hash dish.

Potato Soup.—Take any bones of cold roast meat, or a marrow-bone, or, failing these, a piece of dripping, which put into a pot with cold water, according to the quantity required. Let it boil a short time; then put in a quantity of potatoes well peeled or scraped, which have been previously soaked in boiling water, to extract any disagreeable flavour from them. Add also one or two onions cut in pieces, a little pepper and salt, and let all boil for half an hour.

SAUCES AND FLAVOURS.

Sauces are liquid preparations, to be used in giving a flavour or relish to dishes, and are of various kinds. A number are formed of melted butter, with an infusion of some other ingredients; others are in the form of gravies drawn from fresh juicy meat; and a third kind are composed partly of water, and some preserves, condiments, or spices. There is little merit in making a good sauce when a person has good and proper materials to make it with. The chief merit consists in furnishing a fine flavour from inadequate materials; as, for instance, giving a rich flavour of meat to a mass of potatoes, or some other plain dish, when no meat has been employed. This can only be done by knowing the qualities of various vegetable products, and how these, by means of cookery, may be made to resemble the juices of animal food. The vegetable products of which by far the most can be made by a skilful cook are onions, mushrooms, and carrots. Onions and mushrooms alone furnish the most effectual substitutes for animal juices, and may be dressed so exquisitely, as hardly to be distinguished from the gravy of beef.

Onion Flavour.—Onion flavour is made by stewing. Take several large onions, and remove the thin outer film from them. Put them in a saucepan with a little salt and flour, and a small piece of butter or dripping, to prevent their burning. Cover them quite close, and set by the fire to brown and stew gently. Two hours will dress them, and at the end of this time they will be quite soft, and with the addition of a little water, they will yield a rich gravy. This may be used to fry potatoes with, or to flavour any other dish.

Mushroom Sauce.—Pick out the stems, and skin the mushrooms and the stems. Cut them in small pieces, and wash them. Then put them in a saucepan, with rather more water than will cover them. Let them stew gently for about half an hour, or till they are soft. They will now have yielded a fine rich sauce. Stir in a little flour and butter kneaded together, and season with pepper and salt. This preparation may be eaten with potatoes, the same as meat; it also forms an excellent sauce to many dishes.

Melted Butter.—This must be made of fresh butter. Cut down the butter into small pieces, and put them into a small saucepan with cold water, in the proportion of an ounce of butter to a tablespoonful of water. Throw in flour from a dredger with the one hand, while with the other you turn the saucepan rapidly round, so as to cause the flour to mix without lumping. A small quantity of flour is sufficient. You now for the first time take the saucepan to the fire, and continue turning or shaking it till the butter is thoroughly melted. When it boils, it is ready; it should then have the consistency of rich cream. If it should oil in making, it may be partially recovered by putting a little cold water into it, and pouring it several times into and out of a basin. This sauce is the foundation of a number of other sauces, various additions being made to it for the sake of variety.

Onion Sauce.—Skin the onions, and boil them in plenty of water. When soft, take them from the water and chop them very fine. Melt butter as above, stir them in, and season with a little pepper and salt.

Egg Sauce.—Boil three or four eggs till they are quite hard. Peel and chop them, and then stir them into melted butter. Season with pepper and salt.

Caudle Sauce for Plumpudding.—Melt butter, as above directed, and stir into it a glass of sherry, half a glass of brandy or rum, a little sugar, grated lemon-peel, and nutmeg. Do not let it boil after the spirits have been added.

Lobster and Crab Sauce.—Melt the butter, as above directed. Pick out the meat of a boiled lobster or crab; chop it down very fine, and put it amongst the butter. Season with Cayenne pepper and salt. If the lobster be procured raw, with berries or spawn on the outside, these should be taken off previous to boiling, and being mashed in a little cold water, may be added to the sauce after the lobster is put in. By boiling a little, the whole will become a bright red. This forms an improvement on common lobster sauce.

Bread Sauce.—Grate down crumbs of bread. Put it in a saucepan on the fire, with as much sweet milk as will allow it to be thick. Add a piece of sliced onion, and stir it till the bread is soaked and the sauce is quite smooth. Season with pepper and salt.

Mint Sauce.—Take the leaves of fresh green mint. Wash them, and after drying them, chop them very fine. Mix them with vinegar, and add a little sugar.

Beef Gravy.—A pound and a-half of beef will make a pint of good gravy. Cut the beef in slices, or score it very deeply. Place it in a saucepan, with a bit of butter to prevent it from sticking, and a sliced onion. Brown the meat gently, being careful not to let it burn. Cover it closely, and let it stand beside the fire for about half an hour, to allow the gravy to run from the meat. Then put in about a pint of hot water, and let it boil slowly for an hour and a-half, with some whole pepper. Some persons put in to boil along with it a piece of bread toasted hard and brown, which thickens the gravy a little and adds to its richness. Season with salt, and strain it through a hair sieve.

To make a Stuffing.—Roast veal, fowls, turkey, and some other things require a stuffing. These stuffings have been alluded to in various recipes in the preceding pages, and may here be expressly defined. Take a quarter of a pound of the crumbs of stale white bread, a quarter of a pound of chopped beef suet or marrow, as much chopped parsley as will lie on a tablespoon, about half a spoonful of chopped sweet marjoram, and a little grated lemon-peel, pepper, and salt. Mix all these thoroughly together with one beat egg and a little sweet milk. This forms a species of dough in sufficient quantity for a small turkey or large fowl.

Force-meat Balls.—These are balls formed of stuffing, used as a garnish for roast veal or veal cutlets. Make a stuffing like the above; but instead of being wet with one egg and milk, wet the mixture with two eggs. Roll the dough into small balls about the size of nutmegs. Roll them in flour, and fry them with a little lard, butter, or dripping. When required to be more savoury, the composition may be enriched with a little chopped ham, tongue, or sausage meat.

FISH.

Fish are dressed in a variety of ways, according to the taste of individuals. They are boiled, broiled, baked, stewed, and fried; but the most common modes of preparation are boiling and frying—boiling when required to be done in a plain way, and frying when a high relish or flavour is to be given to them. In all modes of preparing fish, much care is required to prevent them from being broken or disfigured.

To boil Salmon.—Clean out, scale, and rinse the fish in water; then put it in a good roomy fish-kettle, with plenty of cold water, and a handful of salt. The usual time allowed for boiling salmon is twelve minutes to each pound; but this must in a great measure depend on the thickness of the fish. The way to ascertain when it is ready, is to raise one end from the water, and try if a knife will pass easily betwixt the fish and the bone. If it pass easily, it is dressed sufficiently. When done, lift it immediately from the water, and place the fish-drainer across the kettle, to allow the water to drip from the fish. Serve on a dish with a fish plate and white napkin under it, the napkin being next it. Garnish with green parsley. Sauce—plain melted butter, parsley sauce, or lobster sauce in a tureen.

To broil Salmon, or Salmon Steaks.—Cut slices from the thick part of the fish, and having cleaned and scaled them, dry them, and dust them with flour. Broil them on a gridiron over a clear fire. When ready, rub them over with butter, and serve hot, with any of the sauces used for boiled salmon. Slices of hung or *kippered* salmon are broiled in the same manner.

To fry Trouts or similar Fish.—Trouts of a moderate size are dressed whole, and frying is the best mode of preparation. Take the trouts and clean out and scale them. Dust them with flour, and put them in a frying-pan with hot dripping or lard. Turn them, so as to brown them on both sides. Lift them out and serve them on a dish; they will be improved by laying a napkin under them to absorb the grease. In the country parts of Scotland trouts are rubbed with oatmeal instead of flour, and some reckon that this improves the flavour.

To boil Turbot.—Select a thick fish of a white creamy colour. After cleaning, but not cutting any part, except in gutting it, lay it in salt and water, with the addition of a little vinegar, and let it soak a short time before boiling. Put it with the white side or belly upwards in a fish-kettle on the fire, with plenty of cold water, a handful of salt, and a cupful of vinegar. Let it heat slowly, and boil for half an hour after it has come to the boil. When done, serve with belly upwards, and garnish with any small fish fried, or with parsley and scraped horse-radish. Sauce—lobster, oyster, or plain butter.

To bake Turbot.—Cut a small turbot into slices, which clean and free from bones. Dip the slices in beat egg; and roll them in a mixture of crumbs of bread, minced parsley, pepper, and salt. Place them in a dish well buttered all round, and bake them in an oven not very hot, or in a bachelor's or Dutch oven before the fire. They must be basted frequently with butter. When done, lay the pieces in a dish, and pour round them lobster or oyster sauce, highly seasoned with Cayenne pepper, salt, and ketchup. Instead of being baked, slices of turbot may be fried after being prepared as above, and served with plain butter sauce.

To boil Cod.—Wash, clean, and boil as directed for turbot. Serve on a napkin, garnished with parsley and scraped horse-radish. Sauce—oyster sauce.

To dress a Cod's Head and Shoulders.—Take a cod's head and shoulders in one piece, which clean, and let lie among salt all night. When you are going to dress it, skin it, and bind it with tape to keep it firm. Put it in a fish-kettle, back upwards, with plenty of cold water, a handful of salt, and a little vinegar. Let it heat slowly, and boil for about half an hour. Then let it lie on the drainer across the top of the kettle, for the water to drip from it. After this, place it, back upwards, on the dish in which it is to be carried to table, cutting and drawing away the tapes very carefully. Brush it over with beat egg, strew crumbs of bread, pepper, and salt over it, and stick pieces of butter thickly over the top. Set it before a clear fire to brown. A rich oyster sauce, made with beef gravy instead of water, and highly seasoned with Cayenne pepper, salt, and ketchup, is poured in the dish around the fish.

To dress a Middle Cut of Cod.—Clean the piece of cod, and make a stuffing of bread crumbs, parsley, and onions chopped small, pepper and salt, a bit of butter, moistened with egg. Put this stuffing into the open part of the fish, and fix it in with skewers. Then rub the fish over with beat egg, and strew crumbs of bread, pepper, and salt over it. Stick also some bits of butter on it. Set it in a bachelor's or Dutch oven before the fire to bake. Serve with melted butter or oyster sauce.

To boil Haddocks.—This is the simplest of all operations. Select haddocks of a middle size. Clean them well, and wash them, and boil with a little salt in the water. Twenty minutes or half an hour's boiling will be sufficient. Serve with oyster sauce.

To dress Haddocks.—This is a most delicious dish when well prepared. Take pretty large haddocks, which clean and wash well. They will be firmer and better if they lie for a night in salt. When to be dressed, wash them and dry them. Cut off the head, tail, and fins; then skin them, being careful not to tear the flesh. Cut the flesh neatly from the bone, and divide each side into two pieces. Dust them with flour, dip them into beat egg, and strew bread crumbs over them. Fry them in a frying-pan, with a sufficiency of hot dripping or lard to cover them. Be careful that the dripping is not hot enough to scorch the fish. The way to ascertain the proper degree of heat of the fat is to dip a thin slice of bread into it, and when it makes the bread of a light brown tinge, put in the fish. If the fat be too hot, it will make the bread of a deep brown. Turn the pieces carefully, so as to brown both sides, and when done, lay them before the fire on a drainer for a few minutes. Serve in a dish, garnished with parsley. Sauce—oyster sauce, or plain melted butter. The fat in which haddocks are fried will answer the same purpose again, if put through a hair sieve, and poured in a jar, and kept in a cool place.

To fry Skate, Soles, Flounders, Whitings, and Eels, and any other white fish.—Skate and soles are skinned and dressed in the same manner as haddocks, but soles are fried whole, not cut in pieces. Flounders are fried in the same manner, whole, but do not require to be skinned. Eels must be skinned and cut in pieces.

To bake Haddocks.—Take two or three haddocks, gut and clean them, and lay them all night among salt. When to be used, skin them, and cut off the heads, tails, and fins. Make a stuffing of bread crumbs, chopped onions and parsley, and a little bit of butter. Sew this into the bellies of the fish. Rub them over with butter, strew bread crumbs over them and bake them in an oven or before the fire.

Fish and Sauce.—Take two or three haddocks, gut and clean them, and lay them all night among salt. When to be used, skin them, cut off the heads, tails, and fins. Boil these trimmings for three-quarters of an hour in a little water. Brown a little flour and butter in a stew-pan, and then strain the liquor and put it to the butter; add sliced onion, chopped parsley, salt, a little Cayenne pepper, and a spoonful of ketchup. When all this has been boiled for a few minutes, cut the fish in pieces, and let it boil gently till dressed.

To scallop Oysters.—Scald the oysters in their own liquor. Pick them out of the liquor, and lay them in a dish, or scallop shells, or tins, strewing crumbs of bread mixed with pepper and salt over each layer, and finishing with crumbs. Moisten the whole with a small quantity of the liquor in which the oysters were scalded, and stick pieces of butter thickly over the top. Place the dish before the fire to bake. From ten to twenty minutes will be required, according to the quantity.

DRESSING VEGETABLES.

All vegetables ought to be cooked fresh from being gathered, or as nearly so as possible. Excepting peas and spinach, each kind of vegetable should be boiled in a large quantity of water, to carry off any rankness of flavour. They should also be served as soon as dressed, and not permitted to lie a moment in the water after they are ready for dishing. All kinds of cabbage and greens are the better for being boiled with a little carbonate of soda in the water, which will preserve their green appearance. The carbonate of soda is a material resembling flour in appearance, and may be obtained from any druggist. Cauliflower and broccoli require great care in boiling, for the flower easily breaks, and their appearance is spoiled. The time for boiling vegetables depends so much on their age, freshness, and size, that no directions can be given on that point. The best way to ascertain when they are ready, is to pass a fork through the stem.

To boil Green Peas.—Peas should not be shelled till just before they are to be used. After shelling, put them into boiling water, just enough to cover them, with a little salt; and when they are not very young, put a little sugar in the water. They will require about twenty minutes to boil. When done, strain them through a cullinder, and put them into a vegetable dish with a few bits of butter; stir them gently till the butter is mixed with them.

To boil Carrots and Parsnips.—Carrots require to be scraped, and to boil till they are soft. The length of time for them boiling depends on their age and size. Small carrots are served whole, but large ones should be cut in four pieces lengthwise. Parsnips require to be scraped and prepared in the same manner.

To boil Turnips.—Old turnips require to be pared much deeper than young ones. When they are very small, peel off the skins, but do not pare them; and after boiling, serve them whole, with a little melted butter in the dish. Large turnips are cut in pieces before being put in the pot, and they are either served in three pieces, or mashed with a little butter, pepper, and salt.

To boil French Beans and Scarlet Runners.—Cut off the tops and tails, and strip the strings from the backs of the pods. Then cut the pods in pieces slantingly across, or split them from one end to the other, and then cut them across. Lay them in cold water for a few minutes; and after straining them, put them into boiling water with a little salt and carbonate of soda. Boil till they are soft; strain them with a cullinder, and serve them with melted butter in a separate dish. Scarlet runners are prepared in the same manner, but usually require to be split into three or four pieces.

Potatoes.—These useful vegetables, as every one knows, may be dressed in a variety of ways. When to be presented plain at table, they may be either boiled in water or steamed. Some potatoes are best when boiled, while steaming is more suitable for other kinds. There is therefore no exact rule upon the subject. In general, they are better when they are boiled, and when put into just enough of cold water to cover them. A little salt should be put into the water to impart a flavour, and they should boil very slowly. Fast boiling will break their skins before they are soft in the inside. In most instances they are spoiled by over-quick boiling. When sufficiently done, pour the water from them, and set them by the side of the fire with the lid off, to allow the steam to escape, or fold a napkin and place it over them to absorb the moisture. Before serving, peel them, and place them in a dish with a napkin over them. Plain potatoes should never be sent to table without a napkin, for it keeps them warm, and at the same time allows the moisture to escape. When potatoes are to be mashed, they are pared either before or immediately after boiling, and mashed so as to be free from lumps. Some milk and butter, and a little salt, are stirred in before serving.

To boil Rice for Curry.—It is customary to serve boiled rice along with dishes which have been seasoned or stewed with curry. When rice is required for this purpose, it should not be soft or pulpy as in boiling for puddings; each grain should retain its perfect individual form, though swelled to nearly its fullest size. After picking and washing the rice, put it into boiling water, and let it boil smartly for about twelve minutes. Just before taking it out, put in a tablespoonful of salt. Drain the rice in a cullinder; then shake it gently out upon a doubled cloth, and lay it before the fire for a few minutes, with a fold of cloth over it. By this process the water will be absorbed from it, and it will be ready for dishing. Pour it lightly into the dish.

Salads.—Salad is a general name for certain vegetables prepared so as to be served and eaten raw. Salads are composed chiefly of lettuce, endive, radishes, green mustard, land and water cresses, celery, and young onions. All or any of them should be washed, and placed ornamentally in a salad bowl; the lettuce is generally cut in pieces lengthwise, and stuck round the dish; the celery, also divided, is placed in the centre; and the small salads, such as cresses and radishes, are placed between. This is the mode of serving a salad plain.

A dressed Salad.—When a dressed salad is to be served, the whole is cut in small pieces, and mixed in the bowl with a dressing. The dressing is made in the following manner:—For a moderate quantity of salad, boil one egg quite hard; when cold, take out the yolk and bruise it with the back of a spoon on a plate; then pour on it about a teaspoonful of cold water and about a teaspoonful of salt. Rub all this together till the egg has become quite smooth like a thick paste. Add a teaspoonful of made mustard, and continue mixing. Next add and mix a tablespoonful of salad oil or cold melted butter. After this, add and mix a tablespoonful or more of vinegar. The dressing is now made, and may be either mixed with the salad, or put into a glass vessel called an *incorporator*, which is sent to table along with the salad. The top of the salad may be ornamented with small bits of the white of the egg and pieces of pickled beetroot.

PIES AND TARTS.

Pies are of two distinct kinds—meat pies and fruit pies or tarts. Both are composed partly of paste, and therefore a knowledge of making pastry is indispensable in the economical housewife and cook. For this operation, the hands should be washed very clean, and care taken to have the board for working upon smooth, clean, and dry. A marble slab is better than a board, but few can command this convenience, and a board is usually kept for the purpose. Should the board or table be anyway rough, lay a sheet of stout white paper upon it. Before commencing to roll or knead the paste, dredge a little flour upon it. In all cases of making paste, the butter, whether fresh or salt, should be perfectly free of taint, or any rankness of flavour. It is very necessary to give this direction, for many persons seem to imagine that butter of any kind, however bad, is good enough for paste. Dripping, when well prepared and kept, or lard, will answer as a substitute for butter, and make the paste equally agreeable to the taste. At one time, raised pies—that is, pies covered all over with paste—were common, but these are now rarely seen of a large size for families. Pies are now made in earthenware dishes, and merely covered with paste prepared as follows:—

Paste for covering Meat Pies.—A good common paste for covering dishes or meat pies, and which paste is intended to be eaten, is made as follows:—Three ounces of butter, and one pound of flour, will be sufficient for one dish. Rub the butter well amongst the flour, so as to incorporate them thoroughly. If the butter be fresh, add a little salt. Mix up the flour and butter with as much cold water as will make a thick paste. Knead it quickly on a board, and roll it out flat with a rolling pin. Turn the dish upside down upon the flattened paste, and cut or shape out the piece required for the cover. Roll out the parings, and cut them into strips. Wet the edges of the dish, and place these strips neatly round on the edges, as a foundation for the cover. Then, after putting in the meat, lay the cover on the dish, pressing down the edges closely to keep all tight. If any paste remain, cut or stamp it in ornaments, such as leaves, and place these as a decoration on the cover.

On taking pies from the oven, and while quite hot, the crust may be glazed with white of egg and water beat together, or sugar and water laid on with a brush.

Beef-Steak Pie.—Take some slices of tender beef mixed with fat; those from the rump are the best. Season them with pepper and salt, and roll each slice up in a small bundle, or lay them flat in the dish. Put in a little gravy or cold water, and a little flour for thickening. Cover as above directed, and bake in an oven for about an hour.

Veal Pie.—Take chops from the back ribs or loin, and take out the bones. Lay the chops flat in the dish, and strew over each layer a mixture of minced parsley, flour, pepper, and salt. Add a little gravy, which may be made from the bones. Cover as above directed, and bake for rather more than an hour, for veal requires to be well dressed.

Pigeon Pie.—Pick and clean the birds well. Cut off the heads, and truss them by turning the wings on the back, cutting off the feet, and drawing the skin of the belly over the legs. Put a bit of butter, and a little pepper and salt, inside each bird. Place a single layer of beef or veal in the bottom of the dish. Lay the birds on the meat, with breasts upwards, and with the gizzards and livers round them. Some add a few whole hard-boiled eggs. Add a little gravy or water. Cover as above directed, and bake for an hour.

Icing for Tarts.—After tarts are baked, they are sometimes iced on the top, to improve their appearance. The icing is done thus:—Take the white of an egg, and beat it till it is a froth. Spread some of this with a brush or feather on the top or cover of the tart, and then dredge white sifted sugar upon it. Return the tart to the oven for about ten minutes.

Apple Pie.—Pare and take out the cores of the apples, cutting each apple into four or eight pieces, according to their size. Lay them neatly in a baking dish, seasoning with brown sugar, and any spice, such as pounded cloves and cinnamon, or grated lemon-peel. A little quince marmalade gives a fine flavour to the pie. Add a little water, and cover with puff paste, as above directed. Bake for an hour.

Gooseberry Pie.—Pick the heads and stems from unripe or hard gooseberries, and rub them with a towel to clean them. Fill the dish with them, and add a considerable quantity of brown sugar, with a very little water. Cover as above directed, and bake for upwards of an hour. Some persons stew the gooseberries in sugar before putting them in the dish, in which case they require less baking.

Rhubarb Pie.—Take stalks of fresh-pulled rhubarb. Cut off all the leaf, and strip off the skins. Cut the stalks into pieces of an inch long. Fill the dish, adding plenty of sugar. Cover as above directed, and bake for half an hour. Some persons stew the rhubarb before baking; the advantage of this is, that more can be put into the dish, for it shrinks considerably in dressing.

Cranberry, Raspberry, and other Tarts.—Cranberries, raspberries, and other small fruits, may be made into pies in the same manner as gooseberries. All require to be picked and wiped, and to have sufficient sugar to sweeten them. The dish should also be well filled, and raised higher in the middle than the edges, for the fruits diminish considerably in bulk in baking.

Mince Pie.—Mince pie is a composition of meat, fruit, various spices and seasonings, and also spirits. The following is a properly-proportioned mixture:—Take and mince a pound of beef suet, and a pound of roast beef, or dressed fresh bullock's tongue; also a pound of apples pared and cored, minced separately from the suet and meat; a pound of currants washed and picked, a pound of stoned and chopped raisins, an ounce of ground cinnamon, half an ounce of ground ginger, an ounce of orange and an ounce of lemon peel, and a little salt; half a pound of raw sugar, one nutmeg grated, two glasses of brandy and two of sherry. Mix all these ingredients together, and lay the bottom of your dish or small tin pans with paste; fill these with the mince, and then cover them with puff paste. Put in the oven, and bake for half an hour. If the whole of the mixture be not used, what remains over will keep for a long time if placed in a close jar. Some persons do not put any meat in their mince pies.

Open Tarts.—These are tarts without covers, made in flat dishes. Cover the bottom of the dish with a common paste; then cut a strip of puff paste and lay round the edge of the dish. Fill in the centre with any jam or preserved fruit. Decorate the top of the jam with narrow bars of paste crossed all over, or stamped leaves. Bake for half an hour.

PUDDINGS AND DUMPLINGS.

Care should be taken in making puddings to have the suet and the eggs which are put into them perfectly fresh. If there be any doubt of the freshness of the eggs, break each individually in a teacup, for one bad egg will spoil all the eggs in the dish. The cloths used for puddings should be of tolerably fine linen. Let them be carefully washed after using, and laid aside in a dry state, ready for the next occasion. Before putting the pudding into the cloth, dip the cloth in boiling water, and after the water has run from it, spread it over a basin, and dredge it with flour. Every pudding should be boiled in plenty of water, so as to allow it room to move freely; and it must be kept constantly boiling. It is a general saying among cooks that a pudding *cannot be too well boiled*; and it is certain that there is much more danger of boiling it too short than too long a time. When you take the pudding from the pot, plunge it for a few seconds into a jar of cold water. This will chill the outside, and allow the cloth to be taken away without injuring the surface. The best way to dish a pudding is to place it with the cloth in a basin, then open the cloth, and lay the face of the dish upon the pudding; turn the whole upside down, lift off the basin, and remove the cloth.

Plumpudding.—A plumpudding may be made either rich or plain, according to the quantity of fruit and spices put into it. The following is the direction for making what would be considered in England a *good Christmas pudding*:—Take a pound of good raisins and stone them; a pound of currants, which wash, pick, and dry; a pound of rich beef suet minced, and a pound of stale bread crumbs, and half a pound of flour. Mix the bread, flour, and suet in a pan. Beat six eggs in a basin, and add to them about half a pint of sweet milk. Pour this egg and milk into the pan with the suet and flour, and beat it well with a flat wooden spoon for some time. Then stir in the currants and raisins, mixing well as you proceed; mix in also a quarter of a pound of candied orange and lemon-peel, cut in thin small pieces, an ounce of powdered cinnamon, half an ounce of powdered ginger, a nutmeg grated, and a little salt. Next add a glass of rum or brandy. The pudding is now made, and ready to be either baked or boiled, according to taste. If to be baked, butter your tin or basin, and put the pudding into it, and bake in an oven for an hour and a-half, or nearly two hours. If to be boiled, pour it into a cloth; tie the cloth, allowing a little room to swell if made of bread, and boil for six hours. Serve with caudle sauce.

Currant Pudding.—An excellent family pudding may be made of the following ingredients:—A pound of minced suet, a pound of bread crumbs or flour, three-quarters of a pound of currants, washed and picked, a little powdered cinnamon and grated nutmeg, and a very little salt. Beat two eggs, and add as much milk to them as will wet the whole. Mix all together, tie in a cloth, as previously directed, and boil for three hours. Serve with caudle or any simple sweet sauce.

Hard Dumpling.—This is the plainest of all puddings, and is sometimes served with boiled salt beef. It is also sometimes cut in slices and placed in the dripping pan below roasting meat for about half an hour before the meat is dished. Take a quarter of a pound of suet minced very fine; mix it with a pound of flour; add a little salt, and wet it with water to the consistency of dough. Divide it into small dumplings, and put them into boiling water, and boil for an hour and a-half, taking care that they do not stick to the bottom of the pot. No cloth is used.

Bread Pudding.—Boil as much milk as will be sufficient for the pudding you want. When it begins to boil or rise in the pan, pour it upon crumbled down stale bread in a basin. The quantity of bread should be as much as will thicken the milk to a stiff consistency. Cover it up for ten or fifteen minutes, to allow the bread to swell. Then beat or mash it up to make a fine pulp, stirring in a small piece of butter. Beat three or four eggs, a teaspoonful of ground cinnamon, a little grated lemon-peel, and sugar according to taste. Stir this among the pudding. A little brandy or rum may be added; also a few currants, if required. The pudding may be either boiled or baked. If to be boiled, put it in a well-buttered pudding shape or basin, with a buttered paper over it, and also a cloth over all: boil for an hour. If to be baked, put it into a buttered baking dish, and bake in an oven for half an hour.

Rice Pudding.—Take a pretty large cupful of rice, pick it, and wash it well in cold water. Boil it in water for about five minutes. Drain the water off, and put it on again with as much milk as you require. Let it boil till the rice is quite soft, stirring it frequently, to prevent it from burning. When done, put it into a basin, and stir in a piece of butter, or some suet minced very fine. When cold, add to it four eggs, beaten, with a little ground cinnamon, grated nutmeg and lemon, and sweeten with sugar. All is to be mixed well together. It may be either boiled or baked, as directed for bread pudding. The above composition may be enriched by using more eggs and less rice, also by adding currants, spirits, and candied orange peel.

Custard Pudding.—Take four eggs, and beat them well with two tablespoonfuls of flour and a little cold milk. Season this with sugar, ground cinnamon, grated lemon-peel, and pour on a pint of boiling milk, stirring all the time. It may be either baked or boiled. By using more eggs, the flour may be omitted.

Bread and Butter Pudding.—Cut several slices of bread rather thin; butter them on one side; put a layer of them in a pudding pan or dish, and a layer of currants above; then another layer of bread; and so on till the dish is full. Beat four eggs, with a little ground cinnamon and nutmeg, also some sugar. Add milk to this, till there is sufficient to fill up the dish. Then pour it over the bread, and allow it to stand for a time to soak. It will now be ready for either baking or boiling, as directed for bread puddings.

Tapioca Pudding—Sago Pudding.—Take a quart of milk, and put in it six tablespoonfuls of tapioca. Place it on the fire till it boil; then sweeten to taste, and let it simmer for a quarter of an hour. Stir it frequently, and be careful that it does not burn. Then pour it into a basin, and stir into it a little fresh butter and three eggs well beaten; you may now pour it into a buttered pudding dish, and bake for about an hour; or, after adding another egg, boil it in a basin or mould for an hour and a-half. Sago pudding may be made in the same manner.

Batter or Yorkshire Pudding.—Take a quart of sweet milk, and mix in it a large cupful of flour, making the mixture very smooth. Beat four eggs, and strain them into the batter. Add a little salt, and mix all well together. Butter your dish or tin, and pour the batter into it. Place the dish either before the fire under roasting meat, or under meat sent to the oven. The pudding, when done, easily shakes out of the dish into another dish to be carried to table. It should have a nicely browned appearance. When dressed before the fire, either turn the pudding, or place the dish a short time on the fire to brown the under side.

Peas Pudding.—Pick a quart of split peas—that is, remove all impurities, or discoloured peas, or shells. Tie them loosely in a cloth, leaving plenty of room for the peas to swell. Boil till they are soft, which may be in from two to three hours. Take the pudding from the water, and put it into a basin. Open the cloth, and bruise or mash the peas well. Mix in a piece of butter, with pepper and salt. Then tie it up tightly, and put it into the pot again, and boil for about half an hour. When ready, turn it out of the cloth into a vegetable dish. If properly managed, it will turn out whole.

Fruit Puddings.—Fruit puddings consist of fruit enclosed in a paste, and boiled. They may be made of apples pared and cut in pieces, green unripe gooseberries, currants, raspberries, cherries, and other fruits. They are all made in the same manner. The best paste for them is made of beef suet chopped very fine, and flour, in the proportion of four ounces of suet to a pound of flour. Mix it into a dough with water and a little salt; then knead it, and roll it out; place the fruit in it, gather up the edges, and tie it in a cloth, or place it in a basin, as directed for other puddings.

A Roll Pudding.—Make a paste of flour and dripping, or suet, as previously directed for plain paste. Roll it out flat, to about half an inch thick. Then spread gooseberry jam, or any other preserved fruit, over the paste, but not quite to the edges. After this, roll it up, and cause the outer edge to adhere. Next roll it in a cloth, and tie the ends tightly. Boil it for an hour or an hour and a-half, according to the size. When done, take the cloth off, cut the pudding in slices, and serve with any sweet sauce over it.

Meat Puddings.—Meat puddings are made in the same manner as fruit puddings, the only difference being, that pieces of beef, mutton, lamb, or veal, are placed inside of the paste instead of fruit. The meat should be seasoned with salt and pepper. One of the commonest of this kind of puddings is a beef-steak pudding. If it contain two pounds of meat, it will require about two hours and a-half to boil, and if larger, it will take a longer time.

Omelettes.—Omelettes are composed of eggs and anything that the fancy may direct to flavour and enrich them. For a common omelette, take six eggs, and beat them well with a fork in a basin; add a little salt. Next take a little finely-chopped parsley, finely-chopped eschalot or onion, and two ounces of butter cut into small pieces, and mix all this with the egg. Set a frying-pan on the fire with a piece of butter in it; as soon as the butter is melted, pour in the omelette, and continue to stir it till it assume the appearance of a firm cake. When dressed on one side, turn it carefully, and dress it on the other. It will be dressed sufficiently when it is lightly browned. Serve it on a dish. The flavour may be varied by leaving out the parsley and onion, and putting in finely-chopped tongue or ham, oysters, shrimps, grated cheese, or other ingredients.

Pancakes.—Pancakes are made of eggs, flour, and milk, in the proportion of a tablespoonful of flour to each egg. To make two small pancakes, take two eggs, and beat them well, and add to them a little milk. Then take two tablespoonfuls of flour, and work it into a batter with the egg and milk; add a little salt. Set a clean frying-pan on the fire, and put a piece of butter or lard into it. When the butter is quite hot, pour in the batter. Shake it frequently, to prevent it from sticking. When the under side is of a light brown, turn it. Serve the cakes folded, with sugar strewed between the folds. This is the way of dressing common pancake; when required to be lighter, use more egg and less flour; and grated nutmeg may be added.

Fritters.—Make a batter of eggs, flour, and milk, as for pancakes, but with a little more flour. Apple fritters are made by cutting large pared apples in slices, dipping the slices in the batter, and frying them separately. They are done when lightly browned on both sides. Another, and perhaps more common way, is to cut the apples in small pieces, and mix them with the batter, frying them, a spoonful in each fritter. Fritters may be made with currants in the same manner. Serve all fritters with sugar sprinkled over them.

LIGHT DISHES AND CONFECTIONS.

Under this head is included those various light and elegant dishes which are generally put upon the table in the last course, along with puddings and pies; also those preserves which are occasionally served at tea and supper parties. In making all articles of this description, very considerable care and cleanliness are required. The tin shapes or moulds for jellies should be kept particularly clean; if they are used with any particles of dirt inside, the jellies will in all likelihood not turn out neatly. It has been already mentioned that the turning out may be facilitated by dipping the mould for an instant or two in hot water. It is a common belief that fruits, such as gooseberries and currants, cannot, without spoiling, be dressed for preserving except in a brass, copper, or silver pan. This is an error. They may be dressed equally well in a tinned iron sauce-pan. Every kind of berries for preserving should be gathered in sunny weather, when the fruit is as free of moisture as possible.

Custards.—Boil a quart of sweet milk with stick cinnamon, the rind of a lemon, and a few laurel leaves or bitter almonds, and sugar. Beat the yolks of eight eggs along with the whites of four of them; add a little milk, and strain the egg into another dish. When the quart of milk boils, take it off the fire and strain it; then stir the egg into it. Return the whole to the sauce-pan, and set it on the fire again, stirring constantly. Let it come to the boiling point; then take it off the fire, pour it into a large jug, and continue stirring it till it is nearly cold. It should now have the consistency of thick cream, and is ready for being poured into custard glasses. When the glasses are filled, grate a little nutmeg over them.

Calf's-foot Jelly.—Take two calf's feet, well cleaned; break them in several pieces, and put them in a sauce-pan with three quarts of cold water. Boil it slowly, till it is reduced to about a quart and a-half. Strain it, and let it stand till cold. Take off the fat carefully when cold. Put the jelly into a sauce-pan, keeping back the sediment; put in along with it the juice and the yellow rind of three lemons, two stalks of cinnamon, half a bottle of sherry wine, the whites of eight eggs well beaten, with the shells broken, and white sugar according to taste. Mix this all together, and put it on to boil for twenty minutes. Take it off, and let it settle with a cloth over it for a few minutes. Then pour it through a clean jelly-bag made of thick flannel. It will take some time to run; therefore hang the bag near the fire, cover it, and let the liquid run slowly from it into a jar. If not perfectly clear, run it through the bag again; but if as clear as is required, it is now ready, and may be poured into the shapes. Plain calf's-foot jelly may be made with ale instead of wine, and vinegar instead of lemons.

Blamange.—Blamange, or Blanc-Mange—so called from its white appearance—is a jelly made of isinglass and milk. Take a quart of sweet milk, or cream, and put in it two ounces of the best isinglass. Put it in a sauce-pan, with the rind of a lemon, a blade of mace, and white sugar to taste. Let it boil a quarter of an hour. Take the skins off six bitter almonds and twenty-four sweet ones, and pound them to a paste with a little water. Mix this with the boiling milk, and strain it through a muslin sieve. Let it settle for a short time, and then pour it into the shape, keeping back the sediment. Turn out when cold, as already directed.

Arrowroot Blamange.—This is a jelly closely resembling the above, and is made with much less trouble. Take a quart of sweet milk, and put it all in a sauce-pan, excepting about half a pint. Sweeten it with white sugar. Mix about three tablespoonfuls of arrowroot with the half pint of milk, taking care to bray it all well down. When the milk on the fire boils, pour in the arrowroot, stirring quickly, to prevent lumping or burning. It will become thick immediately. Let it boil for two or three minutes. Wet the shape with cold milk, and pour the arrowroot into it. Let it stand till cold, and turn out as already directed. Some flavour the milk in the pan with essence of lemon.

Moss Blamange.—There is a moss of a peculiar kind found on the sea-shores of Iceland, Ireland, and other places, which is of a glutinous quality, like isinglass, and which, when boiled in milk, forms a fine white jelly. It is called Iceland or Irish moss, and is sold by druggists, and when bought, resembles dried sea-weed of a yellowish colour. Take one ounce, and pick from it all gritty or sandy particles. Soak it in cold water for about twelve hours. Take it from the water, place it in a cullinder, and drain it. Being drained, place it in a sauce-pan on the fire with a pint and a-half of sweet milk. Let it boil for half an hour, and keep stirring it all the time, to prevent it from burning. During the boiling, sweeten it with sugar, and flavour with cinnamon, or any other spice you please. At the end of the half hour's boiling the moss will be almost entirely dissolved, leaving nothing but a few thready fibres. You now strain it through a sieve into a shape or mould. When cold, it will turn out easily, and have all the appearance of a firm blamange. This forms one of the cheapest blamanges that can be served to table; it is also agreeable to the palate, and very nutritious. In cases of a hurry in cooking, six hours' soaking of the moss will do, but this causes a waste.

Gooseberry Fool.—Take a quart of full-grown unripe gooseberries. Pick them, and put them into a sauce-pan with a cupful of water. Cover them, and let them heat very slowly. When the gooseberries are soft and dressed, but not so much heated as to burst, strain the water from them, and put the gooseberries in a dish. Bruise them to a fine pulp, with sufficient sugar to sweeten them. Let them stand till cool, and then mix milk or cream with them. Serve in a hash dish or large bowl.

MEDICINE—HOUSEHOLD SURGERY.

Error in diet, drink, dress—in fine, the erroneous treatment of ourselves as organised beings—is sure sooner or later to be productive of bodily ailment. Even were we perfectly nurtured as to food and clothing, and were we born with perfectly sound constitutions, still are we liable to injury from numerous external causes; hence the necessity for remedial agents, either in the shape of *medicines*, strictly so called, or in the form of *surgical* operations. A man, for instance, may be afflicted with some internal or external malady, and he has recourse to a medicament or healing substance, in the faith that it will remove his affliction, and restore him to health. Again, he may have received such bodily injury, or his malady may have assumed such a form, that a medicament of itself would be unavailing, and he submits to the instrumental operations of the surgeon, which, however, are generally accompanied with medicinal administrations. Thus it is customary to distinguish between the surgeon, physician, and apothecary or chemist; and such distinctions, though unnecessary for our humble purpose, are not without their advantages. In the following pages, therefore, while separating Medicine from Surgery, we follow no technical distinction farther than seems likely to facilitate the ordinary reader's comprehension of an art as necessary to his wellbeing as those which relate to his food and clothing. Our utmost aim is to convey to the class whom we more especially address a general notion of the science; those who seek for more will find themselves disappointed. To adopt the language of a recent medical writer—'No one who reads herein is to expect that he is to find a whole body of surgery, or that he will be fitted thereby to set up for an amateur surgeon, capable of practising upon himself or his neighbours, for a vast deal must be passed by. Not that there are any "secrets of the prison-house" to be kept, because we are of those who think it would be well if people generally understood something about how they were treated, and what they were treated for, as they would then be less open to the tricks of cunning knaves, whether enjoying the honour of a diploma or not, and more capable of estimating the value of honourable and upright practitioners; but everything cannot be told, usefully at least, to general readers, for this simple reason—that were it set forth, they could not rightly comprehend it. Still, there is much to be mentioned which may be of good service at a pinch, without interfering with the doctor.'

MEDICINE.

All those drugs which in some form or other are applied to the alleviation or cure of bodily ailments are known by the name of medicines; and they consist for the greater part of substances prepared from vegetable and mineral bases, a few only being of animal origin. The introduction of medicine has afforded much ground for discussion, but the question is really of little importance. The rudest tribes of the present day direct their attention in their own way to the cure of those complaints incident to their climate and situation; and we may safely conclude, that before society had advanced far in civilisation, the aborigines of the world cultivated the art of medicine. On looking around on the face of nature, they would perceive numberless plants and substances unfitted for food, and equally so, to appearance, for any other useful purpose of life. Chance would probably determine, in the lapse of time, the uses of many of these; and indeed, at no very distant period, one of our most valuable medicines was discovered by mere accident. A quantity of Peruvian bark had been thrown as useless into a small well, out of which some soldiers afflicted with the ague had the good fortune to drink. To their own surprise, as well as that of others, they became rapidly well, and the cure happily was attributed to the right cause. In the same manner a knowledge of many important medicinal articles might be attained, and occasionally some bold inquirer might arrive at the same end by actual experiment. As among the African and North American tribes of the present day, however, a great portion of the medical art of our forefathers lay in working on the fears and imaginations of the patients by means of pretended charms and incantations.

The medicinal preparations of the ancients were taken almost entirely from the vegetable kingdom, though the Arabian school of medicine, which arrived at great eminence while the Saracens were masters of Spain, was well acquainted with several metallic remedies. The researches, however, of the chemists, or rather alchymists, of the dark ages, first brought fully to light the great value of the metals in the hands of the physician, and this credit these ingenious individuals are at least entitled to, though we may smile at their absurd attempts to transmute baser minerals to gold, or to find out the elixir of life. They made thus a most important addition to the number of medicines, and effected a change in the healing art which is felt to the present time. The liability of herbs to spoil by keeping, whether in the state of roots, leaves, or seeds, gave a great superiority to the mineral preparations, which retain their powers for a long period. At the time when they were first introduced, the sensation excited was so great, that the numerous believers in their virtues were called, in contradistinction to the admirers of vegetables, the chemical school. This sect went so far as to refer all the functions of the body to chemical processes, and to treat all diseases upon chemical principles. The discovery of the circulation of the blood founded a new set of philosophers, who maintained that the body was entirely framed upon, and regulated by, mathematical laws. Though this doctrine was supported by some eminent men, and for a short time superseded the chemical theory, yet its total failure to account, upon mechanical principles, for all or for any of the vital actions, soon caused it to fall into disrepute.

It is scarcely necessary to mention any other changes in the progress of the science of medicine, and indeed those taken notice of are of consequence only from their effects on the nature of the remedies for disease. During the eighteenth century, anatomy was prosecuted with deep attention, the nature of medicinal preparations closely investigated, and their number increased; the result of which was, the reduction of the practice of physic to principles more agreeable to reason and to truth. Men, too, partaking of the wide spread of knowledge during the period mentioned, began to object to nostrums when labouring under illness, and became reluctant to swallow a dose without being informed of the nature of the action and the effects expected. Hence medicines, instead of being applied indiscriminately to every species of disease, were arranged into some sort of order, and classified according to their known operation. This is the most simple method of viewing the range of medicinal substances, and it is the one we shall adopt in the present instance, though it will be impossible to enumerate any other medicines than those principally in use.

Some substances employed in the cure of disease act *mechanically*, and others *chemically*, on the system; but by far the greater proportion of them act *vitally*. A medicine is said to act mechanically when its effect on the body is the same as that which it exerts over inanimate matter. Demulcents, for instance, or remedies taken to remove the acrid effects of some other substance, operate simply by coating the stomach with a gummy fluid, an action which is entirely mechanical. The chemical operation of medicines may be thus explained: When an acid and an alkali are mixed in a glass of water, they unite together, and form a third substance, a salt, having new properties altogether. The same chemical process takes place when sourness, or an acid, is neutralised in the stomach by soda, or any alkali. The vital action of medicines differs totally from the two former. In this case the substances are absorbed into the blood, and are conveyed by the vessels of the heart to the quarter whither their nature determines them. Diuretics, or medicines which stimulate the urinary organs, may form an example of vital action. From the stomach the diuretic is absorbed into the blood-vessels, and carried to the kidneys, stimulating them to the secretion of urine, though by what process of separation from the rest of the blood we know not. Under these three divisions, mechanical, chemical, and vital agents, all the articles used in medical practice—technically, *materia medica*—are comprehended. After this general explanation, and before proceeding to examine the nature of the more important substances, it will be necessary to allude to the forms and manner in which medical preparations are usually administered.

Forms and Modes of Preparation.

Some medicines are prepared in a liquid, others in a solid form, according as they may be soluble or insoluble, or according to the remedial state in which it may be desirable to administer them. In general, the more finely a substance can be divided, the more rapidly is it taken up by the system, and the more instantaneous its effect; hence, instead of administering the crude vegetable or mineral, the necessity of preparing infusions, decoctions, tinctures, and the like. Another reason for adopting such preparations is, that the active or medicinal principle of a substance may constitute but a small portion of its bulk; while the greater portion may be of no value whatever, or may be even positively detrimental.

Infusions of vegetable substances are common and convenient forms: they are prepared by pouring boiling water upon the materials in a lightly-covered vessel, and allowing it either to cool directly, or to continue at a gentle heat for a few hours; then straining, filtering, and bottling for use. Boiling water has sometimes the disadvantage of dissolving ingredients which we may not be in search of; hence the use of cold water by way of percolation or displacement. In addition to this advantage, cold infusions are found to have less tendency to decay. Infusions by the ordinary method may be preserved, however, for months, by pouring them, while boiling hot, into bottles up to the top, and quickly forcing in strong corks of good quality.

Decoctions differ from infusions in being prepared by actual boiling of the substances; and, if possible, in vessels of glass or earthenware. Decoction, though often resorted to on the large scale, is by no means an accurate or scientific mode of preparation; inasmuch as the active principles of many vegetables are destroyed or weakened by prolonged boiling, at the same time that other constituents than those we may be in quest of are apt to be liberated, and mingle with the result. Thus calumba-root, which yields an active and excellent bitter, cannot be boiled without liberating a large amount of starch, which is not only not wanted, but is actually detrimental to the preservation of the active solution. Decoctions, when had recourse to, should be made in covered (not closed) vessels; and the process should be continued no longer than is necessary to extract the principle sought for.

Extracts, which are much valued in pharmacy, are usually prepared by evaporating the expressed juices of plants, or their infusions or decoctions in water or spirits, at a temperature not exceeding 212°, by means of a vapour bath. Many of them, however, may be obtained of superior quality by the process of evaporation *in vacuo*; and the extracts of expressed juices cannot perhaps be better prepared than by spontaneous evaporation in shallow vessels exposed to a current of air. Extracts should be evaporated, according to the Pharmacopœias, till they are of such a consistence as to form a firm pill-mass when cold. In this condition they are thought to keep better and longer, and can also be administered in a more convenient and concentrated form. Though extracts in general keep well, yet all sooner or later deteriorate; hence the necessity of care in their preservation, as well as in examining them before administration.

Tinctures are solutions of vegetable, animal, or mineral substances, in some spirituous fluid—as proof-spirits, rectified spirits, and the like. They are prepared by breaking down the solid mass into fragments, and macerating in the spirit for a week or more without artificial heat. The liquid is then poured off, the residuum subjected to pressure, or further macerated by the addition of new spirit, and the whole fluid so obtained filtered and bottled for use. 'The form of tincture,' says Christison in his Dispensatory, 'is one of the best in pharmacy; for the menstruum is a powerful solvent of the active constituents of drugs; it presents them in a small volume; it preserves them very long unaltered; and it is for the most part a convenient medium for uniting them with other substances in extempore prescriptions.'

Syrups are intended sometimes to cover the disagreeable taste of drugs, but more generally to preserve them in a convenient state for making mixtures, without the risk of their undergoing decomposition. They are prepared sometimes by simply dissolving sugar in a watery solution of the drug, sometimes by concentrating the syrup to a certain density after the sugar has been dissolved. The most desirable density is 1385 at 60°; and to prevent the influences of external heat and cold, it is recommended to keep syrups in a situation where the temperature is stationary at 55°. Instead of sugar, treacle is very commonly used, both on account of its disguising the taste more effectually, and being less apt to crystallise.

Medicated Wines—that is, where wine is used as the menstruum for some vegetable or mineral drug—are now less frequently employed than formerly; partly because they are apt to spoil, and partly because proof-spirit is on the whole a more active solvent. Where still used, the variety taken is sherry, which contains about 30 per cent. alcohol by volume.

When administered in the solid state, one of the most common forms is that of *Powders*. These are prepared by first drying the substance, then pounding it in a mortar, passing it through a sieve to get rid of the grosser particles (which may be again subjected to the pestle), and ultimately preserving in closely-stoppered vessels. Being in a state of fine division, powders act with considerable rapidity, and are administered in admixture with some fluid or conserve.

Conserves, Electuaries, and *Confections*, are intended as vehicles to impart a convenient form to other drugs, and especially as adhesive menstrua, to give them the form of pills. When the dose of any insoluble medicine is bulky, or when it is of disagreeable taste, such adjuncts are of considerable importance.

Pills are regarded as the most convenient of all officinal forms, both for preservation and for administration; but in many instances not the most efficient in point of activity. 'The making of a good pill-mass,' says Dr Christison, 'is a more difficult problem than it may seem at first sight. The mass must be of such consistence as to cohere strongly, and firm enough to retain the globular form: it should be so composed as not to be liable to grow mouldy: it ought not to contract moisture; and yet it ought not to be apt to harden quickly by undergoing desiccation. The materials for securing these objects, or Excipients, as they are technically called, must vary in some measure with the active ingredients of the pill. Those in common use are bread-crumb, hard soap, extract of liquorice, mucilage, syrup, treacle, conserve of red roses, and conserve of hips. For extempore use, the most common solid excipients are bread-crumb and liquorice-extract; and the liquids generally employed are syrup and mucilage. These substances answer very well when the pills are not to be kept above a few days; but pills so composed become very hard, in which state their activity is greatly impaired. In this respect treacle, and conserve of red roses, or hips, but especially the two conserves, are greatly superior. When pills contain a large proportion of resinous matter, one of the most simple and effective methods of keeping them long soft is to use a little rectified spirits for softening them sufficiently in the first instance. Pills are covered with a great variety of substances, to prevent them from adhering, or to obscure their taste. At one time it was the custom to cover them with gold-leaf or silver-leaf; and some physicians have lately proposed to revive this absurd practice. Liquorice-powder, wheat-flour, and wheat-starch, are now most commonly employed. . . . Inveterate custom and economy have sanctioned the practice of keeping pills in boxes of wood or pasteboard. They retain their activity better—because they are preserved soft much longer—if they be kept by the patient in small bottles. There is reason to suspect that the officinal pills are in general too large. Five-grain pills often pass through the body apparently but little altered; and it has occurred to me to observe that four colocynth and henbane pills, of one grain each, will operate as effectually as two five-grain pills, and more mildly.'

Lozenges or *Troches* is another solid form in which drugs are now administered. Whatever the active principle, the basis consists of sugar, gum, and sometimes liquorice-extract. Care must be taken in preparing them to avoid too much heat, otherwise they may be rendered unpleasantly empyreumatic, or their active ingredients may undergo decomposition.

Besides the preceding liquid and solid forms, there are others of a mixed nature which are equally common and important. Thus *Cerates*, *Ointments*, and *Liniments*, are preparations for external use, differing chiefly in their consistence—cerates being the firmest, ointments softer, and liniments softer still, or even liquid. In compounding these, the wax, resin, or fatty matters employed are to be melted with a gentle heat. When removed from the fire, they are to be diligently stirred till they concrete; and meanwhile any dry substance to be added should be sprinkled in a state of very fine powder into the melted mass. As ointments are of use merely to protect wounds from their coverings, from the air, and from filth, the simpler they are the better. The same rules are to be observed in preparing *Plasters*, which have a similar basis spread equally on cloth, leather, or other tissue.

Poultices are well-known external applications. They are described by Abernethy as of three kinds—the evaporating or local tepid bath, the greasy, and the irritating. The first is thus made:—'Scald out a basin, for you can never make a good poultice unless you have perfectly boiling water; then having put in some hot water, throw in coarsely-crumbled bread, and cover it with a plate. When the bread has soaked up as much water as it will imbibe, drain off the remaining water, and there will be left a light pulp. Spread it, a third of an inch thick, on folded linen, and apply it when of the temperature of a warm bath.' The linseed-meal or greasy poultice is, on the same authority, to be made in the following manner:—'Get some linseed powder, not the common stuff, full of grit and sand. Scald out a basin; pour in some perfectly boiling water; throw in the powder, stir it round with a stick, till well incorporated; add a little more water, and a little more meal; stir again, and when it is about two-thirds of the consistence you wish it to be, beat it up with the blade of a knife till all the lumps are removed. Then take it out, lay it on a piece of soft linen, spread it the fourth of an inch thick, and as wide as will cover the whole inflamed part; put a bit of hog's-lard in the centre of it, and when it begins to melt, draw the edge of the knife lightly over, and grease the surface of the poultice.' The irritating poultice, to be used in cases where a blister is unnecessary or inconvenient, is made simply of mustard and water, mixed as if for the dinner-table, and put within the folds of a piece of fine muslin, so that only the watery part, oozing through, touches the skin.

Mixtures and *Emulsions* are extempore preparations, of such strength, consistence, or quality, as each particular case may demand. The same may be said of *Fomentations*, which are warm fluids applied to the skin; and of *Lotions*, or washes, which are similarly applied either cold or warm.

Enemas, or *Clysters*, are drugs administered in the form of injections; they vary in composition and volume according to the object to be effected.

Volatile Oils are obtained chiefly from the flowers, leaves, fruit, barks, and roots of plants, by distilling them with water, in which they have been allowed to macerate for some time. A few, as the oil of orange, lemon, and bergamot, are obtained by expression. They are of various densities, and exist in various states of fluidity under the ordinary temperature of the atmosphere. All of them should be preserved in dark bottles, carefully stoppered, and nearly full.

Distilled Waters or *Essences* consist of the volatile oils of odoriferous vegetables dissolved in water. They are either obtained by distilling the crude vegetables (fresh or dried), or by agitating pure volatile oils with distilled water until sufficient admixture has been procured. Of the various *Salts* obtained from the mineral and vegetable kingdom it is unnecessary here to speak, as they are all administered in one or other of the liquid or solid forms already mentioned.

In whatever form medicinal preparations may be administered, the quantity is invariably regulated by weight or by measure. Though differing in nomenclature and mode of subdivision, both of these are based on the imperial standard of the country. Thus the imperial pound is divided into ounces, drachms, scruples, and grains; and the imperial gallon into pints, fluid ounces, fluid drachms, and minims. In detail—12 ounces make 1 pound, 8 drachms 1 ounce, 3 scruples 1 drachm, and 20 grains 1 scruple. Again, 8 pints make 1 gallon, 20 fluid ounces 1 pint, 8 fluid drachms 1 fluid ounce, and 60 minims 1 fluid drachm. The different denominations of weights and measures are denoted in the language of prescriptions by the following signs:—Pound, ℔; ounce, ℥; drachm, ʒ; scruple, ℈; grain, gr.; Gallon, C; pint, O; fluid ounce, f℥; fluid drachm, fʒ; and minim, ♏. Medical prescriptions are generally written in Latin, which, conjoined with these signs, Roman numerals, and a large amount of contractions, gives them a very formidable and mysterious aspect. Thus, ℞ (*Recipe*) *Nitratis Potassae* gr. xv.; *Aquae destillatae* f℥iss; *Syrupi Limonum* fʒij. *M* (*Misce*). *Fiat haustus, ter in die sumendus*, is but the technical form of ordering the patient to 'Take fifteen grains of the nitrate of potass; one and a-half fluid ounces of distilled water; and two fluid drachms of syrup of lemon. To mingle and form a drink of them, and take it three times a day.' Further, each university of importance has a list of medicinal preparations drawn up for the guidance of its own members and pupils, and this list is termed its *Pharmacopœia*; with the enumeration is given a full account of the processes by which the various substances are prepared for use. Thus London, Edinburgh, and Dublin have their respective Pharmacopœias; differing occasionally in particulars, but rarely or ever in essentials.

With these preliminary explanations, we now proceed to examine the more important remedial agents, as exhibited in modern and approved practice—classifying them according to their ultimate effects, and arranging the classes in alphabetical order, for the sake of perspicuity and facility of reference:—

Characters, Uses, and Effects.

Antacids, as the name imports, are those medicines which correct acidity of the stomach and digestive organs. The stomach of many individuals is liable to a continued conversion of their food, particularly vegetable food, into a species of acid, which produces the annoying feeling called heartburn. This acid may be neutralised by any of the earths or alkalies, and the process of relief is as purely chemical as if it were performed in a glass of water for experiment. The three alkalies, potass, soda, and ammonia, the alkaline earth magnesia, and carbonate of lime (chalk), are the most useful medicines of this description. The relief obtained from them is, as might be expected, merely temporary, since they do not prevent the generation of the acid anew. Antacids should in general be prescribed along with vegetable tonics, and in no case ought their administration to be long persisted in without occasional interruptions. It is further necessary to observe in what condition, and in what region, the acidity more particularly manifests itself, as all antacids have not precisely the same properties and modes of action. Thus the best corrective for *gaseous* acidity in the stomach is found to be the ammonia and its carbonate; for acidity in the lower bowels, lime and magnesia; and where acid exists in the urinary organs, potass and soda are preferable. Calcined magnesia is one of the simplest and best known of the antacids. It is employed in indigestion, attended with acidity of the stomach and constipation; in which cases it is generally preferred to the alkalies, as being less irritant, and as the combinations which it forms with the free acids of the stomach are gently laxative. In gastrodynia and heartburn, given in combination with some aromatic, a short time before the meals, it seldom fails to prove beneficial. It is also administered with much advantage in the acidity attendant on infantile diseases, and to persons of a gouty and rheumatic tendency. Carbonate of magnesia is also used; but it is less active.

Anthelmintics, also known as *Vermifuges*, are those drugs possessing the property of destroying worms, or expelling them from the intestinal canal. Other medicines, as the more active cathartics (which see), may also effect this purpose, but not specifically, as the class now under review. Among the more common vermifuges may be mentioned powder of tin, oil of turpentine, pomegranate bark, powdered fern root, Corsican moss, and worm-seed. 'As the action of these remedies is merely temporary,' says Dr Neligan, 'it will be requisite, as soon as the worms are expelled, to employ means calculated to restore the digestive organs to a healthy state, and to correct that peculiar character of them which promotes the generation of intestinal worms. The means best calculated for this purpose are:—Keeping the surface of the body warm by proper clothing; a light but nutritious diet, with a moderate use of common salt; and at the same time the administration of bitter tonics, with gentle aperients; and if anemia be present, the preparations of iron.'

Antiseptics, though still ranked as a distinct class of medicines, are very little trusted to in the present day. They were great favourites with the ancients, and were supposed to possess the property of resisting putrefaction, or that tendency to mortification which sometimes appears towards the termination of fevers and other complaints. Peruvian bark is commonly believed to have antiseptic qualities, and, with the exception of alcohol and vinegar, is perhaps the only drug of this class worthy of notice.

Antispasmodics are used to remove spasms or convulsive contractions of the muscular fibre in the body, and are very similar in their action to the class Narcotics. Opium, camphor, ammonia, valerian, galbanum, and assafœtida, with most of the narcotics (which see), are the antispasmodics generally in use. Valerianate of zinc, a recent addition to the list, is a tonic antispasmodic of great power, especially in the treatment of neuralgic affections. It does not seem liable to produce sickness; and as it is used in doses of from one to three grains, it may be conveniently administered in the form of a pill.

Aperients are purgatives of the gentlest kind, for which consult the class Cathartics.

Astringents, as commonly defined, are substances which produce contraction and condensation when they come in contact with living matter; their mode of action, however, is rather obscure. Their power appears to depend in a great measure on the presence of the principle called tannin, and they produce their effect by bringing into closer contact the particles of the body to which they are applied, without in other respects affecting its mechanical structure. They are believed to be often of service in restoring tone to the stomach, and it is evident that their astringency will be of great advantage when any laxity of the surface of that organ exists; hence in many instances the most powerful tonics will be obtained from the class astringents. All the vegetable astringents contain tannin; and those most generally employed are preparations from gall-nuts, catechu, kino, oak-bark, logwood, and creasote. A number of the acids, and some of the salts, those particularly in which the acid preponderates over its base, as in alum, which is a compound of vitriol and the earth alumina, possess astringent properties, although they contain no tannin. Some of the metallic salts, as superacetate of lead (sugar of lead), and sulphate of zinc (white vitriol), are ranked in this class. Cold is also a direct astringent, and is often employed in this character with great advantage in checking bleedings. 'All the astringent medicines taken from the vegetable kingdom,' says Gregory, 'are so mild and safe, that they may be taken inwardly, and the use of them long continued without difficulty or danger, in larger or smaller doses, according to the strength of each; but those from the mineral kingdom cannot always be so employed, indeed they are fitted more for external than for internal application.'

Carminatives are those medicines which produce the discharge of flatulence from the alimentary canal. This malady is more annoying than dangerous, though it rises occasionally to a most painful height. The warm essential oils, such as caraway, anise, or peppermint, and some aromatic stimulants, as cinnamon and ginger, are the carminatives in greatest repute.

Cathartics is the general term for those numerous medicines which quicken or increase the alvine evacuations. As they differ considerably in their effects, they are usually spoken of as *laxatives* or *aperients*—that is, gentle evacuants; *purgatives* when more powerful; and *drastics* when they are particularly powerful and energetic. Whatever be their energy, they may be arranged under three heads:—those of an oily or saccharine nature; those which are derived from vegetables, such as resins and extracts; and those formed by a combination of acids with earths, alkalies, and metals, termed neutral and metallic salts. The operation of all these three is of the character of an irritation upon the mucous or inner membrane of the bowels, though in their effects they differ considerably from each other. The first-mentioned seem simply to discharge the contents of the bowels; the second appear to increase the quantity of matter evacuated, by stimulating the mucous membrane, and increasing the natural flow of mucus; while the third class produce evacuations of a watery consistence:—

The principal purgatives of the *first* kind are, castor-oil, olive-oil (seldom used), manna, tamarinds, honey, and so forth; croton-oil, an essential oil, (that is to say, procured by distillation, not by expression, as the castor-oil is), is scarcely to be included in the class of oils, as its great strength prevents its being used except in desperate cases. The medium dose of the castor-oil is one ounce, of the croton-oil a fraction of one drop. The former is imported in immense quantities into this country annually. It is one of the most useful and safe medicines of the purgative class. The rest mentioned are exceedingly mild in their operation, and are generally employed merely to palliate or disguise the bad flavour of some stronger drug.

The *second* kind of purgatives includes aloes, scammony, jalap, colocynth, senna, and rhubarb. The general character of all these has been given above, though the rhubarb possesses one remarkable distinction from the others. It is supposed to act on the muscular membrane of the bowels, producing a natural discharge simply, without altering the character of the fæces.

The principal neutral and metallic salts, which form the *third* order of purgatives, are sulphate of soda, Epsom salts (sulphate of magnesia), cream of tartar (supertartrate of potash), phosphate of soda, and calomel (submuriate of mercury). The latter is the most universal in its application of all medicinal preparations. By proper regulation of the dose, and in conjunction with other drugs, it can be employed with benefit in almost every disease to which man is subject. But in proportion to its usefulness, so is its danger when misapplied. The dose should be very small at first, and cold ought always to be guarded against during its use. With respect to the others, little can be added to the general description already given; it may be mentioned, however, that the pleasantest, though not the cheapest of all medicines, is the phosphate of soda, or *tasteless salts*.

As cathartics of some kind or other are very largely —perhaps too largely—used in this country, where there are so many sedentary and in-door employments, it may be well to transcribe a few remarks from one of the fathers of modern medicine on the subject:—'The operation of cathartics,' says Gregory, 'is dangerous to the weak, the irritable, the slender. It is also to be attempted with great caution, even by the gentlest medicines, in inflammation of the stomach and intestines, or when these are in a delicate state, as in dysentery or protracted diarrhœa. Too frequent repetition of purging, though at first necessary, does great injury, both to the whole system, which it weakens exceedingly, and especially to the intestines themselves, which it sometimes renders preternaturally feeble, tender, and irritable, but more frequently torpid and slow; whence proceeds constipation, and a necessity of having habitual recourse to cathartics. It also renders the blood thin and pale, in the same manner as too frequent bloodletting. . . . But where necessary, due allowance should be made for the patient's idiosyncrasy, not only in regard to the nature of the medicine, but also to its quantity, mixture, preparation, and time of taking it. It is often of advantage not to take the whole of the medicine at once, but by little and little, in equal portions, at proper intervals; for by this means neither is the stomach unnecessarily loaded, nor does vomiting come on, nor is too large a dose taken, nor are the intestines so severely irritated, while the effect is more easily, and indeed more certainly produced. When there is a tendency to nausea or vomiting, it becomes necessary not only to give the cathartic in small doses, but along with it, or a little before, to try an anodyne for composing the agitation of the stomach. During the operation of cathartics, patients are very easily injured by cold, possibly not more by reason of the body being then weakened, than on account of the current of fluids being drawn off more than usual from the external parts: it is therefore proper at such a time to guard carefully against exposure.'

Caustics are a class of substances employed to create artificial sores or ulcers, for the purpose of relieving some deep-seated malady. The operation of caustics is considered chemical, being the result of some attraction between the animal body and the substance employed. The same action takes place on the application of caustics to a portion of the dead subject. Where suppuration is going on in any internal part, they are exceedingly useful in creating a drain on the surface of the body. The principal caustics employed in medicine are potass, blue vitriol, nitrate of silver, arsenic, and some preparations of mercury. The nitrate of silver, or lunar caustic, is the substance in most common use, chiefly on account of its great manageableness, in consequence of its solid form, its property of not deliquescing, and its mild but effectual action—the pain produced by it being but of short duration.

Counter-irritants—known also as vesicants, rubefacients, and epispastics—are substances which produce redness, vesication, or inflammation, when applied to the skin. The extremities of the vessels which convey the blood from the heart over the body are supposed, when they terminate on the skin, to divide into minute tubes, one kind of which carries the red globules, and another the colourless serum of the blood. When strong stimulants, such as mustard or Spanish flies, are applied to the skin, they are supposed to excite these minute vessels so powerfully, that those which contain serum become filled with red globules; hence the term *rubefacients*. This can only be produced during an extraordinary flow of blood to the part, and is the cause of the redness consequent on the application of mustard cataplasms or blisters. A blister is simply a rubefacient allowed to remain on the skin until a deeper layer of it becomes affected, and pus or serum exudes. Like caustics, blisters are exceedingly useful in substituting a superficial inflammatory action for one existing in some deeper and more dangerous seat, and they are therefore called *counter-irritants*. The principal substances employed in exciting cutaneous inflammation are Spanish flies, mustard, tartarised antimony, ammonia, turpentine, and a few other drugs of a stimulant nature. The Spanish flies are almost exclusively used in blistering, and mustard, as a rubefacient, is held in a similar degree of estimation. Latterly a new and improved method of employing Spanish flies, or cantharides, has been introduced into practice. It consists in applying an extract which contains the essential powers of the material to the skin, by spreading it on paper. The blister so formed, which bears the name of *tela vesicatoria* (blistering tissue), produces a much more rapid effect than the common fly blister, and does not give the same pain to the patient. 'Cantharides should not be employed to produce vesication where any irritation or inflammation of the urinary organs is present, in consequence of their peculiar tendency to produce strangury. In infants and young children, blisters should be used with great caution, as they are liable to produce troublesome sloughing, which in many instances has caused death. As a general rule, they should only be left on until redness of the surface is produced, when the application of a warm poultice to the part will produce vesication.'

Demulcents—known also as *emollients*—are a class of medicinal agents the operation of which seems entirely mechanical. A poultice is applied externally to soften an inflamed or irritated part, and with exactly the same views are demulcents used to soothe any irritation of the alimentary canal. Solutions of gum, and syrups, with barley-water, rice-water, and other farinaceous drinks, are employed for this purpose. Iceland moss (lichen Islandicus), liquorice root, almonds, figs, sugar, marshmallow, linseed, and others, are included in the class of demulcents.' 'Of the non-medicinal used as emollients,' says Neligan, 'warm water is the most important, and the higher the temperature at which it can be applied without the actual production of pain, the greater will be its emollient power; for this reason it will be found productive of most advantage when employed in the form of vapour.'

Diaphoretics are those remedies which promote the insensible perspiration; *Sudorifics* such as produce profuse perspiration or sweating. These two classes of remedies are very closely connected, and scarcely, if at all, admit of being distinguished; since the same means may, by the mode of administration, produce either the one or the other effect—while these effects differ rather in appearance and degree than in nature. With regard to their action, it has been questioned whether there exist any medicines possessing any specific quality of stimulating the skin, or exciting to more vigorous action the vessels which exhale the perspiration. The action seems to be sympathetic rather than direct: nausea and vomiting produce profuse sweating; sudden fears and other mental emotions do the same thing; and all the diluents, stimulants, sedatives, and emollients act less or more in this way. Among the simplest diaphoretics may be ranked whey, gruel, barley-water, and other warm drinks and infusions. For those of a more energetic character see *Sudorifics*. 'Among the most excellent and salutary diaphoretic remedies,' says Dr Gregory, 'is deservedly reckoned proper bodily exercise; for when moderate, it accelerates the circulation, and eminently promotes perspiration: when more violent, it generally induces a profuse sweat, even in those persons who can scarcely be compelled to sweat by the medicines commonly used. In cases which do not admit of exercise, diligent friction may in some measure supply its place.' In fine, bathing, change of dress, quality of dress (see CLOTHING), are all favourable to this end.

Diluents, as water, and all weak liquids of which water forms the greater part, are generally ranked as medicinal agents. Being drunk in large quantity, and conveyed by the lacteals into the blood, they have a powerful effect in attenuating the fluids when these are preternaturally thickened. In health they are as necessary as the air we breathe, for by no other means can we maintain the due equilibrium of the circulating medium, upon which all the vital functions depend.

Diuretics are those medicines which operate in promoting the flow of urine, by stimulating the action of the kidneys, the organs which secrete it. This class is very numerous, though the manner of their operation, like that of all the other vital agents, is not thoroughly understood. 'Some act,' says a recent medical authority, 'as direct stimulants to the secreting vessels of the kidney, being taken into the current of the circulation, and carried, without undergoing any decomposition *in transitu*, to the urinary organs; others are partially acted on by the digestive organs, and some of their component parts thus alimented are carried by the circulation to the kidneys, which are thereby stimulated to increased action; while a third class of substances acts primarily on the stomach, the action they excite being secondarily communicated by sympathy to the urinary organs. In whatever manner the action of diuretics is produced, the general effect is to diminish the watery part of the blood, and by this means promote the absorption of fluid effused into any of the cavities or into the cellular membrane. Hence dropsy is the disease in which they are principally employed; and when the discharge of urine can be excited by their administration, the effused fluid is in general removed more speedily from the system, and with less injury to the patient, than by any other method.' The diuretics chiefly employed in practice are squills, foxglove, juniper-berries, potash, cream of tartar, acetate of ammonia, nitric ether, and Spanish flies. All these act powerfully on the urinary organs—those in highest repute being squills, foxglove, juniper, and cream of tartar. The first and the last of these are the most efficient, being more certain in their effects than the others. The action of diuretics is much affected by the state of the skin; hence the common rule, during their exhibition, to keep the surface of the body cool, and to promote the operation of the dose by the use of simple diluent drinks. Further, from the nature of the above-enumerated substances, it is sufficiently clear that some of them are decidedly heating, others refrigerant; some considerably increase the acrimony of the urine, others diminish and blunt it: so that it is quite evident that all of them cannot be equally adapted to every disease. 'Though diuretics are rarely given in such a way as to do the system much injury'—we quote the 'Theory of Medicine'—'it is nevertheless very evident that some degree of prudence is requisite in the administration of them; the abuse of them being attended with considerable danger, as some have found from experience, whether they had been given of too acrid a quality or too often repeated. For in this manner the whole body is weakened; and, in particular, the kidneys are so injured, that either through torpor they become inadequate to their functions in future, or being softened and relaxed, they excern an excessive quantity of fluid, and that very different from healthy urine. Besides, the irritation of more acrid medicines may seriously injure the urinary passages and bladder, and deprive them of their mucus, whence comes perhaps strangury, and similar complaints, especially in aged people, who, by the ordinary course of nature, also become very obnoxious to disorders of this kind.'

Drastics are the most powerful and energetic of the class Cathartics, which consult.

Emetics are substances administered for the purpose of producing vomiting. It may be supposed, from their being received into the stomach, and acting directly and speedily upon it, that there is no absorption into the blood necessary. Tobacco, for instance, taken into the stomach, excites vomiting; but it is from its reception into the circulation; because, if the tobacco be laid on the arm, the same effect will be produced. Some emetics, indeed, appear to act principally on the muscular covering of the stomach, exciting it to contraction, and thereby causing the expulsion of the contents. Most of them, however, simply produce nausea, which causes the inversion of the receptacle of the food. The most active emetics employed in medicine are tartar-emetic, ipecacuan root, chamomile flowers, mustard, sulphate of copper, and sulphate of zinc. The two first of these are most commonly used; the latter being the gentlest, and perhaps on that account the safest, in ordinary cases. 'Emetics should be employed with great caution where there are symptoms of determination of blood to the cerebral organs, in consequence of the obstruction of the circulation which is occasioned during the act of vomiting; for the same reason also they ought not to be administered in diseases of the large arteries, as in aneurism. From the violent action of the abdominal muscles which is caused, the act of vomiting is attended with great risk in the advanced stages of pregnancy, in hernia, and the like.' Frequent vomiting is very injurious to the body, as it weakens the stomach, of course spoils the digestion, and thus in some measure becomes necessary. The operation is more easy with a full than with an empty stomach: hence the advantage of drinking pretty copiously during the exhibition of emetics. It is often of advantage, especially in very infirm patients, or those who have been much agitated, to give an anodyne after vomiting, to compose such agitation, procure sleep, and recruit the health.

Emollients, already noticed under the head *Demulcents*, are generally ranked under two great classes—the oleaginous and mucilaginous. Whether taken internally, or applied externally as Fomentations (which see), their action is simple and easy to be understood: the solid parts are rendered elastic or resisting, but more flexible; and of consequence some parts, which previously hardly admitted of motion, are afterwards moved with much greater ease. 'Of all medicaments of this kind, by far the most powerful and certain is pure water, especially when warmed; for the innumerable decoctions, fomentations, and infusions which are so frequently prescribed, and so much celebrated for their emollient qualities, are generally nothing else, and have no other virtue than pure warm water. And indeed many experiments instituted for the purpose of investigating this matter, afford sufficient proof that the greater part of the oils, juices, and other substances commonly so highly extolled for their emollient qualities, possess them in a much less degree than water itself. However, it would not be reasonable to conclude, on that account, that those oily and mucilaginous substances which we commonly use do no good; for it is very certain that they render the solid parts of animal bodies more soft and flexible, by moistening, and, as it were, besmearing them with oil, facilitating the motion of the particles among themselves by diminishing or removing the friction which impeded it. Besides, pure water and very many aqueous liquors, whether applied warm or cold, are soon dissipated by evaporation, and by that means leave the external parts which had been fomented with them to dry and stiffen. But oily and mucilaginous applications are generally free of this inconvenience, at least they are much more slowly dissipated. Therefore they are properly mixed with all emollients for softening the external parts.'

Epispastics is the term particularly applied to vesicatories and blistering plasters, already treated under the more general appellation Counter-Irritants.

Errhines, Sternutatories, or *Ptarmics*, are substances which, when applied to the mucous membrane of the nostrils, cause an increased discharge of its natural secretion. The powdered leaves of asarabacca, euphorbium, white hellebore, tobacco and turbith mineral (subsulphate of mercury), are powerful errhines; but they are seldom resorted to in regular practice. Violent sneezing, which these sternutatories occasion, though sometimes of use, as in suspended respiration and suffocation from foreign bodies in the air-passages, is not unattended with danger; especially in plethoric patients, in cases of congestion in the head or lungs, in recent and violent inflammation of the eyes, and in rupture. Though occasionally useful in diseases of the eyes, nostrils, deafness, and torpor of the cephalic functions, the habitual use of errhines (snuffs of whatever name) is alike absurd and pernicious.

Expectorants, or *Pectorals*, as they are sometimes termed, are substances used to promote the expulsion from the lungs of those fluids which are secreted during colds, and lodge there, causing difficult breathing, and sometimes ending in injury of their structure. Thus those remedies which promote expectoration are of great consequence to health, though often neglected. The principal medicines of this class are antimony, squills, ipecacuan, balsam of Tolu, and gum ammoniac. Syrup of squills is the preparation in greatest use, forming one of the best expectorants we possess for the pulmonary affections of children, in doses of from 10 to 30 minims. To these may be added all emetic substances which, by their mechanical action, dislodge accumulated secretions from the respiratory organs, and thus frequently become valuable agents in the treatment of diseases requiring the application of expectoral drugs. Epispastic remedies—as blisters, for example—applied to the breast, side, or back, are also useful in promoting expectoration; and to these may be added all Diaphoretics, the inhalation of steam of warm water, which acts as an emollient, and riding on horseback, which has been much recommended.

Febrifuges are medicines believed to exert a specific influence in ague and other periodic diseases; they belong to the great division of Tonics and Stomachics.

Fomentations (see Demulcents and Emollients) are warm fluids, applied for the purpose of encouraging perspiration on the skin, and thereby to diminish inflammation, and to render the skin yielding, so that the swelling which accompanies inflammation may be less painful, by the greater readiness with which the skin yields than when it is harsh and dry. The usual practice, therefore, of rubbing, dabbing, or pressing, is improper. The patient must be as well defended as possible from exposure to wet, by having something placed under him; and then a piece of thick flannel, or blanket, after being saturated in the warm fomentation, is to be instantly wrung, and laid liberally on the part of the body affected, and covered with oiled silk or a jack-towel, to keep in the warmth. This process is to be repeated every ten minutes or so, for hours if necessary. The foot or hand may be fomented by mere immersion, the heat of the fluid to be kept up by the addition from time to time of more which is hot. Warm water, as already stated, makes of course the readiest fomentation, and is generally the best.

Laxatives is a common appellation for the milder group of Cathartics already described.

Narcotics—known also as *Anodynes, Soporifics*, and *Hypnotics*—are those substances which diminish the natural degree of action in the body, and tend to remove irritation or pain, inducing in general a state of repose. Before this quieting effect is produced, however, there is a primary excitement of short duration, which is well exemplified in the case of opium. Sedatives, viewed as a separate class, are believed to allay pain and promote sleep, without possessing any stimulating qualities. Unless where excessive pain is present, narcotics may be regarded as a class of medicines only to be used with great caution, and never free from danger. Opium and its preparations, lettuce extract, henbane, foxglove, Indian hemp, hemlock, belladona, and tobacco, are some of the strongest narcotics. It is difficult to say which of these is the safest: 'idiosyncrasy,' says Dr Neligan, 'has a remarkable influence on the effects of narcotics: we meet with some individuals almost insensible to their action; while in others small doses produce a dangerous stupifying effect, or in some instances give rise to a degree of excitement amounting to furious delirium. But habit influences the action of narcotics on the system more than any other circumstance—their power being diminished in an extraordinary degree by repetition. Where, therefore, their continued administration is required, it will be necessary gradually to augment the dose, in order to produce their usual effects. The influence of age on their action must be also borne in mind in their administration, the young being much more susceptible to their influence than individuals of maturer age.'

Purgatives is the generic term in ordinary language for all Cathartic remedies.

Refrigerants, known also as *Temperants*, are substances calculated to diminish the heat of the body when morbidly increased, and to produce a soothing sensation of coolness. Applied externally as cooling or evaporating lotions to any inflamed part, their operation is easily understood, as they serve merely to reduce the temperature by carrying off the excess of heat. Taken internally, their mode of action is not quite so clear, for though they produce the sensation of coolness, they do not in reality reduce the temperature of the body. The most common refrigerants are vinegar, citric acid, tartaric acid, lemon-juice, the fruit of the orange, nitrate and chlorate of potash, and conserve or confection of dog-rose. The principal use of these preparations in practical medicine, is in the treatment of fever and inflammatory affections, in which their direct action on the stomach seems to occasion sympathetically a reduction in the force of the circulation.

Sedatives, to which allusion has already been made under the head Narcotics, are those substances which directly or primarily depress the vital powers without inducing any previous excitement. From their effects, which are directly contrary to those of stimulants, they are sometimes termed *Contra-stimulants;* occasionally *Calmatives*. With regard to the distinction which is made between them and narcotics, Dr Neligan remarks—'Were we merely to theorise on their mode of action, it would be perhaps difficult to draw an exact line of distinction, but when we come to consider the remedial powers of the medicines classed under each head, it will, I think, be at once evident how *practically* essential it is that we should recognise this as an especial class of remedial agents.' Hydrocyanic or Prussic acid, aconite, digitalis, hemlock, tartar emetic, chloride of formyle or chloric ether, and cyanide of potass, are the most energetic of this class. The diseases in which these remedial agents are employed are those of over-excitement of the nervous and vascular systems—some of them, as hemlock, acting more immediately on the nerves; and others, as digitalis, more directly on the vascular organs. It is necessary, therefore, before prescribing, to consider attentively the peculiar action of the different sedatives, in order to obtain the most immediate and efficient result. An important rule to be borne in mind with reference to the operation of contra-stimulants is, 'that the dose must be in general proportioned to the degree of excitement present; this *tolerance* of medicines is remarkably illustrated by the large doses of *tartar emetic*, which are administered not only with impunity, but with advantage, when inflammatory action runs high.'

Sialogogues are a small and but seldom-employed class of substances. Their function is that of a *local* stimulant to the salivary organs, increasing the flow of their secretion. 'By this definition we exclude,' says the authority before quoted, 'the so-called remote or specific sialogogues, as the preparations of mercury, gold, &c. which generally produce an increased flow of saliva when their internal use has been continued for some time; but as their remedial powers do not depend merely on the increase of this secretion, it will, I think, be more practical to confine the term *sialogogue* to those agents which are employed as direct stimulants to the salivary glands.' Horse-radish in a fresh state, mezereon, and pellitory of Spain, are vegetable roots possessing this property—the latter especially so. They are chewed in small fragments, and the saliva assiduously rejected.

Soporifics, a familiar term for the milder agents of the class Narcotics. See also Sedatives.

Sternutatories, as the name implies, are substances which provoke sneezing, and relatively an increased discharge from the mucous membrane of the nostrils: they have been already adverted to under the head Errhines (literally, into the nose).

Stomachics and *Tonics* form another class of medicines, acting by absorption into the blood, or as vital agents, which cannot be ranked either amongst those which excite action or those which repress it. The former increase the digestive powers of the stomach, the latter renovate the tone or contractile energies of the muscular fibre. They are slow in their operation, and augment the strength of the body without materially exciting its actions. As these two kinds of medicines are not very distinctly separable, it may be better to enumerate them together. Good nutriment is the most natural and best supporter of the bodily powers, but to effect this purpose, it is necessary that the function of digestion should be in a proper condition. Gentian root, quassia, chamomile, calumba, and canella, assist powerfully this object. Amongst the tonics, Peruvian, cascarilla, cinchona, angustura, and willow barks, the preparations of iron, the sulphuric and nitric acids, are in greatest repute. 'There is no class of remedial agents,' says a high authority, 'which requires more discrimination in their administration than tonics, nor any the injudicious use of which more frequently produces evil consequences. The diseases in which this class of remedial agents are principally employed must manifestly be those of diminished power. In no case, however, should they be prescribed where there is a tendency to irritation or inflammation of the digestive organs, or where the secretions are in a depraved state, without the previous use of means calculated to remove the former or correct the latter; to effect which, the employment of mild purgatives will in most instances be found best adapted. Tonics have a marked action on the various organs of secretion—their effects being to restore them to a healthy state. They are consequently administered with the view of diminishing secretion when it is excessive, or of restoring it when deficient, if either condition depend, as it frequently does, on inertia or want of tone in the secreting organ.' Independently of their tonic properties, some of the remedies contained in this class possess a specific power in ague and other periodical diseases; hence they have been denominated *Febrifuges*.

As remedial agents, few are more largely employed at the present day than tonics and stomachics, not only for the purpose of renewing tone and strength where debility actually exists, but with the view of imparting additional vigour—hence the term *corroborants*—where the constitution is in ordinary condition. It is needless to say that the latter is altogether a mistaken notion; and that the best and safest of all corroborants are—proper dietary, clothing, exercise, cleanliness, freedom from harassing cares, and those general regulations insisted upon in the article PRESERVATION OF HEALTH. Were those regulations attended to as they ought to be, the class of remedial agents now under review might safely be swept from the lists of medicinal preparations.

Stimulants is the general term for remedies which excite sensation in the sentient parts, or motion in the muscular parts—in other words, any excitement of the vital energies. It is usual to distinguish them as *general* and *special*, according as they affect the whole system, or exert a peculiar influence on individual organs or on the system generally. 'It is difficult, however, to define'—says Neligan, whose account of this class we shall adopt—'what is understood in the practice of medicine by the term Stimulant, excitement of the vital energies being produced by such different means under different circumstances. With no class of remedies, therefore, is it more necessary to bear in mind the truth of the maxim, that medicines act merely *relatively*. In their mode of action when administered internally, General Stimulants resemble in some respects Tonics; thus immediately after their administration a feeling of increased tone or power is produced, which, however, is not permanent, but is almost invariably followed by a corresponding depression of vital power; their effects also are more immediate, and more manifestly perceived by the senses, than those of Tonics. Many of them are also closely allied to Narcotics; for example, alcohol and the ethers, the secondary effect of both of which, particularly if given in large doses, is to produce sleep and coma. This does not, however, appear to be, as with Narcotics, from any direct action on the nervous system, but rather to result from the previous over-excitement of the vital energies. The great number of medicines contained in this class, and the material difference of their action in relation to the particular effects which they produce, preclude the laying down of any general rule for their administration.' The general stimulants usually enumerated are—alcohol, sulphuric ether, preparations of ammonia, camphorated acetic acid, camphor, anise, capsicum, ginger, cardamomum, caraway, cinnamon, oil of cassia, cocculus Indicus, lavender, mint, pepper, nutmegs, oil of turpentine, rosemary, sherry wine, sulphur, chloride of soda, chloride of lime; and to these we may add electricity in its various developments.

With regard to Special Stimulants, 'many of them give rise to some alteration, which is not well understood, in the nature or quality of vital action, when they are called *Alteratives*; while others possess a special influence in the treatment of certain diseases, when they are denominated *Specifics*. Many alteratives and specifics have been already described in other classes of medicines, but the articles contained under this head cannot, with a regard to accuracy of arrangement, be included in any of them; inasmuch as the primary influence which some of them exercise on the animal economy has not been satisfactorily ascertained, and others possess a peculiar influence over *certain organs* or *diseases* merely. As examples of the former, we may refer to mercury, iodine, and gold; of the latter, to nux-vomica, cubebs, and copaiba.' The special stimulants commonly enumerated are—iodide of arsenic, iodides and chlorides of gold, bromine, copaiba, cubebs, numerous preparations of mercury, iodine, nux-vomica, iodide of potass, and some marine substances containing iodine, as sponge and cod-liver oil.

Under this section we have mentioned the therapeutical use of alcoholic liquors; and as much error seems to prevail on this matter, we shall here present in brief the opinions of Drs Christison, Pereira, Neligan, and other modern authorities. We avoid the testimony of the older medical schools, as having an evident bias to the employment of these agents; as much as we avoid the dogmas of those who would altogether discard them:—Alcohol, in all its forms, is a highly valuable therapeutic agent. In moderate doses, properly diluted, it acts as a general stimulant, exciting particularly the vascular and nervous systems; in somewhat larger doses, it produces the well-known effects of intoxication; and in excessive doses, it acts as a powerful narcotic poison, rapidly causing death, preceded by slow pulse, contracted pupils, and coma. This effect is most usually observed when a large quantity of ardent spirits is swallowed at once, as for a wager. As a stimulant, alcohol is employed in medicine to support the vital powers in the advanced stages of fevers, particularly those of a typhoid character; for this purpose brandy or whisky is usually employed, but wine is generally preferred. It is also often used as a household medicine in flatulent colic, in indigestion, in vomiting, and in fainting; but for these purposes it is a perilous remedy when resorted to frequently, because apt to lead to the vice of habitual over-indulgence. Mere alcohol is seldom used as a diuretic in regular practice; but it is a powerful and familiar remedy of the kind when united with certain essential oils, of which combinations the most esteemed is Hollands. As an external stimulant, it is a common ingredient in lotions for sprains and bruises, for many forms of external inflammations, as erysipelas and erythema, for various skin diseases, to prevent excoriations in parts exposed to long pressure, and with friction over the region of the heart in syncope and suspended animation. In consequence of its producing cold by evaporation, alcohol is frequently added to cooling and evaporating lotions. Wines, we have said, are also used internally as stimulants, and for this purpose are often better suited than any other alcoholic liquid. Their use is particularly called for in the advanced stages of typhoid fevers, and where delirium is present, with much sinking of the vital powers. They are also given with advantage in convalescence from acute diseases, in chronic debility, especially when it is caused by excessive discharges, in mortification unaccompanied by inflammatory symptoms, and in tetanus or lock-jaw. When any local congestion or inflammation is present, or may be apprehended, the administration of wine in the treatment of disease is for the most part calculated to do mischief. Although sherry is the only wine officinal in the pharmacopoeia, port is generally employed in medicine; claret and Madeira are also used. When its greater strength and astringency are not objectionable, port wine is always to be preferred. Madeira and claret are often inadmissible, on account of their acidity; but when this is not the case, the former is well adapted for debilitated or broken down habits, the latter when the employment of stronger wines might prove injurious. Sherry is chiefly employed in the preparation of medicated wines; but Cape wine, on account of its cheapness, is usually substituted by druggists. In a dietetical view (see BEVERAGES), sherry is the wine in most general use, and the one calculated to agree best with most constitutions.—Such are the opinions of medical authorities with regard to the medicinal or therapeutic uses of alcoholic liquids; and by their enlightened and unbiassed directions ought unprofessional parties to be implicitly directed. The dietetic, habitual, or conventional employment of these beverages is altogether a different question.

Sudorifics (see *Diaphoretics*) are medicines which increase the cutaneous perspiration. Certain substances received through the stomach into the blood, excite through it the vessels of the skin to action, and increase the natural discharge. The mode in which this result is effected is not well known; all we know is, that, during the operation, the heart, and the blood-vessels which terminate on the surface of the skin, are roused to unusual action. Among the most active sudorifics may be enumerated warm drinks; the warm bath; the preparations of antimony, including James's powder; Dover's powder (compound ipecacuan powder); the preparations of ammonia; and all medicines generally which nauseate the stomach. Probably of all these Dover's powder is the best. Sudorifics, in almost all cases, when early used, prevent the effects of colds, which, when neglected, prove so often fatal in their consequences. During the administration of sudorifics, it is essential that the surface of the body should be kept warm; and for this purpose a bad conductor of heat, such as flannel, should be employed. Care also must be taken to avoid the application of cold, either by exposing the surface of the body to cold air, or by the use of cold drinks while the perspiration continues, or for some time after it has ceased; lastly, when it is wished to check the perspiration, this must be done gradually, by drying the surface of the body with dry warm towels, by diminishing the covering, and by cautiously exposing the hands and arms to the air.

Vermifuges is an old and popular term for the remedies treated under the head Anthelmintics.

Medicine Taking.

The principal medicines employed at the present day for the alleviation or cure of disease have been now enumerated, in an arrangement which may show their several properties and modes of operation. The information will have the effect, we humbly imagine, of dissipating some portion of that veil of mysticism which enveloped the art of medicine, and of showing what are the rational objects to be expected from the action of drugs upon the animal frame. There are at present two injurious opinions prevalent in the world on this subject, both of which are entertained alike by the ignorant and by the enlightened, and which are equally at variance with the truth, and noxious in their consequences. The first of these opinions is, that the science of medicine is from beginning to end a deception; that medical men are as much in the dark as their patients with regard to the cause and nature of disease, and are consequently quite unable to provide a remedy. This opinion is generally to be found in its greatest strength among those who set themselves up as free-thinkers on all subjects, and is the natural result of the mystery which has for ages degraded the art of medicine and obscured its true objects; for wherever there is mystery, a belief in, and dread of, chicanery ensues. Enlightened men are more liable, upon the whole, than the ignorant to imbibe this feeling of distrust. One of the most elegant writers of the day, for example, bitterly and satirically defines medicine to be 'the practice of pouring substances of which nothing is known, into bodies of which still less is known.' This is merely satire, it may be said; but satire is seldom attempted, and never becomes current, unless it be directed against a thing which is supposed to deserve it. An opinion of this kind of course leads the person who holds it to regard the regular physician and the empiric as upon a level, and to look upon the prescriptions of the one as equally contemptible, or, in other words, equally valuable, with those of the other. The second opinion, which we alluded to as being prevalent in the world, is directly the reverse of the first, and is more common amongst the ignorant than amongst the intelligent part of mankind. It is a belief in the boundless powers of medicine, which leads those who entertain it to treat their bodies as if these had been designed by nature merely as receptacles for drugs. This opinion tends also to render those who hold it a prey to every successive nostrum that knavery and quackery can invent. It is based upon the very same foundation as the opposite opinion—namely, the mysticism that obscures the true objects and powers of medicine, for with some minds whatever is dark and mysterious, becomes invested with supernatural qualities.

The persons who thus consider the art of medicine as unlimited in its powers, and believe that the body can never be in a proper state unless under the influence of some drug, are generally those who pore over all the medical books they can get hold of, and imagine themselves successively to be the subjects of every disease described. As it would be too expensive to employ every day of their lives a regular physician, they acquire the habit of prescribing for themselves, or of trusting to the prescriptions of an empiric. If these persons perceive, for example, that inflammation in the side is described as characterised by pain in that region, they immediately become alarmed on account of some pain which has troubled them for some time in that quarter, and fly to bleeding and blistering, while, probably, the pain which they felt was merely the consequence of a little flatulence or wind on the stomach. A regular medical man, or any person acquainted with the subject, would have informed them that a chain of symptoms was necessary to establish the fact of inflammation of the side, pain being more or less a characteristic of almost all diseases. By thus observing a prominent symptom in every disease, and imagining their own weakened frames to present an example of it, it is not uncommon, as we said, for persons of this turn of mind to conceive themselves affected in succession with all the ills that flesh is heir to. Finding an enumeration of remedies accompanying the descriptions of diseases in the books they read, they try medicine after medicine, till they impair their bodily powers, and create diseases where none originally existed. Sometimes this method of self-drugging and self-killing is varied by a mania, equally destructive, that leads them to the trial and use of all the pretended remedies which ignorant empirics foist so unremittingly on the world. Those knavish gentlemen, generally termed *quacks*, know thoroughly the points upon which the success of their gulling depends, and accordingly publish imaginary letters addressed to themselves, descriptive of cases in which their invaluable medicine, in the form of drops, pills, powders, or elixirs, 'has been of incalculable service.' These cases embrace every disease, and every symptom of disease, under the sun; and the infatuated beings who read and trust to them find always some fictitious case of cure, which appears to resemble their own complaint, and accordingly are deceived into the purchase of the 'invaluable medicine.' Were these quackeries simply impositions upon the credulous of a harmless drug as a valuable one, the evil would not be so great; but exceedingly few of them have so much merit as to be innoxious. On the contrary, the records of the criminal courts tell a fearful tale of credulity, punished in many instances by death. The examples of this are so notorious as to need no further notice, and we hope that they will make a lasting impression on the public mind. Were people only to consider, however, how excessively inconsistent with each other are the numerous purposes which these nostrums affect to accomplish, how improbable it is that men ignorant of the structure and diseases of the body should have discovered remedies which have baffled the search of those who have studied the frame deeply, and have mastered all the accumulated knowledge of preceding ages on the subject—if they consider these, and many similar arguments, certainly so much credulity would not be evinced on a subject affecting so deeply the comfort and even the existence of man.

It is not with a view to increase the number of those who tamper, in the way described, with medicines that the preceding pages have been written. If such should be the consequence of the information they contain, no one would deplore it more sincerely than ourselves; but we confidently hope that, as far as their humble influence extends, the result will be very different. Those to whom the action of medicines on the system is a mystery, may fly to the quack for a nostrum, or try to discover one themselves; but those who have given the subject so much attention as to be aware that the action of medicinal substances on the body is as varied as the disorders which they are applied to remedy, and at the same time to a great extent demonstrable and intelligible—those who are possessed of this knowledge will scout the idea of a universal panacea, and despise the quack and his nostrums, while at the same time their confidence in the man who has devoted his days to the consideration and relief of disease will be increased tenfold, since they are assured that his objects and his plans are consonant to the soundest principles of true science, of reason, and of common sense.

We have just one word of advice to give in conclusion, and it is this: When any one feels himself afflicted with a complaint anyway beyond a very slight indisposition, let him at once, and without a moment's delay, send for a regular and skilful medical attendant, to whom let him communicate freely the state of his feelings, as well as what has been his previous course of life. Every hour he postpones the execution of this necessary duty, he increases in an immense ratio the chance of premature dissolution; indeed it is our firm belief, founded on very sad experience, that one-half of the deaths which occur might for the time be averted were proper medical advice to be sought for and attended to at the outset of diseases. The grand error in most people consists in 'putting off sending for the doctor' till it be too late; and hence many valuable members of happy social circles—fathers, husbands, mothers, sons, and daughters—are snatched away in the bloom or prime of life, leaving friends and relatives to mourn over the grave of their disappointed hopes.

To these remarks on *medicine taking* by the adult and responsible, we may add with equal advantage the following observations by Dr Combe on the absurd and too-often fatal practice of indiscriminate *medicine giving* to the young and helpless, who are incapable of taking care of themselves:—'Many mothers are continually administering medicines of one kind or another, and thereby deranging instead of promoting the healthy operation of the infant system. Instead of looking upon the animal economy as a mechanism constituted to work well under certain conditions, and having, in virtue of that constitution, a natural tendency to rectify any temporary aberrations under which it may suffer, provided the requisite conditions of action be fulfilled, they seem to regard it as a machine acting upon no fixed principles, and requiring now and then to be driven by some foreign impulse in the shape of medicine. Under this impression they are ever on the watch to see what *they can do* to keep it moving; and altogether distrustful of the sufficiency of the Creator's arrangements, they no sooner observe a symptom, than they are ready with a remedy. Such persons never stop to inquire what the cause is—whether it has been, or can be, removed—or whether its removal will not of itself be sufficient to restore health. They jump at once to the fact that disease is there, and to a remedy for that fact. If the child is convulsed, they do not inquire whether the convulsions proceed from teething, indigestion, or worms, but forthwith administer a remedy *to check the convulsions*; and very probably the one used is inapplicable to the individual case; and both the disease and the cause being, in consequence, left in full operation, instead of being removed, the danger is increased. . . . I have no hesitation in expressing my conviction that a child can encounter few greater dangers than that of being subjected to the discipline of a medicine-giving mother or nurse; and wherever a mother of a family is observed to be ready with the use of calomel, cordials, anodynes, and other active drugs, the chances are, that one-half of her children will be found to have passed to another world.

Even when the child is under the care of a professional adviser, it is by no means safe from the risk arising from the exhibition of heterogeneous medicines. Whenever a child is seriously ill, there is not only great anxiety on the part of the mother, but much sympathy on the part of friends and neighbours, every one of whom has her own story of what was done with such another child in the same situation, and the great good obtained from such and such medicines. In vain the mother may urge that the physician has seen the patient, and already prescribed a different course. Intreaties are poured in with an earnestness proportioned to the danger, just *to try* the vaunted remedy *without telling the doctor*, or interrupting the use of his medicines. Anxious for the relief of her child, the mother often yields before her better judgment can come into play to prevent her, and in a short time the child perhaps suffers from this abuse of incompatible or dangerous remedies, which aggravate the original disease. Those who are accustomed to reflect before they act, would be amazed if they were to witness the perilous follies sometimes perpetrated in this way, and the perfect self-complacency with which the anticipated results are looked for from the individual doses, no matter how much they may counteract each other. . . . The system of concealment from the family physician, into which the adoption of "everybody's" advice is so apt to lead, is itself an evil of the first magnitude. By inducing him to ascribe effects to wrong causes, it necessarily tends to mislead his judgment, and may thus render him also unwittingly an instrument of mischief. The maternal anxiety which lies at the root of the error is highly natural, and every sensible practitioner will make allowance for its impulses, even where they are ill-directed and annoying to himself. But the fair and proper way for the mother is, not to act upon the suggestions of others without the knowledge of the medical attendant, but to state simply, and in an honest spirit, that certain suggestions have been made, and inquire whether they meet with his approbation or not. If they do, they will then be adapted by him to the necessities and peculiarities of the individual case, and the different parts of the treatment carried on consistently and safely. If, on the contrary, they do not, the physician will have an opportunity of assigning a reason for his disapproval, and of pointing out the greater fitness of the means already employed; and if the parent shall not be satisfied with this explanation, but still insist on the suggestion being tried, he can then either decline farther responsibility, or take care that the trial be made with as much safety and prospect of advantage as possible.'

In regard to the quantities of medicine to be employed as doses, that is a branch of the subject which we leave entirely in the hands of the medical practitioners properly empowered to administer them. It may here, however, be mentioned, as an interesting fact, that the action of the dose by no means corresponds with the quantity. The general rule seems to be, that when a too large dose of a medicine is taken, nature makes an effort to expel it, and it is accordingly vomited without doing the intended good. A dose of a moderate size pushes its way to the bowels, which it irritates, and causes to act with a degree of violence. A dose of a smaller size will act only on the stomach. The action of medicines in the stomach is by absorption into the system; and as the stomach is always less or more filled with fluid materials, it follows that the medicines received are diluted, and have a correspondingly weak, or at least slow influence on the absorbents. Thus it has been found that a few drops of certain medicaments dropped on the tongue, by which they are absorbed at once into the system, have as powerful an effect as twenty times the quantity poured into the stomach. (See also statement in p. 755.)

HOUSEHOLD SURGERY.

We now come to the operations of surgery, and here we again wish it to be understood that our aim is in nowise to interfere with the functions of the legitimate practitioner, but rather to facilitate his success by conveying to the ordinary reader some idea of an art from which it may be his misfortune sooner or later to crave assistance. What we chiefly propose is, to show how to manage in cases of accidents and emergencies when and where the doctor is not to be had, and when delay or non-assistance might prove fatal. An interval must necessarily elapse between the occurrence of an accident and the arrival of medical aid, and for want of presence of mind, and a little knowledge how to proceed during this interval, the future efforts of the doctor are often rendered unavailing. Where medical aid is to be had, however, let it be instantly called for. 'Whoever neglects this advice,' it has been quaintly but forcibly said, 'and doctors himself when he can be doctored, is in much the same case as the man who conducted his own cause, and had a fool for his client.'

As stated in the previous section, medicine and surgery are always less or more combined; and for the successful practice of either, even on the simplest domestic scale, it will be necessary to be possessed of certain articles and appliances. For families, and country families in particular, a medicine-chest, supplied by a qualified druggist, is an almost indispensable requisite. Such a store should always be kept with care and caution, and should contain ingredients for simple poultices and fomentations, for cerates and ointments, liniments and lotions; with a few fresh tonic, antacid, purgative, sedative, stimulant, and other common medicines. In this little store everything should be carefully labelled with the name and the doses for children and for adults, and be kept, if possible, in closely-stoppered bottles. Such medicines as castor-oil, syrup of senna, calcined magnesia, laudanum, rhubarb, gum, lime-water, prepared chalk, croton-oil, quinine, calomel, syrup of squills, and so forth, no household should ever be unprovided with; and as for apparatus, a graduated glass measure, a pair of scales and weights, a lancet, scissors, a cupping-glass, perhaps, and a scarificator, are all that is ever likely to be required. It is supposed of course that in every family there are soft clean linen rags for rollers and bandages, and that there is always at hand salt, mustard, vinegar, sweet oil, treacle, flour, loaf-bread, and we may add, without a shadow of countenance to intemperance, some alcoholic stimulant, as brandy. Possessed of presence of mind and a pair of ready hands, and fortified with the above adjuncts and appliances, we may suppose the reader qualified to comprehend and to understand how to act in the cases we are about to describe. In this description we have specially made use of 'Hooper's Medical Dictionary,' as edited by Grant—a little pocket volume on 'Household Surgery,' by Mr South (Cox, London)—and a map-sheet entitled 'Accidents and Emergencies,' by Mr Alfred Smee (Churchill, London), which should be hung up in every nursery, school-room, and factory:—

Bleeding—Blistering.

Bleeding may occur from an artery, vein, or the small vessels which join the arteries with the veins. Arterial blood is known from its bright scarlet colour, and from its issuing in jerks; venous blood by its dark colour and continuous flow.

The best mode of bleeding to be adopted by an unprofessional person is by *cupping*, which is easily learned, although we have no room for the directions. In the absence of a proper instrument, a common cup, or a tumbler (if of a bellying shape, so much the better), may be turned down upon the part, after the air has been rarefied with lighted tow or paper. The skin rises into this, and is afterwards to be wounded with a lancet or sharp knife in half-a-dozen places. Bleeding in the arm is a delicate operation, owing to the neighbourhood of the great artery, and must be learned from a regular practitioner.

Leeches form a safe and convenient mode of bleeding. When they are inconveniently fastidious in their appetite, the skin may be scratched with a needle-point till the blood comes, which will generally be irresistible. A warm bread-and-water poultice, renewed every half-hour, is better for encouraging the bleeding than sponging with warm water. Never let a person go to sleep while leech-bites bleed, as many persons, especially children, have died therefrom. To stop the bleeding, apply your finger for some time to the wound, or use a piece of linen and bandage.

Bleeding from wounds is stopped by pressure on the part; or, if necessary, the ends of any little artery that may be severed are to be tied with a thread; or when the bleeding is important and continued, the main artery that supplies the limb may be stopped till medical assistance is obtained; in the case of the arm, by pressing the thumb behind the middle of the collar-bone; and in the case of the leg, below the crease of the groin. When the bleeding is below the middle of the upper arm, or thigh, a stick tourniquet will answer the purpose. It is merely a handkerchief passed two or three times round the limb, above the wound, and twisted as tightly as may be necessary by means of a stick. For want of this simple precaution, a considerable number of lives are annually lost on our railways and at our great public works.

When blood is coughed up, it is known to come from the lungs by its frothiness, if in small quantities, and its pure bright redness when more plentiful; and when vomited from the stomach, by its dark colour. In either case, all that non-professionals can do is, to keep the patient cool in bed, with his head slightly raised, to enjoin absolute quiet, and give a tablespoonful of vinegar in sugar and water, or a single drop of oil of vitriol in a wine-glass of sugar and water, every half-hour, until the surgeon arrives. When the discharge is from the lungs, the fainter the patient becomes the less danger is to be apprehended.

In blistering, the chief thing to be attended to is, never to allow the plaster to remain on a child under ten years of age longer than till the skin has become well inflamed, which will be in three or four hours at most; and that if any of the disagreeable effects of blisters are feared, they may be easily avoided by covering the plaster before application with tissue paper.

Cuts—Bruises—Wounds.

An ordinary cut or chop with a knife, chisel, axe, and the like, even if it severs a finger or a toe, is only dangerous to the irritable or intemperate. Do not be in a hurry; carefully clean the wound from all dirt or other extraneous matter, and dab with a sponge, dipped in cold water, till all bleeding stops. If the wound be extensive, you may leave it open for half an hour, then bring the corresponding edges together as perfectly as possible, and while thus held, some strips of plaster are to be laid across the wound, with small spaces between every two, so as to allow the escape of an oozing fluid, which often continues for some hours. The edges of the wound should not be dragged tightly together, but merely kept in place by the plaster; and if the wound be in the finger, arm, toe, or leg, it is better that the ends of the plaster should not overlap. If common sticking-plaster be not at hand, court-plaster will do; or thin bands of tow may be wrapped round the part, and smeared with gum-water. Or if nothing else is at hand, a bit of linen rag, by absorbing the blood, constitutes itself a plaster as the moisture dries. In other cases, the parts may be sewn together with a strong needle and silk, as many single stitches being employed as are necessary for that object, and no more. The needle, well oiled, should be thrust well through the skin, which is about a third of an inch in thickness, and each stitch should be tied into a knot. The stitches may be taken out in about twenty-four hours, by carefully cutting the thread on one side of the knot, and gently pulling the other end.

The dressing is to be left on for several days, unless the wound grow painful and throb; in which case it is to be taken off by the aid of warm water or a soft poultice. If the discharge is inodorous, straw-coloured, and creamy-looking, you may apply the plaster again; if otherwise, the wound must be poulticed till these wholesome signs appear. *A bruised cut* must be poulticed with bread and water to moderate the inflammation, and then with linseed-meal, till new flesh grows instead of that which has been killed by the blow. The latter comes away in appearance like a piece of wetted buff-leather. *Scratches* are often fatal, in consequence of soap, pearl-ash, or filth of any kind getting into them, and should therefore be kept covered. *Pricks* with a thorn, &c. are likewise dangerous, occasionally producing locked jaw. Poulticing, leeching, lotions, &c. must be had recourse to if serious appearances present themselves; with a smart dose of calomel inwardly, and some hours after, castor-oil.

Bruises are often attended with the rupture of small blood-vessels, which bleed internally, and cause discoloration. Put the patient in bed, cover the injured part with a cloth dipped in cold water, or spirit and water, and change the cloth every few minutes. If the bleeding increases rapidly, send off with all possible haste to the surgeon, as life will be risked if the vessel is not tied. Use, if possible, the handkerchief and stick as a tourniquet. In the case of a serious bruise, a dozen leeches may likewise be necessary, but only for an adult, and they may require to be repeated two or three times. With regard to the too frequent bruise technically called 'a black eye,' bathing and patience are the only remedies.

Stabs from sharp or pointed instruments are more dangerous than common wounds. Stop the bleeding by the processes already recommended; do not attempt to bring the edges of the wound together, but rather keep them apart; lay a rag over the wound dipped in cold water, and change it every half-hour. Place the patient at once in bed, and enjoin quiet. Should fainting take place, act as directed under that head.

Scalds—Burns—Frost-bites.

The action on the skin of a hot fluid, as boiling water or melted grease, is called a *scald*; that of a solid body, as red-hot iron, a *burn*. The effects of burns are threefold—either simple redness and pain, blisters, or the total destruction of the parts. For redness, Mr Snoe recommends protection from the air by wet lint or linen covered with oiled silk; or, if oiled silk is not at hand, to cover with several layers of linen, slightly wetted with common water, or Goulard water. The part may also be covered with raw cotton, if it can be procured. If blisters arise, leave them alone, if not very tense; and if they be very tense, puncture with a fine needle, and keep on the lint and oiled silk. Absence of pain over the injured part is a bad sign, and shows that it is destroyed. Apply linen and oiled silk as before, or a bread-and-water poultice. 'The object in treating scalds and burns,' says Mr South, 'is to keep up for a time the great heat or high temperature to which the injured part has been raised by the scalding or burning, and to lower this by degrees to the natural heat of the body. The best and readiest dry materials to be applied are flour, or cotton, or cotton-wadding; the wet are—spirits of turpentine, spirits of wine or good brandy, lime-water and oil, lime-water and milk, milk alone, or bread-and-milk poultice; and all these wet applications must be made of sufficient warmth to feel comfortable to the finger, but not hot.' When the blisters become uneasy, after the lapse of perhaps from thirty to fifty hours (for the pain moderates in a few hours after the accident, unless it has been very severe), they must be carefully cut open and dressed.

When the clothes catch fire, the person should be rolled in the carpet or hearth-rug as quickly as possible, in order to stifle the flames. Firmness and presence of mind are essentially requisite in accidents of this nature; and for want of these, numerous lives are hourly sacrificed. The clothes, if any, over the parts injured should be cut away, but only so far as they will come easily. The patient, if severely injured, must be kept moderately warm; and if he continues to shudder or shiver, a little hot wine and water, or spirits and water, should be administered. If excessive sleepiness or stupor, or difficulty of breathing sets in, or great pain ensues about the stomach, danger exists. The surgeon should be consulted in the case even of the slightest scalds or burns, if large in size; for then, especially in children, there is ground for alarm.

Chilblains and *Frost-bites* are the familiar names given to the effects of excessive cold on the surface of the body. In its action on the skin, extreme cold somewhat resembles burning, producing redness, pain, blisters, or destruction of the parts. In restoring a frozen person, or a frost-bitten part, the object is directly the reverse—that is, to keep the cold, which by its exposure the body has acquired, and to withdraw it by slow degrees till the body has recovered its natural heat. If the person or part be brought suddenly into a hot room, or put in a warm bath, he or it will be killed outright. 'The frozen person,' says Chelius, 'should be brought into a cold room, and after having been undressed, covered up with snow, or with cloths dipped in ice-cold water, or he may be laid in cold water so deeply, that his mouth and nose only are free. When the body is somewhat thawed, there is commonly a sort of icy crust formed around it; the patient must then be removed, and the body washed with cold water mixed with a little wine or brandy: when the limbs lose their stiffness, and the frozen person shows signs of life, he should be carefully dried, and put into a cold bed in a cold room: scents, and remedies which excite sneezing, are to be put to his nose; air is to be carefully blown into the lungs, if natural breathing do not come on; clysters of warm water with camphorated vinegar thrown up; the throat tickled with a feather; and cold water dashed upon the pit of the stomach. He must be brought by degrees into rather warmer air, and mild perspirants, as elder and balm tea (or weak common tea), with Minderer's spirit, warm wine, and the like, may be given to promote gentle perspiration.' Frost-bitten parts should be bathed or rubbed with cold water or snow. A sudden application of heat instantly and irrecoverably destroys the vitality of the parts. For chilblains, employ friction with soap liniment. Various chemicals, such as nitric acid, nitrate of silver, strong sulphuric acid (oil of vitriol), &c. may destroy some parts of the skin. In such cases cover with linen and oiled silk, or bread-and-water poultice, as directed in the case of ordinary burns.

Sprains—Dislocations—Fractures.

Sprains are sudden strainings of the tendons and ligaments, and always require time for their complete recovery. For injuries of this kind warm moist flannels applied to the part, and a bread-and-water poultice on going to bed, are recommended; but this, in our humble and unprofessional opinion, is only adapted to cases in which the patient thinks proper to look forward to weeks of such coddling. We have before now cured ourselves in a few hours of a severe sprain of the ankle-joint, attended with swelling, by fomentations of water as hot as we could bear them.

Dislocations of the joints are common accidents among an active and mechanically-employed population. Severe injuries and sprains are sometimes apt to be mistaken for dislocations; but in the latter case the joint cannot be moved, while its form is manifestly altered. When such an accident occurs, make no attempt at reduction or setting of the joint till the surgeon arrives, or you may make the patient worse. Time is always an important object, as the longer the reduction is delayed, the more difficult is it to be accomplished. A dislocation is reduced by the limb being returned to its place; and the chief difficulty lies in the instinctive or involuntary resistance made by the patient. A great part, therefore, of the operator's dexterity consists in his putting the sufferer off his guard at the critical moment.

Fractures.—People generally themselves know when a bone is fractured, from having felt it snap. There is mostly a distortion of the limb, and upon moving it, the ends of the bone may be felt distinctly to grate. Especial care should be taken not to move the patient roughly, otherwise the ends of the bone may be thrust through the flesh. Procure a door, or a hurdle, and place the patient upon it, and let him be carried carefully, and not in a cart or other carriage. If the patient has to be moved far, it would be a good plan to strap the limb, and apply an apparatus made by rolling a bunch of twigs, the length of the limb, in each end of a piece of thick sheeting tied round, after being applied, by three or four pieces of broad tape. By these means the limb would be kept better in situation. If a surgeon is within an hour's journey, and the day is not cold, it is better to wait and allow him to superintend the moving. In the meantime, if the skin be broken, take means to prevent bleeding; look also to fainting. Broken limbs should not be set—that is, bound up with roller, splints, and pads—for the first three or four days, as for some hours after the accident the part continues swelling, and if bandaged up tightly whilst this is going on, much unnecessary pain is produced; and if the bandages be not slackened, mortification may follow, which I (Dr South) have known to occur. It is best then, at first, only to lay the broken bone in as comfortable a posture as possible, and as nearly as can be in its natural direction; and it may be lightly bound to a single splint, merely for the purpose of keeping it steady. The arm, whether broken above or below the elbow, will lie most comfortably half-bent upon a pillow. The thigh or leg will rest most easily upon the outer side, with the knee bent. In the case of broken ribs, a flannel or linen roller, about six yards long and two hands'-breadth wide, must be wound tightly round the chest. Bleeding should not be had recourse to unless the patient complains of pain, or is troubled with cough. The bowels should be cleared with a purge, and twenty drops of antimonial wine, with a teaspoonful of syrup of poppies in a glass of water, given three or four times a day. After a few days, the person will find himself much more comfortable sitting up than lying in bed. In the special treatment, which must differ according to the parts injured, the patient should in every case be guided by the directions of the practitioner; the less one attempts to doctor himself in cases of this kind the better.

Poisons—Poisoned Wounds, &c.

Poison is the name for that which, when taken into the human body, or applied externally, uniformly effects such a derangement in the animal economy as to produce disease or death. It is usual to divide poisons according to the source from which they are obtained—as mineral, vegetable, and animal; or according to their effects—as irritant, narcotic, or narcotic-acrid. Whatever their nature or effects, those most frequently met with in practice are arsenic, certain salts of lead, oxalic acid, prussic acid, opium, laudanum, nux-vomica, poisonous fish and poisonous vegetables eaten through ignorance. In every case where there exists the least suspicion of poisoning, instantly send for medical aid, and meanwhile excite vomiting either by one of the emetics formerly mentioned, or by tickling the throat with a feather. Most poisons have antidotes or correctives—that is, substances which neutralise or modify their effects. In the case of arsenic, for example, olive-oil, milk, white of egg, or flour and water, should be repeatedly taken, and repeatedly vomited, till the surgeon arrives; in oxalic acid, chalk and water, with emetics, are found to be useful; and in the case of acetate of lead, an active emetic with sulphate of soda, or hydro-sulphuret of potash or ammonia, is likely to prove beneficial. In the case of opium or its extracts, excite to vomiting; dash cold water over the face; administer the strongest coffee after vomiting; make the patient walk between two persons; pull the hair, or otherwise inflict pain to prevent sleep. This treatment must be pursued for many hours. For prussic acid, it is recommended to 'give half a teaspoonful of hartshorn in brandy and water immediately, and repeat every ten minutes till the fourth time. Dash cold water upon the spine and face, to rouse, but not to chill the patient.' In vegetable poisons, emetics, conjoined with exhibition of animal charcoal, are generally adopted.

Under *Poisoned Wounds* may be classed the bites and stings of insects, serpent bites, the bites of mad dogs, or wounds poisoned by the absorption of dead animal matter. For stings, two or three drops of hartshorn are quite effectual; and for the after-irritation of bites or stings, a little spirits and water, or Eau de

Cologne, is said to be efficacious. As to dog-bites, 'not one in ten thousand comes from an animal which is mad. Where any one is bitten by a dog which is unquestionably mad, take a carving fork and break off one prong, and heat the other in the hottest part of a common fire. Apply this thoroughly to the whole of the bite, so as to destroy the surrounding parts. If a surgeon be within half an hour's journey, tie a string tightly immediately above the part, and use all possible despatch to secure his aid. In all suspected cases of madness, keep the dog chained up, for perhaps it may be a false alarm, and the continuance of the dog in health will be a great satisfaction to the party bitten. Wounds which are suspected to be poisoned by absorption should instantly be washed and fomented with warm water, and sucked with a small tube, with a view to remove the poison. When swelling and inflammation ensue, trust everything to the surgeon.'

External Inflammation is characterised by a feeling of heat and pain, redness, swelling, and throbbing, or formation of matter. For the first thirty hours or so use cold applications; after which, hot-water fomentations and poultices are best adapted. When taken in time, inflammation resulting from external injury may in general be subdued before assuming the ultimate stages of suppuration.

Lotions or Washes are employed to lessen the inflammatory condition of a part by diminishing its increased heat, which is one of the signs of inflammation; and they are of two kinds—cooling, and stimulating. The cooling lotion acts by means of evaporation, and should be applied by dipping a single piece of linen in the wash, and laying it upon the part, which of course is to be kept uncovered. As the evaporation goes on, the linen is to be kept moist with the lotion by means of a sponge. A spirit wash is made of half a gill of spirits of wine, or a whole gill of ardent spirits, to a pint of water; and a vinegar wash, by mixing one-fourth of vinegar with three-fourths of water. In case of very severe pain, a tablespoonful of laudanum may be added to a pint of lotion. 'Stimulating washes are employed for encouraging sluggish sores to heal. They are usually applied by dipping lint in them, which, being then put on the sore, is confined with a roller.' Common black wash is the most valuable of this kind, and is composed of a drachm of calomel in half a pint of lime-water.

Liniments are chiefly used to remove swellings, and are applied by rubbing *gently* with the flat of the hand for ten minutes or a quarter of an hour at a time. In the case of a large joint requiring the operation, the two hands are to be used, one at each side, and moved alternately up and down at the same time, making each hand travel half round the joint. One-third of hartshorn to two-thirds of oil make a good liniment for stiff neck and lumbago; another is an ounce of camphor rubbed down in four ounces of olive-oil; and a third, called *opodeldoc*, is composed of three ounces of hard white soap and an ounce of camphor, put into a bottle with half a pint of spirits of wine, or other strong spirit, and as much water, and shaken from day to day till dissolved. But the best is the mustard liniment, made of 'an ounce of fresh flour of mustard put into a bottle with a pint of spirits of turpentine, and shaken daily for two or three days.' After this, the liquid is fit to be decanted for use; and its advantage is, that it may be made to act slightly or severely, according to the length of time it is rubbed; to tickle, prickle, or smart the patient, or take off his skin, whichever he likes.

Fits—Convulsions, &c.

In Fainting, as in all other fits, the face and lips turn pale, the pulse is scarcely to be felt, the senses are lost, or very much diminished, and the power of motion is interfered with or takes place involuntarily. Place the patient flat, and the actions of the system will generally be spontaneously restored in a short time. This is accelerated by the horizontal position, which throws the blood on the brain, and thereby stimulates it to resume its wonted functions. Pungent volatile substances (smelling salts) applied to the nostrils, cold water sprinkled on the face or chest, and the internal administration of gentle stimulants (a little brandy in water) as soon as the patient can swallow, may also be resorted to. If coldness of the extremities continue, apply hot bottles to the feet and legs.

In Apoplexy, which is a sudden deprivation or great diminution of the powers of sense and voluntary motion, the pulse is generally strong; and the patient usually shows symptoms of pain or oppression over the head, which is aggravated when he lies down. Sometimes half the face drops, or half the body becomes powerless. Keep the head well raised; remove the neckcloth; unloose the shirt and all other clothes; and give nothing by the mouth. Send immediately for a surgeon, and if one cannot soon be procured, apply six leeches to the temples, if the pulse be strong.

Under Epilepsy the patient drops momentarily, and often issues a piercing shriek. The epileptic is apt to drop into the fire, under a cart, or other dangerous situation. Usually convulsions occur, especially in the face and limbs. The tongue is often bitten. The pulse is often not much altered. Lay the patient on a bed, with the head slightly raised. Undo neckcloth, unloose the clothes, place a piece of wood between the teeth, to prevent the tongue from being injured. Apply a cloth, dipped in cold water, over the head. The fit generally passes off in a few minutes, though I (Mr Smee) have known it to last for ten or twelve hours. If coldness ensue, apply warm bottles. After the fit, give an emetic if the stomach be gorged.

Hysteria or *Hysterics* appears under such various forms, imitates so many other diseases, and is attended with such a variety of symptoms, that it is difficult to give a just character or definition of it. In general the body is much agitated, and the patient gives way to alternate fits of laughing, crying, and screaming. The pulse is not much altered. 'Place the head over a basin, and pour water from a jug over the head and chest till the patient becomes chilly, and revives. Never use anything but cold water for the hysterical fit, unless the party turn very cold, when you should discontinue it, and apply warmth to the feet.' However dreadful and alarming a hysteric fit may appear, it is seldom accompanied with danger; and the disease never terminates fatally unless it changes into epilepsy, or that the patient is in a very weak reduced state.

Shock is described in Mr Smee's sheet, and recommended to be treated as follows:—A severe accident of any kind, as a bruise, fracture, scald, burn, or a sudden emotion, as that of joy, grief, or rage, or even a sudden attack of a serious disease, prostrates the vital powers. The face and lips turn pale, the pulse becomes scarcely perceptible, the body and extremities turn very cold. Place the patient flat; enjoin absolute quiet; and apply warmth to all parts of the body. Give a small spoonful of brandy and water every two or three minutes, and a few hours afterwards the same quantity of beef-tea. Constant care will alone preserve the patient.

Convulsion Fits, which so frequently carry off children, are usually caused by the constitutional disturbance incidental to their cutting their teeth; and the remedy, or rather the safeguard, against these frightful consequences is trifling, safe, and almost certain, and consists merely in lancing the gum covering the tooth which is making its way through. Lancing the gum is very easily managed; and any intelligent person, after seeing it done once or twice, will do it very effectually. Cline taught a mother of a family to do this; and after lancing her children's gums, she never lost another, at least from that cause; for so soon as the teething symptoms appeared, she looked for the inflamed gum, lanced it, and they ceased. The operation is performed with a gum-fleam, the edge of which must be placed vertically, on the top of the inflamed gum, and moved along, pressing firmly at the same time till the edge of the fleam grate on the tooth, and the business is finished. When the patient is under the fit, the most direct remedy is a warm bath, in which he should be plunged up to the neck.

Intoxication, when carried to excess, produces stupor and insensibility nearly allied to several of the preceding fits. It is recommended 'to place the patient quietly in bed, with the head raised, to loosen the body-clothes, and to keep watch. If the extremities turn cold, warmth may be applied, and as soon as he can swallow, a mustard or ipecacuanha emetic may be administered.' Strong coffee is said to be of service. In many cases nothing will preserve the life of the unfortunate victim except immediate recourse to the stomach-pump.

Choking, by attempting to swallow too large a piece of food, 'may usually be overcome by taking large draughts of water, and making great efforts to swallow. Sometimes, if a bone or pin be near the top of the throat, it may be got out by pushing the finger far down, and hooking it up with the nail. But if below the reach of the finger, the best thing to try for immediate relief is to take some crust of bread, or some hard apple into the mouth, chew it coarsely, get down two or three mouthfuls without swallowing it completely, and then to swallow quickly three or four gulps of water, which acts like a rammer to the bread, and forcing it against the bone or pin, not unfrequently carries it down into the stomach, and there the matter ends.' The buttons and other small matters a child sometimes swallows are rarely attended by any troublesome consequences, although the source of so much alarm to parents.

Suspended Animation.

In cases of apparent or supposed death, there are three things which ought always to engage attention—1*st*, To remove the hurtful cause; 2*d*, To regulate the temperature and circulation; 3*d*, To restore breathing.

In Drowning, which is one of the most frequent causes of suspended animation, the following advice may be of advantage:—Lose no time, but do things orderly and quietly. Avoid all roughness, hurry, and crowding; and observe to regulate the heat and strength of all remedies. Let one intelligent person alone direct, while the necessary assistants implicitly obey. Send for medical aid, and in the meantime act thus:—1. Carry the body carefully with the face upwards, and the head and shoulders a little raised, to the nearest house. If to a distance, especially in summer, previously remove any wet clothes, rub the body dry, and wrap it in a blanket, or the garments of the bystanders. A covering such as a dry coat over even wet clothes will check further chilling from evaporation. 2. The body being removed to a warm room, instantly strip and rub it dry; and then cover it with warm blankets, carpets, or the like. Increase the warmth by hot bottles, sand-bags, bricks, or other substances placed in contact with all parts of the body. A hot bath will also be found of great value. 3. Have several assistants to rub the body with their hands. Clear the mucus from the mouth, hold the nose, and then suck out the foul air with a tube, and blow in fresh air in the same manner. When breathing begins to show itself, assist by gentle compression and friction of the ribs and abdomen; and occasionally apply some pungent scent or other irritant to the nostrils. 4. Nothing should be given inwardly by the mouth, unless the power of swallowing exists; and then only small quantities of warm ginger tea, spiced negus or ale, or weak spirit and water occasionally. 5. Means of recovery should be persisted in for several hours: restoration has been known to follow after eight hours' perseverance. When recovery seems established, rest and quiet should be enjoined; but a strict watch must be kept for some hours, as sinking is apt to happen from subsequent neglect.

In Strangulation or *Hanging*, proceed at once to loose the cord and strip off the clothes. Use the same means to keep up warmth and to restore the circulation and respiration as in cases of drowning, with this addition, that six or eight leeches may be applied to the head with advantage. In cases of this kind, medical aid should always be sent for, as the after-symptoms often require skilful treatment.

For Suffocation from noxious vapours, as carbonic acid or foul air from old wells, coal-pits, brewers' vats, ships' holds, ill-ventilated rooms where stoves are kept burning, and the like, proceed as in drowning. Always remove quickly into the open air; dash a little cold water upon the face, but in such quantities as not to depress the warmth of the body. Where necessary, keep up the heat by bottles, warm blankets, &c.

Sudden Death.—'In every instance,' says Mr Smee, 'where one dies suddenly, without a clear equivalent cause which is irremediable, the heat of the body should be maintained at least twelve hours by hot bottles, and artificial respiration should be attempted as for drowning. Remember that the death may be only apparent, and your care may be repaid by the inexpressible delight of seeing life gradually resumed, and the party restored to his family.' Pulsation is the common test of animation; but when any doubt exists, the ear may be applied to the left side of the chest, where the action of the heart may sometimes be heard, even when the pulse can scarcely be felt.

Medical Power of Nature.

All the appliances, internal and external, which we have above enumerated, are administered upon the faith of *a healing power or principle in nature*, which, for the satisfaction of those who are prone to take a desponding view of the human constitution, we shall now endeavour to illustrate:—

When a man accidentally cuts his finger, or otherwise receives a similar wound in a non-vital part of his body, he does not generally regard it as a matter of serious consequence. He knows that, with a little care, it will heal, and that in a great measure by a power apparently residing in nature herself. This feature of the animal economy is so familiar to us, as to excite little notice; yet it is one of the most wonderful and beneficial of all those arrangements which have been made by a bounteous Creator for our welfare. Without it, the human frame would have been continually liable to destruction; the most insignificant injury would have led to speedy dissolution. A property of such exceeding value is not impressed feebly in the constitution of the person, but is associated with the principle of life itself, and is therefore developed with lesser or greater force through all the stages of existence, and according to the healthfulness of the individual. The property of healing ought to be described as an ever-acting principle in the system—a principle operating to compensate the regular decay of parts, and acting with increased vigour upon emergencies when any injury is sustained. In this latter respect, the healing principle is like a sentinel which is placed on guard over the functions of the body. No sooner does the object of its charge receive damage from an attack, than it flies to the injured part, and sets immediately about effecting a cure. The means which it adopts not only to cure, but to prevent injuries to the person, and expel maladies from the system, may almost be described as something instinct with human reason. Take, for instance, its operations upon a wound or cut. If not prevented by some foul or foreign body, placed or remaining in the wound, it commences by a slight inflammation of both sides of the cut; during the progress of this inflammation, a thin liquid substance, of a glutinous nature, exudes, to form a species of cement. At first the liquid is inorganic, but it in time assumes an organised character, with exceedingly minute blood-vessels interweaved throughout, and communicating with the surrounding vessels. In this manner it gradually puts on the appearance of cellular tissue, and at last, when skinned over, cannot be distinguished from the surrounding parts, unless by the scar which remains when nature is disappointed in effecting a cure in this ready manner, or, as it is called, by the *first intention*, in consequence of the presence of some foreign body in the wound, it goes on more slowly, and on a different plan. It commences by suppurating, or festering, in order to expel the offensive substance; and this being effected, it proceeds to throw up small granulations, or protuberances of a fleshy substance, till by this means—by this growing of matter—the wound is filled up, and healing accomplished. This is called healing by the *second intention*.

Nature is equally ready to act in the case of broken bones. No sooner is the bone broken than the healing principle sets to work to mend it. The chief object to be attained in this case is the repose and close union of the parts. Surgeons, therefore, begin by binding up the broken limb in such a way as to prevent any kind of movement or shifting. Nature is all the time facilitating the same object. It throws out a liquid around the break in the bone, which turns into a cartilaginous substance, and acts the character of a bandage to support the junction. The adhesion of the parts takes place gradually, by the formation of a bony matter, and thus the soundness of the limb is restored. Should the two broken ends of the bone happen not to be placed in juxtaposition, so as to produce adhesion, even in such untoward circumstances nature is not inclined to be baffled. The fractured parts make an effort to push forth a bony connection between the two, and establish a union, at the expense, however, of a slight distortion of the limb.

The vigilance of nature in caring for the comfort of the patient is particularly observable in the case of those who are under the painful necessity of parting with their limbs. The total disjunction of a limb, by sawing through the bone, is a calamity which nature has foreseen may occur, and provision has accordingly been made for its melioration. The bone, after amputation, presents a flat terminating stump, the edge of which is sharp, and calculated to irritate the flesh or muscle drawn over it for protection. It is clear that, in such circumstances, the wound would either never heal, or that the sharp-edged flat stump, in pressing on the muscle, would prevent any use being made of the amputated limb. But see how nicely nature manages this difficulty. Let us suppose it is a leg which is cut off. As soon as the amputation is effected, nature pushes forth a liquid matter, covering the point of the stump; and this gradually increasing in bulk and firmness, at length becomes solid, and rounds off the bone like a ball; wherefore the pressure upon the muscle neither creates irritation nor gives pain.

The intelligence of the healing principle in nature, if such a term may be used, is perhaps still more surprising in cases of internal inflammations and abscesses, or gatherings of purulent matter. It is a remarkable truth in our physical economy, that nature acts upon the principle of expelling disease from the interior to the external surface of the body. Internal inflammation seems to be repugnant to nature, and there is an unceasing effort to eject it. Small-pox, measles, and other similar diseases, are only the external symptoms of bodily inflammations in the course of expulsion. Dr Mackintosh of Edinburgh, whose work on 'Pathology and Practice of Medicine' is well known in the medical world, states 'that every instance of cutaneous affection, whether attended by fever or not, depends on derangement of the functions of some internal organ—sometimes of the brain, or stomach and bowels, at others of the liver, or mucous membrane of the lungs,' &c. He considers all the eruptions, even erysipelas, in the light of natural blisters, established by powers inherent in the constitution, which enable it to translate disease from the internal organs to the skin; and he has no doubt that the frequent observance of these circumstances first led the ancients to blister and make extensive external sores, by means of the application of red-hot iron, in cases of dangerous internal diseases. The eruptions which take place on children in cases of teething and other complaints—such as sores behind the ears, and so forth—are just so many demonstrations of the desire which animates nature to bring disease to the surface; and, as such, ought to be very cautiously dealt with. The effort to expel is not less energetic in the case of local inflammations. A portion of the viscera, not connected with the outer frame of the body, receives an injury or becomes diseased; it inflames, and there is a danger of the inflammation leading to morbid symptoms and death. Nature, however, making a bold push, endeavours to create a connection betwixt the inflamed part and the framework of the body; and this it sometimes actually effects. A junction takes place, and thus a channel is formed for the expulsion of the disease. Inflammations of the liver have been known to be carried off in this manner. When inflammation takes place in a part having already a tolerably direct connection with the surface, the difficulty of expulsion is of course not so great, and the cure is more certain. Natural abscesses, or accumulations of matter, may likewise be considered the result of efforts to expel disease from some internal part of the system, and it is fortunate for the patient in such cases that the constitution possesses strength to cast forth the malady.

In speaking of abscesses, we are put in remembrance of a provision in nature particularly worthy of notice. When the foul matter which is to compose the material of the abscess begins to form, choosing a certain situation for that purpose betwixt the skin and the muscle, nature is on the watch to prevent the possibility of the purulent matter insinuating itself extensively among the adjacent cellular tissue, and thereby doing irreparable mischief. To avert this contingency, it sends out beforehand a thin glutinous liquid, which forms a sac or bag, into which the matter of the abscess is secreted. This thin membranous sac remains in use as long as the abscess exists; but no sooner is the matter evacuated, and nature has effected her purpose in establishing the drain, than it begins to discharge a watery fluid, and the sides of the sac finally come to adhere. Occasionally, when the abscess has been deep or long-seated, nature has a difficulty in freeing itself in this manner; a sinus or cavity remains, secreting a thin serous humour, which may be pressed daily from the orifice; and this dull tedious process of secretion sometimes continues such a length of time, that art is required to step in to relieve the patient—the surgeon ripping up the surface with his appropriate instrument, and exposing the whole of the interior of the sac, by which granulation and healing, by the second intention, are allowed to restore soundness and healthiness to the parts so affected.

A physician once mentioned to us a striking instance of the wonderful efforts which nature makes to preserve life, or, as it may be called, the continued action of the animal mechanism. It was a case of complaint in the bowels, wherein one intestine was projected or drawn so completely into another, that there was an effectual stoppage of all communication. The agonizing death which ere long would have ensued to the patient, was fortunately averted by an extraordinary natural provision. The intestine above the point of obstruction formed a junction with that placed below it, and, by means of inflammation and ulceration, an opening was formed from the one into the other, through which artificial channel the ordinary motion in the bowels was carried on!

Admirable as these provisions in nature are which we have been contemplating, it ought not to pass unnoticed, that we have no right to expect the performance of such kind operations in our systems, unless we afford nature a fair field for exertion. The more sound that our constitutions are from exercise and temperance, the more shall we be benefited by the natural principle of healing; and if, by our own folly or intemperance, or by the folly or intemperance of our progenitors, we be afflicted by constitutional weakness, we must not, in such a case, be surprised to find that outraged nature is unable to lend a helping hand in the hour of need, and allows us to sink, the victims of moral delinquency, into a premature grave.

CLOTHING—COSTUME.

WHETHER inhabiting a tropical, temperate, or arctic region—existing in abject barbarism, or enjoying the highest degree of civilisation and refinement, man is essentially a clothing animal. Some kind or other of covering or decorative appendage he always affects, being instigated to this necessity by motives of defence, shelter, decorum, or vanity. From the simple head-dress and loin-cloth of the South Sea islander, to the elaborate costume of the gay Parisian, the ruling principle is much the same; more rational, perhaps, in the case of the savage than in that of the individual laying claim to superior enlightenment. In obeying this clothing instinct or necessity, attention is always paid not only to the kind and quality of the covering, but to the form and manner in which any particular article of dress shall be worn. Thus originates the distinction between clothing and costume—the one having reference to the fitness of the material for the purposes of shelter or protection, the other having reference to taste or a sense of the becoming, though often marred by the absurdities of vanity and caprice.

CLOTHING.

Admitting the above distinction, and laying aside consideration of all dress or armour of a defensive kind, clothing must be regarded simply in the light of a protection from the extremes of heat and cold, so that the body may perform its functions healthfully and without obstruction. For this purpose a warm climate requires a light and loose covering, a cold climate one of a heavier and denser texture. Such a difference, indeed, is in some degree indicated by the supplies of nature; the tropics yielding the light and flocculent down of the cotton, while higher and colder latitudes furnish abundance of hair, wool, and fur. Other adaptations are rendered imperative, according to the activity or inactivity of a population, the amount and nature of their food, and the kind of dwellings they inhabit—all these modifying less or more the normal or natural amount of heat which seems indispensable to healthy existence. 'The usual temperature of the body,' says a recent authority, 'is about 97°, and its warmth is derived from the decomposition of a certain portion of the food in combination with the air taken in by respiration, which is necessary to supply the continual loss of heat to which we are liable. Clothing checks or prevents in some degree this loss; and it follows of course that the materials which are the best non-conductors form the warmest clothing. But there are several other circumstances to be taken into account in making choice of the materials most suitable for this purpose. The skin, by its structure, performs the functions of regulating the temperature; by perspiration through its pores the excess of heat is carried off; and hence, when this function is deranged, and the insensible perspiration obstructed, fever is the consequence. In addition to this use, the pores of the skin serve as an outlet for getting rid of matters no longer necessary in the animal economy, and which, if retained, would prove injurious. Besides this *excretory* function, the skin has likewise an *absorbing* power, by which it takes up matters in contact with it; and we may also observe that it is abundantly supplied with minute nerves, which are the source of feeling, and which demand a certain degree of warmth to preserve their vital action. From these facts, it is easy to deduce that clothing should be of such a nature as not to impede the necessary escape of perspirable matter, but to suffer it to pass through its texture; that it should be of such a non-conducting quality as to confine the heat generated by the blood sufficiently to preserve the activity of the nervous system; and that, by its lightness, softness, and pliancy, it should permit the free motion of the limbs.' Clothing which would subserve all these purposes, and which, moreover, would absorb or reflect the solar or external heat as required, would be nearly perfect in its hygienic properties; and such an attire we could readily assume, were it not that considerations of economy, special avocations, and the like, are always interfering less or more to disturb the equilibrium. With these preliminary remarks, and referring the reader for further information on the general hygiene of dress to the article PRESERVATION OF HEALTH, we shall now consider the peculiar characteristics of British clothing, as manifested in the various fabrics prepared, as detailed under TEXTILE MANUFACTURES, from wool, cotton, linen, silk, fur, and leather.

Quality of Clothing.

Woollen fabrics, as articles of clothing, have several advantages over other materials. They are bad conductors of heat; hence their warmth by preventing the heat of the body from escaping, and their utility in preserving the equability of its temperature, though exposed to sudden changes. From their filamentous texture and elasticity they are light and pliable; and yet, from their peculiar property of being *felted*, they can be prepared to any degree of weight and thickness. They possess also the property of not being easily wetted, the while they are sufficiently porous either to absorb or to permit the escape of all cutaneous exhalations. Further, when worn next the skin, their rough and uneven surface produces in every motion of the body a gentle friction, which greatly assists and promotes the functions of the minute cutaneous vessels and nerves. 'In a climate like ours, which is so variable, and usually so cold, the article of dress that is worn next the skin ought always,' says Dr Robertson of Buxton, 'to be a bad conductor of heat at all events. In general, flannel of an adjusted degree of thickness and fineness answers this intention sufficiently well, without proving to be too heating, or irritating, or relaxing. In summer time, if the flannel which proved to be well borne in the colder seasons of the year, should be so far irritating and heating as to relax or fever the system, this may be remedied by substituting for it a thinner and finer quality of flannel; or in extreme cases of this kind, an under-garment of calico, of a proper degree of thickness, may be substituted for the flannel at that season of the year. Many prefer wearing chamois leather as the under-garment, because it does not irritate the skin so much as flannel. Leather is chiefly objectionable from its not affording, however well dressed, so ready a passage to the insensible perspiration as flannel or calico. I think that thin and very fine flannel may generally be well borne, and must be always greatly preferable; or that this, lined with calico, or even calico alone, is usually much better than the use of leather for this purpose.'

But strongly as the importance of having a bad conductor of heat next the skin should be impressed on the mind, there is a point connected with it which is almost as important. The inner garment, especially if made of flannel, ought not to be worn during night. It ought invariably to be taken off at night, and as invariably resumed in the morning. In bed it is unnecessary: it is worse than unnecessary, for it does harm: it then stimulates the skin, and produces a preternatural waste of the secretions, and corresponding debility of system—a corresponding liability to suffer from the depressing influence of cold—a corresponding incapability of resisting its influence. But, further, removing this garment during the night relieves it from the scurf, some degree of dampness, and other impurities which it must acquire during a day's wear, and so renders it fresh and more agreeable to the sensations of the wearer. Not wearing it at night renders it more effectual in protecting the surface from the cold by day, on the principle that a greatcoat is not of the same service to the wearer when out of doors, if he is in the habit of wearing it in the house. It would be easy to adduce strong evidence in behalf of the value and importance of wearing flannel next the skin. 'Sir John Pringle,' says Dr Hodgkin, 'who accompanied our army into the north at the time of the Rebellion, relates that the health of the soldiers was greatly promoted by their wearing flannel waistcoats, with which they had been supplied on their march by some Society of Friends;' and Sir George Ballingall, in his lectures on military surgery, adduces the testimony of Sir James Macgrigor to the statement that, in the Peninsula, the best-clothed regiments were generally the most healthy; adding that, when in India, he witnessed a remarkable proof of the usefulness of flannel in checking the progress of the most aggravated form of dysentery in the second battalion of the Royals. Captain Murray told Dr Combe that he was so strongly impressed, from former experience, with a sense of the efficacy of the protection afforded by the constant use of flannel next the skin, that when, on his arrival in England, in December 1823, after two years' service amid the icebergs on the coast of Labrador, the ship was ordered to sail immediately for the West Indies, he ordered the purser to draw two extra flannel shirts and pairs of drawers for each man, and instituted a regular daily inspection to see that they were worn. These precautions were followed by the happiest results. He proceeded to his station with a crew of 150 men; visited almost every island in the West Indies, and many of the ports of the Gulf of Mexico; and notwithstanding the sudden transition from extreme climates, returned to England without the loss of a single man, or having any sick on board on his arrival. It would be going too far to ascribe this excellent state of health solely to the use of flannel; but there can be little doubt that the latter was an important element in Captain Murray's success.'

There can be no doubt that flannel is by much the best article for being worn next the skin when the body has to be exposed to such a temperature, or to such a severe degree of exercise, as increases the perspiration in a material degree. It retains a warm and dry atmosphere next to the body, while, from its porous and fibrous character, it carries off the moisture to the external surface of the flannel. This is well seen when horses are stabled in a state of heat and perspiration after a journey, and covered with the usual clothing. Very soon it will be found that the outside of the woollen clothing is quite wet, and often studded with drops of moisture, whereas the skin of the horse and the inside of the clothing are perfectly dry. The common practice among the workmen in potteries, foundries, collieries, &c. of wearing thick flannel shirts, tends much to preserve their health, under the circumstance of the profuse perspiration caused by the excessive labour they are called upon to undergo, or the extreme heat of their places of work, alternated as this must be with the much colder atmosphere out of doors, amounting, it may be, to a difference of temperature of no less than 60° or 70°. Dr Kilgour, in his Lectures on Therapeutics and Hygiene, says 'that the use of flannel was found to be beneficial in the prevention of cholera, by maintaining the equilibrium of the temperature and the functions of the skin, and thereby preventing that derangement of the bowels which is so general a consequence of cold applied to the surface.' To the preceding excellent testimony, we may add that woollen fabrics, from their ready elasticity, are less liable than any other species of clothing to interfere with the circulation of the vital fluids, or prevent the free and easy motion of the body. When made to fit the person, and not too closely felted, they are exceedingly pliable, yielding to every turn and expansion, and never producing any painful or dangerous constriction. Further, as they are slow conductors of heat from the body, so are they also bad conductors of heat from any external source; and thus subserve the double purpose of preserving natural heat where it exists, and of warding off excessive solar heat where is would be injurious.

Cotton, though greatly inferior, ranks next to wool in non-conducting properties. From its comparative cheapness, lightness, and the facility with which it can be cleaned, it has of late years been gradually superseding the use of flannel as an underclothing. But, though recommending itself for these reasons, it can by no means be considered as a perfect substitute for flannel, whether used in a pure state or when mixed with a certain proportion of wool. Its ultimate fibre is altogether different; being void of that springy softness and elasticity so peculiar to wool, and incapable, moreover, of being felted to any thickness without becoming hard, heavy, and obstructive. Further, it is far from being so absorbent, is more readily wetted, and requires therefore to be more frequently changed and submitted to the laundress. Nevertheless it is a valuable staple of dress, and is in general use both as under and exterior clothing from the tropics, of which it is a native produce, to the limits of the polar circle.

We have said that cotton is inferior in its non-conducting properties to wool; that is, all things being equal, cotton fabrics form a cooler dress than those of woollen. These remarks apply to our own climate; let us hear the opinion of the authority already quoted in reference to the requirements of tropical regions:—'Cotton, from its slowness as a conductor of heat, is admirably adapted for the tropics. It must be recollected that the temperature of the atmosphere, in the open air, in the hot season, exceeds that of the blood by many degrees; and even in the shade it too often equals, or rises above, the heat of the body's surface. Here, then, we have a covering which is *cooler* than linen; inasmuch as it conducts more slowly the *excess* of external heat *to* our bodies. But this is not the only advantage, though a great one. When a *vicissitude* takes place, and the atmospherical temperature sinks suddenly far below that of the body, the cotton, still faithful to its trust, abstracts more slowly the heat *from* our bodies, and thus preserves a more steady equilibrium there. To all these must be added the comparative facility with which it absorbs the perspiration; while linen would feel quite wet, and, during the exposure to a breeze under such circumstances, would often occasion a shiver, and be followed by dangerous consequences. That woollen and cotton should be *warmer* than linen in low temperatures will be readily granted; but that they should be *cooler* in high temperatures will probably be much doubted. If the following easy experiment be tried, the result will decide the point in question:—Let two beds be placed in the same room at Madras, we shall say when the thermometer stands at 90°, and let one be covered with a pair of blankets, the other with a pair of linen sheets, during the day. On removing both covers in the evening, the bed on which were placed the blankets will be found *cool* and pleasant, the other uncomfortably warm. The reason is obvious. The linen readily transmitted the heat of the atmosphere to all parts of the subjacent bed; the woollen, on the contrary, as a non-conductor, prevented the bed from acquiring the atmospherical range of temperature; simply by obstructing the transmission of heat from without. This experiment not only proves the position, but furnishes us with a grateful and salutary luxury, free of trouble or expense. The musical ladies of India are not unacquainted with this secret, since they take care to keep their pianofortes well covered with *blankets* in the *hot season* to defend them from the heat, and prevent their warping.

From this view of the subject, *flannel* might be supposed superior to *cotton*; and indeed at certain seasons, in particular places—for instance, Ceylon, Bombay, and Canton—where the mercury often takes a wider range in a very short space of time, the *former* is a safer covering than the latter, and is adopted by many experienced and seasoned Europeans. 'But in general the use of flannel in the tropics is inconvenient for three reasons:—1. It is too heavy; an insuperable objection: 2. When the temperature of the atmosphere ranges pretty steadily a little below that of the skin, the flannel is much too *slow* a conductor of heat *from* the body: 3. The spiculæ of flannel prove too irritating, and *increase* the action of the perspiratory vessels on the surface, when our great object is to *moderate* that process. From the second and third objections, indeed, even cotton or calico is not quite free, unless of a fine fabric, when its good qualities far counterbalance any inconvenience in the above respects. In some of the upper provinces of Bengal, when the summer is intensely hot and the winter sharp, the dress of the native shepherds, who are exposed to all weathers, consists in a blanket, gathered in at one end, which goes over the head, the rest hanging down on all sides like a cloak. This answers the triple purpose of a *chattah* in summer to *keep out* the heat, of a tent in the rainy season to throw off the wet, and of a coat in the winter to defend the body from the piercing cold.' To this may be added, that no tropical head-dress can compete in point of comfort and safety with the loose, light-coloured turban of calico.

Linen, though inferior both to cotton and wool as a non-conductor of heat, and absorbent of moisture, is now extensively used as an article of inner clothing. In this capacity it has been of essential service to personal cleanliness, rendering the bath less necessary in modern Europe than in any other region of the globe. It is comparatively cheap, is easily kept clean, and its snowy whiteness enables us at once to detect when it is soiled or unfit for wear. It has been said by some one in jest, that 'a change of linen is a luxury;' and really so it is when well washed, bleached, and dried under the open air. There is a freshness and positive feeling of comfort about it not to be found in any other fabric however costly or fine. On the other hand, it must be confessed that linen has many disadvantages as an article of inner-clothing. Being denser in the fibre than cotton, and much more so than wool, it forms a good conductor of heat, and thus rapidly robs the skin of its free caloric; hence the cold feeling experienced when linen is just put on. But though rapidly conducting the heat, it does not readily absorb the insensible perspiration, and thus soon becomes saturated, leaving the pores of the skin clogged and obstructed unless the garment be frequently changed. Having little elasticity of fibre, it forms a smooth and dense fabric, totally void of that stimulating function often so much valued in flannel. From the experiments of Count Rumford, it appears that linen does not attract dampness so readily as wool, hair, or other animal substances; nevertheless, when it is damp, it is more prejudicial than these, and therefore requires to be well dried and aired before being worn.

Silk, as a non-conductor of heat, ranks next to cotton: but its qualities in this respect depend in a great measure upon the kind of fabric into which it is woven. Generally speaking, silken fabrics are light and thin; articles of luxury and ornament rather than of every-day utility. Nevertheless silk possesses several valuable hygienic properties, of which the most curious and least understood is that appertaining to its electric qualities. We have stated under another head (No. 17, p. 272), that on the whole the state of the body when healthy and vigorous is *positive*, or that a surplus of positive electricity tends always to appear on the surface, from the actions of the vital organs; but that, after severe labour, hard exercise, and exhaustion, the state of the free electricity generally changes to *negative*. It was further observed, that when the actions of electricity on the animal system are better understood, it may be possible to use artificial methods of maintaining, under all circumstances, the charge that is identical with health and activity; we have acquired by means of our houses, clothing, and fires, an almost perfect command of the element of heat; and it is to be hoped that we may some day attain an equal command over the element of electricity, and keep at a distance the deleterious negative charge as effectually as we defy the winter cold. On this important subject, so far as the influence of silk—which is an excellent non-conductor of electricity—is concerned, Drs Robertson and Carpenter have the following interesting remarks, which we transcribe at length:—

'However little or unsatisfactory our knowledge of the operations of this remarkable agent in the animal economy, there is no doubt that electricity fulfils important and necessary purposes in the living system, and that a certain amount of positive or negative electricity is being constantly given off from the surface of the body, in greater or less degree, according to sex, temperament, weather, the nature of the clothing, &c. It has been said that the skin and most of the internal membranes are in opposite electrical conditions; and according to a theory of Dr Wollaston, the existence of free acid in the urine and gastric juice marks the prevalence of positive electricity in the kidneys and the stomach; whereas the existence of free alkali in the bile and the saliva indicates an excess of negative electricity in the liver and the salivary glands. Whether this view be tenable or not, it seems that the living body is never in a state of perfect electrical equilibrium with the substances or bodies around it, unless it be maintained by free contact with them; and it is stated, in illustration of this, that if two persons, both insulated, join hands, sufficient electricity is developed to influence the electrometer. Some electric disturbance is manifested by almost every individual, if it be carefully sought for. In men, it is most frequently positive; and irritable men, of sanguine temperament, have more free electricity than those of phlegmatic character; whilst the electricity of women is more frequently negative than that of men. Some individuals exhibit these phenomena much more frequently and powerfully than others. There are persons, for instance, who scarcely ever pull off articles of dress which have been worn next the skin without sparks and a crackling noise being produced, especially in dry weather; this may, however, be partly due to the friction of these materials on the surface, and with each other, as it has been proved to be greatly influenced by their nature. The most remarkable case of the generation of electricity in the human subject at present on record, is one that has been met with in America (American Journal of Medical Science, January 1838). The subject of it, a lady, was for many months in an electric state so different from that of the surrounding bodies, that whenever she was but slightly insulated by a carpet, or other feebly-conducting medium, sparks passed between her person and any object which she approached. From the pain which accompanied the passage of the sparks, her condition was a source of much discomfort to her; when most favourably circumstanced, four sparks per minute would pass from her finger to the brass ball of the stove, at the distance of one and a-half inch. The circumstances which appeared most favourable to the generation of electricity, were an atmosphere of about 80°, tranquillity of mind, and social enjoyment; while a low temperature and depressing emotions diminished it in a corresponding degree. The phenomenon was first noticed during the occurrence of an aurora borealis; and though its first appearance was sudden, its departure was gradual. Various experiments were made, with the view of ascertaining if the electricity was generated by the friction of the articles of dress; but no change in these seemed to modify its intensity. It was no doubt generated, or the electrical equilibrium was disturbed in an undue and very extraordinary degree, by the condition of the nervous system, probably influenced by some deranged condition of certain of the organic functions. It seems to have been proved that electrical manifestations are the invariable consequence of the action of the nerves in producing muscular action; and it is probable that this powerful agency of electricity exercises an important influence on the digestive processes, and perhaps especially in facilitating the decomposition of the food, and so far preparing it to enter into new combinations for the nutrition of the body. But however this may be, and however large, or little important, the influence of electricity may be in carrying on the vital and organic processes of the system, there is no doubt that a certain amount of electrical matter is constantly being given off from the surface of the living body; that the amount of this varies according to the dryness or dampness, the coldness or warmth, of the atmosphere; and that the degree to which it is permitted to escape may be influenced by the nature of the clothes, and particularly according to the nature of the fabric which is worn next the skin; and that the escape of this electricity is so far attended with diminished power and energy of the general economy, and in the same degree to which such escape may be prevented, is the system maintained in a state of more vigorous vitality. The depressing influence of wet and cold weather may be largely referred to the effect of such an atmosphere in carrying off rapidly the free electricity of the system; and the colder and more damp the climate man lives in, the more important is it that he surround the body with such articles of clothing as will check, as far as may be, the escape of this extraordinary agent; and the greater the habitual depression and debility of the economy, the less the degree of its vital energy, the more important does this consideration become.

Silk, as a remarkable non-conductor of electricity, deserves to be made use of more generally than it is in this country, as an article of under-clothing. For this purpose it should be woven entirely of what is called *bright* or *wrought* silk, in contradistinction to what is called *spun* or *spurious* silk; and the under-garment is to be manufactured in a similar way, and of a similar material, to stockings; but woven with much thicker thread into a very thick and heavy fabric.'

Furs and *down* are by far the warmest materials, but in Britain they can scarcely be considered as articles of general clothing. Soft, light, elastic, they constitute excellent adjuncts during the winter months, while their fine colours and markings add greatly to their appearance. When worn, as furs usually are, with the skin attached, they are rather impermeable to exhalations, and are not in this light to be considered as equal to the finer fabrics woven or knitted from wool. *Leather*, unless peculiarly prepared (as chamois), is by no means fit to be worn as an inner garment; in fact, the common application of this material is for boots and shoes, for which it is admirably suited by its strength and durability. Unless made somewhat easy, so as to allow room for a worsted sock or stocking and a certain amount of air, leathern boots form but a cold covering, at the same time that they are all but impermeable to any kind of exhalation. When well manufactured, leather should be soft and pliable; and when fashioned into shoes, these should be rather large and easy. There is, in general, no member of the body more sinned against—the chests of stay-wearing ladies scarcely excepted—than the foot; and the certain penalty is corns, callosities, and deformities, an unspeakable amount of pain, and in the long-run, a partial destruction of the powers and functions of one of the most essential of the bodily organs. The feet, with proper treatment, ought to be as free from disease and pain as the hands; their structure and adaptation to the wants and comforts of man being naturally perfect. 'Thirty-six bones and thirty-six joints,' says a writer on the foot, 'have been given by the Creator to form one of these members, and yet man cramps, cabins, and confines this beautiful arrangement of one hundred and forty-four bones and joints—together with muscles, elastic cartilage, lubricating oily fluid, veins, and arteries—into a pair of boots or shoes, which, instead of forming a protection, produces the most painful and permanent injuries.' These objections as to room cannot be urged with the same force against the numerous *elastic fabrics* now coming into use, as these, to a certain degree, expand and contract according to the requirements of the foot; but then there is this objection—all of them are impermeable to perspiration. The foot while heated perspires, the moisture is not allowed to exhale, and on resuming a state of rest, cold and damp is the result. This objection, indeed, is fatal to all the elastic *waterproof fabrics* now so much in vogue: the insensible perspiration must be absorbed or exhaled, and if not, discomfort and disease are the inevitable consequences. Numerous ingenious attempts have been made to remedy these defects, so as to retain the other valuable properties of elastic and waterproof clothing; but as yet we have seen none completely successful; and for our own parts, we would rather undergo a drenching which can be laid aside with the garment which sustains it, than sit for hours enveloped in effete and offensive exhalations.

Amount of Clothing.

The amount of clothing should be regulated as much as possible in reference to the climate under which we live, the season of the year, the degree of exposure to which we are subjected, the exercise or fatigue we undergo, the food consumed, age, sex, and other constitutional peculiarities. Thus other things being equal, a cold climate requires a heavier and thicker dress than a warm one: in winter we could not wear a light summer dress with impunity; a man undergoing healthful exercise in the open air needs less muffling up than a sedentary dweller within doors; the individual enjoying a full invigorating diet feels comfortable in garments under which an ill-fed man would shiver; and, generally speaking, the young and vigorous require less clothing than the aged and infirm. Regarding the first of these circumstances as axiomatic, let us consider the others in detail:—

1. Although it is proper to adapt the warmth of our clothing to the season of the year, yet change in this respect must be made with caution. The animal constitution is no doubt endowed with considerable plasticity; but that plasticity must be operated upon by insensible gradations. 'Very light clothing during the summer months,' says an able writer on domestic economy, 'exposes the body to the effects of those sudden changes of weather which we experience in our climate. It is safer to wear the same clothing nearly all the year than to make frequent and sudden changes; exercise under too warm a dress occasions violent perspiration, the effects of which are often dangerous. It is remarkable that in some countries custom differs materially from ours respecting clothing. We dress in general somewhat warmer when we go out than when we sit in-doors; the Turks, who seldom have fires in their apartments, keep themselves comfortable within doors by using warmer clothing than when they go out, considering the practice of moving about a source of heat, which it really is: the Chinese of rank, it is said, practise the same mode—putting on an additional garment in the house, which they throw off as the sun ascends to the meridian, and resuming it in the cold of the evening.' 2. As to exercise, there can be no doubt that it is a source of heat: respiration goes on more briskly, the carbon of our food and blood is more rapidly consumed, a greater degree of heat is experienced, and this continues so long as the body is in a healthful vigorous condition. To overload one's self with dress during exercise is but to irritate and fatigue; as the same time care is required on relapsing into a state of rest, that the exhausted frame be properly protected. During exhaustion every function goes on less briskly, little heat is supplied by respiration, and that little requires to be carefully retained. 3. The same remarks are applicable to the case of food. A well-fed man, as explained in No. 46,

has a source of heat within him; and if the doctrines of Liebig and others be correct, food may be said to supplement clothing, and clothing food. If we lose heat through lack of clothing, the food must supply it; and *vice versâ*. 4. The young and vigorous, other things being equal, require less clothing than the old and infirm. While the respiration and circulation of the system is vigorous, and the diet wholesome and full, every function is performed with activity; heat is freely formed; and the exercise generally taken by the young greatly augments the supply. But the young and vigorous must not neglect the ordinary rules of clothing on this account—a neglect they are but too apt to perpetrate, and which, in the case of infancy, is too often perpetrated against them by ignorant nurses, and equally ignorant and foolish mammas. 'Are the little "Highlanders,"' asks Dr Erasmus Wilson, 'whom we meet during three out of the four quarters of the year under the guardianship of their nurserymaids, dawdling about the streets in our public walks or squares, properly protected from the cold? Are the fantastically-attired children whom we see "taking an airing" in carriages in our parks, sufficiently and properly clad? If these questions can be truly answered in the affirmative, then, and then only, my remarks are needless. There can enter into the parent mind no more baneful idea than that of rendering children "hardy" by exposing them unnecessarily to cold, and by clothing them inefficiently. I have known instances wherein parents, acting on this principle, have failed entirely in rearing their offspring. Does nature treat her progeny thus? Does she not, first of all, insure the birth of her young only at a kindly season, and then provide them with downy coverings, warm nests, and assiduous protectors? And we must imitate nature, if we would give to Britain a race capable and worthy of maintaining her independence and honour. The little denizens of a warm nursery must not be subjected, without a carefully-assorted covering, to the piercing and relentless east or north-east wind; they must not be permitted to imbibe the seeds of that dreadful scourge of this climate—consumption—in their walks for exercise and health; they must be tended, as the future lords of the earth, with jealous care and judicious zeal. *One-sixth of the deaths of young children*, it must be remembered, *result from cold*.' 'The large mortality,' says another medical authority, 'among the children of the poor, is to be referred to an undue exposure of their feebly-acting and sensitive surfaces to the influence of the cold.' It by no means follows, however, from what has been said, that the systems of the young are to be overheated, relaxed, and enfeebled by an excessive amount of clothing; an amount disproportioned to the requirements of health and growth.

As to special articles of dress, and the clothing of special parts of the body, there is often injudicious management, partly from mistaken physiological notions, and partly from caprice and fashion. Thus there is nothing more common than to dress heavily when we go out of doors, and put on some thin flimsy covering within doors; to clothe well during one portion of the day, and be in loose, open, undress during another; to wear strong boots or shoes when we take open air exercise, and immediately thereafter to be sedentary and in slippers. Such sudden changes are contrary to all reason, and cannot fail to be prejudicial to sound health and comfort. The human body is not a piece of mechanism, which can be wound up and adjusted at pleasure; and far less is it to be tampered with in direct opposition to the natural laws under which it is constituted. What more preposterous than to dress heavily when under the warming influence of exercise, and to dress loosely and lightly when sedentary, and when all the functions of circulation and respiration are languid and slow! Another error, very common in this country, is the inordinate wrapping of the neck and shoulders with kerchiefs, shawls, and furs. To behold men and women, old and young, all be-muffled and be-boa'd, no matter what the day or what the occasion, a stranger would be apt to imagine the country labouring under one huge epidemic; and yet the truth might be some absurdity of fashion—some monkey imitation of A by B, C, D, and all the other letters of the alphabet. 'Unless when much or unusually exposed to the influence of cold,' says a high medical authority, 'the risk of local relaxation from this practice, and of an unadvisable degree of chill when such extra clothing is removed, deserve consideration, and may lead to greater evils than such extra wrapping is calculated to obviate. It is only justifiable under circumstances of extreme and long-continued exposure to cold, or in the instance of very delicate and susceptible systems.'

Another instance in which very irrational and often fatal errors are committed, is the due protection of the feet. 'Of all parts of the body,' says the same authority, 'there is not one the clothing of which ought to be so carefully attended to as the feet. The most dependent part of the system, this is the part in which the circulation of the blood may be the most readily checked; the part most exposed to cold and wet, or to direct contact with good conducting surfaces, it is the part of the system where such a check is most likely to take place. Coldness of the feet is a very common attendant on a disordered state of the stomach; and yet disordered stomach is not more apt to produce coldness of feet, than coldness of feet is apt to produce disorder of the stomach; and this remark does not apply only to cases of indigestion, but to many other disorders to which man is liable. Yet do we see the feet of the young and delicate clad in thin-soled shoes and as thin stockings; no matter whether the weather is dry or damp, or whether the temperature of the atmosphere is warm or cold. But this is not the whole of the evil. These same feet are frequently, at different times of the day, differently covered as to stoutness of the shoes and their soles, and very often likewise as to the thickness of the stockings. . . . I am sufficient of a Goth to wish to see thin-soled shoes altogether disused as articles of dress; and I would have them replaced by shoes having a moderate thickness of sole, with a thin layer of cork or felt placed within the shoe, over the sole, or next to the foot. Cork is a very bad conductor of heat, and is therefore to be preferred. Its extreme lightness, the remarkable thinness to which it may be cut, its usefulness as a non-conductor not being greatly impaired thereby, and the inappreciable effect it has on the appearance of the shoe, all seem to recommend its use for this purpose in the strongest manner.'

Among the special instances of error as to the amount of clothing, the writer just quoted places pre-eminently that of bedclothes. In Britain, where a great variety of material is used, such as feathers, down, hair, woollen blankets, cotton counterpanes, and linen sheets, this subject is deserving of more attention than it generally receives; and all the more, seeing that while in bed the skin usually throws off much more of its secretions than at other times. What is required is a mere sufficiency to keep the surface warm; everything beyond this is exhausting and detrimental. What is sought for in bed is rest, quietude, and a total avoidance of all excitement; and this most certainly cannot be obtained when half-smothered, heated, and irritated by an undue amount of warm clothing. 'A free and sufficient use of exercise, and particularly walking exercise; a regular exposure to the open air; a daily change of air, as far as may be practicable—walking as far away from home as strength, and time, and weather allow, instead of confining the exercise to a circle near the house; and a regulated diet, are the great means, next to sufficiently frequent ablutions, of keeping the vessels of the skin in a state of efficient activity, and preserving or restoring the natural temperature of the surface. And this point having been gained, very few and light bedclothes are all that will be required: the system, having been sufficiently exhausted of its vital energies by the day's work, will need no bed of down to lull or soothe it to repose; and a hair mattress, a sheet, a blanket, and a counterpane, will generally suffice to defend the body from the ruder approaches of the cold air, even during sleep, and in the coldest of our country nights.'

Colour of Clothing.

It has been already stated that different bodies part differently with their heat, by *conduction* and by *radiation*. Thus a bit of stick can be held in the hand with impunity till burned almost to the fingers, while a rod of iron must be dropped long before it has become red-hot. A well-polished silver teapot will retain water for a long while almost at the boiling-point; while in one of rough earthenware, the water will quickly lose its heat by radiation to the external air. Not only do substances part with their heat in this way, but they radiate with different degrees of quickness according to the colour of the surface—according to the ray or rays of light which the surface of the heated substance reflects. Of all colours, *black* reflects least, and absorbs more of the heat that strikes upon it than any other colour, which warmth it communicates to the body; but, on the other hand, it radiates more than any other colour, and of course gives out more of the heat which it receives from the skin, producing a counteracting effect. On the contrary, *white* is the least warmed by the sun, but is more effectual in confining the heat of the system by its imperfect radiation. The difference between them with respect to warmth is, that black clothes are the hottest when the sun is most powerful, and white the warmest when the sun has the least power; in other words, white is the coolest in summer, and black the coolest in winter. The delicate and the invalid should thus generally prefer white or light-coloured clothes, whether as summer or winter wear; and as winter clothing, the light-coloured greatcoat is very much warmer than one of a darker hue. It is to be regretted that we have no very accurate experiments to determine the proportionate radiating and absorbing powers of different colours; but so far as attempts have been made, the *radiating* power of black in one experiment was 21, while that of red was 26, and of white 28. On the other hand, the *absorbing* power was found to be for black 4½, dark-green 5, scarlet 5¼, and white 8. Another important fact connected with the absorbent power of different colours, is the facility of acquiring and retaining odours, and it may be infectious exhalations. So far as experience goes, black is in this case not only the most absorbent but the most retentive.

COSTUME.

Dress may be said to consist of three generic forms—the simple attire of savage life, in which a skin, blanket, or some other loose covering is nearly all that is employed; the flowing and elegant dress of the East; and the precise and more closely-fitting clothing of modern European nations. Of the first-mentioned little need be said. In the absence of manufactured articles, savage tribes in all countries are, and have been, in the habit of attiring themselves in such rude materials as nature has placed within their reach. The Indian of North America clothes himself in skins on which the fur is left, or with a blanket procured from the wandering trader. His legs and feet he dresses in moccasins made from a species of leather, and in full dress he fancifully paints his skin with pigments. In some of the islands of the Pacific (as also till lately in New Zealand), the inhabitants *tattoo* the surface of the body by puncturing it with an instrument, and inserting coloured juices in the wounds. Such likewise was the barbarous practice and fashion of the original inhabitants of the British islands.

Throughout Asia, in North Africa, and in Turkey, the dress is generally of a loose and flowing form; that of the common people in China being least so. The *turban* is almost universal. It is a male head-dress, composed of muslin swathed in folds, for the most part round a cap; and by presenting a mass of light material to the sun, it is considered to be a suitable covering for the head in Eastern climes. The forms of this head-dress, however, differ considerably; some being more tasteful than others. The first represented in the accompanying figure is the round turban common in Africa; the second an elegant modern Egyptian form.

A crowd in Constantinople, previous to the late modifications of costume, was, says a traveller, a picturesque group: 'there was the graceful Effendi Turk with snow-white turban, jetty beard, sparkling and full eyes, long flowing caftan, scarlet trousers, yellow boots, rich Cashmere shawl round the waist, in which shone the gilded dagger; next was the gay but cunning-looking Greek, with short chin, black turban, enormous but short trousers, bare legs, and black shoes; then the grave Armenian, with his calpac of black felt balloon-like upon his head, his long Turkish robe, silver ink-horn in his girdle, and his feet in the crimson slipper or boot; next was the Jew, with his blue turban and slippers; and with these were seen the high taper calpac of the Tartar, the melon-shaped head-piece of the Nizam Djedid, the gray felt conical cap of the imaum and dervish, and occasionally the ungraceful hat of the Frank, with the be-buttoned and mean-looking costume of Western Europe.'

The dress of the modern Greeks is a mixture of Eastern and European costume, with little to mark the classical origin of the people. The chief article of attire of the poorer Greeks is a *capote*, or large woollen garment, with a hood, shaggy with short threads of yarn; it is heavy when dry, but nearly insupportable when wet; it is as serviceable for home and bed to the wandering Greek as the *bunda* is to the Hungarian shepherd, and it is a perfect defence against cold and dew. All but the poor classes of Greeks, however, dress showily; and even a servant will expend every farthing of his wages in fine clothes. Thus a physician's janissary may be seen in a rich robe of scarlet, his vest of blue velvet trimmed with gold lace, and in his silk girdle a brace of pistols embossed with silver; turban, short petticoats, and trousers of purest white, and gaiters or 'leggings' of scarlet velvet, embroidered with gold; altogether, a costume that might suit a prince. The general dress consists of a short embroidered jacket, without collar, and with sleeves open from the elbow; an embroidered vest, a cotton shirt, a tunic of several folds, secured by a sash or shawl about the waist, and reaching to the knee; loose breeches or trousers, short socks, and slippers between sandals and shoes. In one corner of the sash, the common people carry their money, which the rich put into purses, and carry, with their handkerchiefs, watches, and snuff-boxes, in their bosoms. The head-dress is various; as the turban, *à la Turque*; the fur-cap, like a muff; the fez or tasseled cloth cap, worn on one side; the plain caps of the peasantry; and skull-caps of velvet or gold, embroidered and tasseled. The young Greeks are the handsomest race in Europe; their long hair falls over their shoulders from under the cap, their embroidered jackets, vests, and buskins, their arms mounted with silver, and even jewels, and their white kilts, compose, on the whole, one of the most graceful and becoming costumes in the world.

The Greek.

The costume of the Greek female more closely resembles that of the Turks. She wears loose trousers of fine calico, embroidered with flowers, a closely-fitting vest, a jewelled zone about the waist, and a long-sleeved gown, flowing off loosely behind, or a veil covering the body; and sometimes a rich pelisse trimmed with fur. Jewellery is worn to excess; and bracelets of gems, or strings of gold coins round the arm and neck, across the forehead, and in the hair, which the younger girls let fall down their backs and over their brows and cheeks. Little caps, similar to those of the men, are also worn by the females, studded with coins, but worn on one side of the crown, the girls wearing in them flowers, and the matrons heron-plumes or jewels. The young women often dye their hair auburn, and the old ladies red, with which colour the nails are also tinged. The females walk abroad in a robe of red or blue cloth and an ample muslin veil.

The dress of modern Europe, and, we may add, that of civilised America, differs little in essentials. With few exceptions, it is well fitted for an active, hard-working, city-dwelling people; it has little cumbrous or unnecessary about it, and if not always so graceful or picturesque as could be wished, it is free at least from the reproach of 'barbaric pomp and ornament.' Climate, business avocations, and conventional usages require it to be somewhat precise; but this precision can never become ridiculous unless through some temporary freak of what the gay world denominates *fashion*. The usual notions concerning flowing or classical costume are more traditionary than rational; for if there be really anything in 'the human form divine,' the less that any costume clogs, and cumbers, and conceals it—consistently with comfort and decorum—the more becoming must it of necessity be. With this much for the too often reviled costume of modern Europe, and without entering into particulars as to the styles it assumes in different countries, we shall now devote the remaining pages to the history and development of

BRITISH COSTUME.

Partly from a wider acquaintance with other countries, partly from the introduction of new pursuits and avocations, and partly from caprice and fashion, the costume of our country has undergone many changes in the course of ages. Among the Southern Britons, at the time when Julius Cæsar landed in the country (55 B.C.), the arts connected with clothing had made some advance; but in the more northern parts, the practice of living half naked, with painted and tattooed bodies, was common, and, notwithstanding the severity of climate, remained till a much later period. Such fanciful decorations are supposed to have given name to the nation of *Picts* (from the Latin word *picti*, painted); but on better authority, the appellation has been referred to a different origin.

Pict.

The usual Roman dress, in the latter period of the Empire, consisted of a tunic, or loose upper garment, with a dress for the lower limbs, called *braccæ*; hence the modern term *breeches*. Over all was occasionally worn by the higher classes the *toga* or mantle. It is believed that these Roman costumes were generally copied by the greater number of British, at least among the more opulent classes. In the dress of the women, however, there was but little change. They appear in two tunics, the one reaching to the ankles, the other having short sleeves, and reaching about half-way down the thigh; in other words, they resemble a round gown, or bed-gown and petticoat, though the latter, distinct from a body and sleeves, is not considered to be ancient. This tunic was called in British *gwn*; hence our word *gown*, of which we still see specimens of short dimensions worn by women of the humbler classes in England, Scotland, and Wales.

Anglo-Saxon and Danish Periods.

The Anglo-Saxon and Danish periods of English history are marked by new peculiarities in costume. Soon after the departure of the Romans and the arrival of the Saxons in 449, fashions of apparel were introduced from Northern Germany, which were copied by the Romanised British, and continued with no material change for several centuries.

The most important improvement in the ordinary dress of the people was the introduction of the *shirt*, a linen garment worn next the skin, for which we are indebted to the Saxon invaders. The common dress of the eighth century consisted, as we find, of linen shirts; tunics, or a kind of surcoat; cloaks fastened on the breast or shoulders with brooches; short drawers, met by hose, over which were worn bands of cloth, linen, or leather, in diagonal crossings. Leathern sandals were worn by the early Anglo-Saxons; but afterwards the shoe became common; it was very simple, and well contrived for comfort, being opened down the instep, and there, by a thong passed through holes on each side of the slit, drawn tight round the feet like a purse. A felt or woollen cap, called *hæt* (hence our modern word hat), was worn by the higher class of Anglo-Saxons; but it is generally believed that the serfs or lower orders were without any other covering for the head than what nature had given them.

Although Sir Walter Scott, with the natural modesty of genius, disclaims pretension to complete accuracy in the costume of the characters in his historical romances, the following portrait of Gurth, the Saxon swineherd in 'Ivanhoe,' is nearly correct: 'His garment was of the simplest form imaginable, being a close jacket with sleeves, composed of the tanned skin of some animal, in which the hair had been originally left, but which had been worn off in so many places that it would have been difficult to distinguish from the patches that remained to what creature the fur had belonged. This primeval vestment reached from the throat to the knee, and served at once all the purposes of body-clothing. There was no wider opening at the collar than was necessary to admit the passage of the head, from which it may be inferred that it was put on by slipping it over the head and shoulders, in the manner of a modern shirt or ancient hauberk. Sandals, bound with thongs made of boar's hide, protected the feet; and a sort of roll of thin leather was bound artificially round the legs, and, ascending above the calf, left the knees bare, like those of a Scotch Highlander. To make the jacket sit more closely to the body, it was gathered at the middle by a broad leathern belt, secured by a brass buckle, to one side of which was attached a sort of scrip, and to the other a ram's horn, accoutred with a mouth-piece for the purpose of blowing. In the same belt was stuck one of those long, broad, sharp-pointed, and two-edged knives which were fabricated in the neighbourhood, and bore even at this early period the name of a Sheffield whittle. The man had no covering upon his head, which was only defended by his own thick hair matted and twisted together. One part of his dress only remains, but it is

Anglo-Saxon Serf.

too remarkable to be suppressed: it was a brass ring resembling a dog's collar, but without any opening, and soldered fast round his neck; so loose as to form no impediment to his breathing, yet so tight as to be incapable of being removed, excepting by the use of the file. On this singular gorget was engraved, in Saxon characters—"Gurth, the son of Beowulf, is the born thrall of Cedric of Rotherwood."'

The Anglo-Saxon females wore under-tunics, with sleeves; another inner garment—the linen kirtle; and over these the long full gown, with loose sleeves. The head-dress was a hood or vail, which, falling down before, was wrapped round the neck and breast; and this was the only head-covering of the women when abroad. The hair was carefully dressed, and golden head-bands, half-circles, neck-bands, and bracelets, were worn; with earrings, necklaces, crosses, and jewelled ornaments too numerous to describe. The hose and shoes resembled those worn by the men. The long sleeves of the gown or the mantle, drawn over the hands, served as gloves, which were not worn before the eleventh century. All classes used on their cheeks a red cosmetic, so that the art of painting the face is not the creature of refinement. The general colours of the dresses were red, blue, and green, sometimes embroidered in patterns; and gold tissue and cloth of gold were worn by princesses and nuns; and the latter embroidered robes, sandals, tunics, vests, cloaks, and veils of enormous cost—for pearls and precious jewels were interwrought with the materials, and sometimes three years were spent in working one garment; and their dresses were often lined with sable, beaver, and fox furs, or the skins of lambs or cats.

In the article of dress, the Danish intruders into Britain were, after a time, equally profuse. The Anglo-Danish kings appear principally to have worn a red habit, embroidered with gold, and a purple robe; and their mantles were richly embroidered with gold and pearls. Upon a manuscript of the reign of Canute, he is, however, represented in a Saxon dress, the mantle being richly ornamented with cords or ribbons, and tassels; and he wears shoes and stockings with embroidered tops. His body, when discovered in Winchester Cathedral in the year 1766, was decorated with gold and silver bands, and a richly-jewelled ring; bracelets were worn by all persons of rank, and invariably buried with them. Canute's queen wore the tunic, mantle, and long veil. The materials of the Danish dresses were cloths, silks, or velvets, procured either from Spain or the Mediterranean, by plundering the Moors.

From the Danish invasion to the Norman Conquest there were few changes in costume, if we except the imitation of Norman-French fashions in the reign of the Confessor, by shortening the tunics, clipping the hair, and shaving the beard, but leaving the upper lip unshorn. Tattooing after the Pictish fashion was practised even to this time, although it had been forbidden by a law passed in the eighth century.

Eleventh till Fourteenth Century.

The Norman Conquest introduced a greater degree of taste and splendour into British costume; but the dress of the common order of people remained long of a comparatively rude fashion, partly from the effect of caste and sumptuary laws, which prevented any decided change. As time advanced, the materials of dress improved, but the fashioning was little different, and, till this day, we have a sample of the Anglo-Saxon tunic in the *smock-frock*, a species of overall linen shirt, very generally worn by the peasantry of England. The *blouse*, a coarse linen shirt of blue instead of white, which is now universally worn by workmen in France, Switzerland, the Low Countries, and part of Germany, had an equally early origin.

In the reign of Rufus many costly changes were made in dress: the tunics were lengthened, and the under garments even trailed upon the ground. The sleeves were also drawn over the whole hand, although gloves were worn, at least by the higher classes. The cloth mantles were lined with rich furs; and one lined with black sables and white spots cost £100. Extravagantly peaked-toed boots and shoes were worn; and a court coxcomb, who caused the points of his shoes to curl like a ram's horn, received the name of *De Cornibus*, or with the horns. The hair, which had been shorn from the back of the head as well as the face by the Norman-French, was now again worn long; and the courtiers in Stephen's reign even wore artificial hair, so that wigs may date from the twelfth century. The long beard also reappeared in the reign of Henry I. (1100-1135).

About this period *gloves*, highly ornamented, appear to have been used by kings and the higher church dignitaries. Gloves, or a clothing of leather for the hands, had not been unknown in early ages; by the Greeks and Romans they were employed as a protection in certain kinds of rough labour. Now they were employed as part of a mailed dress, and also on ceremonial occasions. From the monumental effigy of Richard I., it is seen that he wore gloves ornamented with jewels on the back of the hand. Throwing down a glove became a challenge of defiance to single combat, according to the etiquette of these partially barbarous ages. From being worn only by kings, archbishops, courtiers, and knights, gloves made of various materials gradually became a portion of ordinary dress.

In the course of the thirteenth century, the sumptuousness of apparel increased: rich silks woven with gold, embroidered and fringed, and French velvets, were much used; and a rich stuff manufactured in the Cyclades was made into a dalmatica or super-tunic, called Cyclas, which was worn by both sexes. The furs of ermines, martens, squirrels, the vair, and the minevair or miniever, were added to the list of furs for winter garments.

The general male dress consisted of the cyclas just mentioned; and the tunic open as high as the waist, to show the drawers, with chaussies or stockings. The principal novelty is the super-totus, or overall, worn like the mantle or cloak, and consisting of a kind of large-sleeved shirt, with a capuchon. Long-toed shoes and boots were resumed, with embroidery and colours.

The female costume differed in fashion and name, rather than in form, from those of the twelfth century. The veils were of gold tissue or superbly-embroidered silk, and over them was worn a diadem, circlet, or garland, or a cap-like coronet, by persons of rank, and sometimes a round hat. The head-dresses were very numerous: the wimple covered the head and shoulders, and was fastened under the chin; and the hair was worn in a net or caul of gold thread, which continued in fashion for the next two centuries. A very ugly kind of wimple, called the Gorget, appeared in the thirteenth century; it was a neck-covering, poked up by pins above the ears. The long robe was also worn trailing on the ground; the cloth stockings were embroidered with gold; and trinkets of gold, as buckles, rings, earrings, and chaplets, and jewels, were much worn. In this century, too, we first meet with the surcol, which Strutt calls a corset, boddice, or stays, worn over the rest of the dress, which enlarged in the skirt, and spread into a train: it was made high in the neck, and had long tight sleeves.

The dress of the working-classes may be supposed to have been improved about this period by the introduction of the worsted manufacture: it is stated to have been brought to the country by a colony of Flemings, who in the reign of Henry II. settled at *Worsted*, a village in Norfolk; hence the name of the fabric.

Fourteenth and Fifteenth Centuries.

We now come to the fourteenth century, in which Edward III. and his queen Philippa led the fashion in apparel. As seen from the effigy on his tomb, the costume of Edward is characterised by its dignified simplicity. The dalmatica is low in the neck, falls in straight folds to the feet, and is open in front nearly half its height, being embroidered at the edges of the aperture; the sleeves of the under-tunic have at each wrist a row of buttons, a fashion of the reign of Edward III.; the mantle, embroidered at the edges, is worn over the shoulders, and confined by a jewelled band across the breast; the shoes or buskins are also embroidered, and the hair and beard are patriarchal; the crown has been removed or lost. The effigy of Queen Philippa, also at Westminster, is equally distinguished by its simplicity; the skirt is long and full, the boddice closely fitting, the waist-belt jewelled, and the mantle ornamented on the shoulders, and confined by a diagonal band across the breast; and upon the head is a low crown, jewelled, and from it depends a kind of draped ornament half-way down the cheek. The costume of the nobles in this reign was, however, far less simple than that of the sovereign. In place of the long robe and tunic was worn a close-fitting body-garment (jupon) superbly embroidered, reaching to the middle of the thigh, and confined across the hips by a splendid belt; from the sleeves of this garment hung long slips of cloth, called *tirippes* (tippets), and over the whole was occasionally worn a long mantle, fastened by buttons upon the right shoulder. This dress was, however, the extreme of foppery. The caps were of various shapes, and among them we find the knight's *chapeau*, nearly in the form now used in heraldry. Beaver hats were also worn; but the greatest novelty was a single feather in the front of the cap. The golden chaplets, by the addition of leaves, now assumed the form of coronets. The gay tournaments of this period led to the introduction of many costly foreign fashions; so that, in 1363, expensive dress, beyond the income or rank of the wearer, was forbidden by law; furs of ermine and pearl ornaments (except for head-dress) were forbidden to all but the royal family and the wealthiest nobles; cloths of gold and silver were permitted only to the next in fortune; and persons of small income were forbidden to wear silks, embroidery, or trinkets. But the ladies dressed still more sumptuously, as in the engraving, where the gown fits close in the boddice, and the train is so long in the front as to be held up, and thus display the embroidered under-dress; the sleeveless jacket worn over the gown is also embroidered and trimmed with fur; the hair is worn long, and the cap is low, and resembles a coronet. Tippets from short sleeves, and the jupon, were also worn by ladies as well as by gentlemen; and both sexes wore daggers stuck through pouches in their rich girdles. In this reign *mourning habits* appear to have been first worn, the colours being black and brown.

Lady of 14th Century.

Gentleman of 14th Century.

The reign of Richard II. must have been the high carnival of coxcombry. The sovereign himself, according to Holinshed, had a coat or robe which cost 30,000 merks. Party-coloured dresses were universally worn, and even the hose were of two colours, so as to render the term *a pair* inapplicable: the colours of the king and his court were white and red. Men and women alike wore hoods set with jewels; and their tippets were jagged, and reached to the heels; and the long-peaked shoes, called *crackowes* (from Cracow, in Poland), were fastened to the knees with gold and silver chains. The preceding engraving shows a gentleman of this period, with shoes and hose all in one, the mantle cut into the shape of leaves at the edges, a belt and pouch, and a fantastically-turbaned head-covering. Chaucer has left us the costume of several ranks at this period: his squire wears a short gown, 'with sleeves long and wide;' his yeoman 'a cote and hoode of grene;' his merchant many colours, with a forked beard, and a 'Flaundrish beaver hat,' and clasped boots; the reeve or steward a long surcoat and rusty sword, his beard and head shaven and shorn; the miller wore a white coat and blue hood, a sword and buckler, and red cloth holiday-hose; and the hats, caps, and bonnets of all classes were very fantastical. Knives, ornamented with silver, and purses, were worn by most classes in their girdles; and shoulder-belts, with bells, were a mark of rank. Liveries are also now mentioned as worn by substantial artisans, as well as by menial servants; but the ploughman appears only in a tabard or sleeveless coat, and the mechanic in a tunic. The hair was worn long and curled, and the beard forked.

In the female costume of this reign the fantastic party-coloured dresses were retained, with the embroidered jupons and kirtles, hip-girdles, and long tippets from the elbow; and the *surcot* or external coat, faced with fur, and terminating in a train sometimes so long as to be carried over the arm, or shorter, opened up the side, and bordered with ermine. The head-dress continued as in the preceding reign. The attire of the carpenter's wife in the 'Canterbury Tales,' with a silk girdle and head-fillet, and brooch, indicates the condition of this class of females.

Gentleman of 15th Century.

The costume of the fifteenth century was equally gay and foppish, but perhaps more neat in form. The annexed engraving represents a gentleman of the reign of Henry V.; he is dressed in a short tunic, buttoned in front, with girdle, large loose sleeves, tight hose forming pantaloons, and stockings in a single piece, peaked shoes, and head-cloth or cap. About this period, silks and velvets of divers colours came into use among the higher classes, by whom gold chains were generally worn. The dress of ladies was of the richest kind. Gowns were embroidered, and bordered with furs or velvet; and the boddice, laced in front over a stomacher, now first appeared. But the greatest eccentricity was the lofty steeple head-dress, shown in the annexed portrait; this consisted of a roll of linen covered with fine lawn, which hung to the ground, or was mostly tucked under the arm. Richard III. (1483-85) according to his wardrober's books, was a right royal fop, for we find him wearing a blue cloth-of-gold doublet and stomacher, 'wroght with netts and pyne-apples,' and crimson and purple-velvet robes, embroidered and furred, and crimson satin hose, and tissue cloth-of-gold shoes, at his coronation. The nobles in this reign had their hose tied by points to the doublet, which was sometimes worn open, but laced like a boddice; and over it was worn a long or short-gown, the former hanging loose, and the latter plaited before and behind, and girded about the waist; and both gown

Lady of 15th Century.

and doublet were slashed. The general head-dress was a closely-fitting cap or *bonet* (bonnet), with a single feather in it; and scarlet hats and hoods were worn. The boots had very long-pointed toes, and reached to the middle of the thigh.

Hitherto the authorities for costume have been illuminated manuscripts, tapestry, and monumental effigies, in which there is often perplexing indistinctness. Now painting comes to our aid; and the portraits by Holbein are the best illustrations of the costume of the two succeeding reigns. The male costume of the wealthier classes in the reign of Henry VII. consisted of a fine shirt of long lawn, embroidered with silk round the collar and wristbands. The sleeves of the doublet were slashed at the elbow, as in the reign of Edward IV.; or they were in two or more pieces, fastened at the shoulders and elbows with laces or points, through which the shirt protruded. The doublet was laced over a stomacher and petticoat, the male costume thus resembling that of the females in name as well as form. The outer garment was a long coat or gown, with loose hanging sleeves, and a broad turn-over collar of velvet or fur. The long hose were differently coloured in the upper and lower portions, and in the former slashed or puffed; the shoes were absurdly long and broad-toed, and high boots were worn for riding. In the head-coverings there was great variety. The hoods were abandoned to official habits, and instead were worn broad felt-hats or caps, and bonnets of velvet or fur profusely decked with ostrich feathers; or the large plumed cap was slung at the back, and a smaller cap of velvet or gold net worn on the head. The knave of our playing-cards has a cap peculiar to this period.

In these distracted times party-colours were worn. Thus the family colours of the House of Lancaster were white and red; those of York purple and blue; and those of Tudor white and green. Buttons also bore partisan figures or emblems.

The female costume of the reign of Henry VII. is distinguished by the square cut of the boddice in the neck, and embroidered and jewelled stomachers, belts, and girdles hanging in front nearly to the feet; the sleeves were large and full, and when confined at the wrist, resembled 'the bishops' sleeves' imitated in England, from the French, a few years since. These sleeves were slashed, divided, and joined like those of the men. The head-dresses were close caps and cauls, from beneath which the hair hung down to the waist; and several kinds of capuchons were worn. In the dress of the humbler classes we find mentioned a 'furred flocket and gray russet rocket,' 'kirtle bristow red,' 'blanket hose,' 'Lincoln green,' &c.

At the close of this century the mourning habits had become so sumptuous as to be limited by law; the principal article being a barb or veil, used at funerals, which was tied on above the chin by duchesses and countesses, and lower by all other ranks.

Throughout the above period the principal material of the clothing of the middle classes must have been abundant; for, in the reign of Edward III., our woollen manufacture almost rivalled that of the Flemings, and our exports to the continent were very large; there appears, however, to have been little or no linen made at this period in England.

Sixteenth Century.

In the sixteenth century the upper part of the long hose began to be worn loose, or slashed with pieces of different colours let in, and the arms and shoulders of the doublet or jacket were fashioned in a similar style. Boots were also worn loose on the leg, with the upper part falling down; hence the origin of the buskin. Ruffs or ruffles, collars, and velvet bonnets with feathers, came likewise into use, as may be seen from the paintings of Henry VIII. Hall, the chronicler, describes several of Henry's superb dresses, and among them a *frocke*, or coat of velvet, embroidered all over with gold of damask, the sleeves and breast cut and lined with cloth of gold, and tied together 'with great buttons of diamonds, rubies, and orient pearls.' The cloaks and mantles were of corresponding magnificence. The shirts were pinched or plaited, and embroidered with gold, silver, or silk. The term *hose* continued to be applied to the entire vestment, from the waist to the feet, throughout this century: the material is more distinctly stated, for Henry wore knit silk, as well as cloth hose; the precise period of the separation of the hose into breeches and stockings, is not so clear as the derivation of the latter term from the '*stockying* of hose;' 'that is, adding the lower part that covered the legs and feet to that which was fastened by points to the doublet,' and was called the *stocks*. The shoes and buskins were of the German fashion, very broad at the toes, and of velvet and satin, slashed and puffed. The hats, caps, and bonnets were of almost endless forms and colours.

Henry passed sumptuary laws, directing that cloth of gold and tissue should be used only for dukes and marquises, and that purple should be kept for the royal family. Earls might use embroidery, and commoners of distinction silks and velvets; and it was even thought necessary to restrict the commonalty and serving-men to cloth of a certain price, and lambs' fur, and to forbid them wearing any ornaments, or even buttons, save the badge of their lord or master. The king likewise forbade his courtiers wearing long hair, according to the general fashion, and made them poll their heads, which led to the introduction of the peruke, afterwards written *periwig*, and more shortly *wig*. The masques, or plays in masquerade, in Henry's reign, were very splendid; and in the ladies' dresses worn at one of them, are mentioned 'demy sleeves, naked down from the elbows,' which M. Planché considers to have been the first appearance of bare arms since the time of the ancient Britons.' Gloves were not unknown, for Henry left a pair to one of the executors of his will. They were sometimes finely perfumed, and brought from Spain and Italy as presents. In this and the preceding reign the head-dresses assumed a different character, having long lappets or ear-pieces hanging down below the shoulders, and when made of velvet studded with pearls, jewels, and gold, they were truly superb. Three-cornered caps of minever were also worn throughout the reign; and the close-fitting cap reaching to the ears, and known as 'Mary Queen of Scots' cap,' was first worn about this period. The ladies' hunting-dress differed but little from the riding-habit of the present day; across it was usually slung, from the right shoulder to the left side, a horn resembling a bugle.

In this reign *pins* were first brought from France, and used by Catharine Howard, before which time the different parts of the dress were kept together by ribbons and loopholes, laces with points and tags, clasps, hooks-and-eyes, and skewers of brass, silver, and gold; but the poorer classes used the natural thorn for the above purpose.

The dress of the middle ranks in this reign may be seen in prints of the time: plain russet coats, and white kersey sloppes, or breeches, with stockings of the same piece, were the ordinary suit; and the London apprentices wore blue cloaks in summer, and gowns of the same colour in winter, as badges of servitude; for this appears to have been the age of domestic distinctions — the relics of the feudalism of the middle ages. The women wore sheep, russet, or long woollen gowns, worsted kirtles (hereafter called *petticoats*), and white caps and aprons; and milk-white underlinen came into general wear. The engraving shows a man and woman in the ordinary dress of this period.

Man and Woman of 16th Century.

The principal novelty of the reigns of Edward VI. and Mary was the flat round bonnet or cap, of plain velvet or cloth, worn on one side of the head, and decorated with a jewel and single ostrich feather. The bonnet itself is preserved in the caps worn at the present day by the boys of Christ's Hospital; and their blue coat and yellow stockings are such as were worn by the London apprentices at the date of the foundation of the hospital by the youthful Edward. The gown of the wealthier classes was furred with sables in front and round the broad sleeves. Philip, on his marriage with Mary, brought into England a richer style of dress for the men, particularly the close ruff; the doublet, which fitted exactly under the chin, and the short Spanish cloak—all of which remained for a considerable time in fashion. The preposterously large stocks, or trunk hose, continued to be worn, but the broad-toed shoes were discarded. The armour continued nearly the same as in the preceding reign. To female costume the chief addition was the *fardingale*, an immense hooped petticoat, introduced from Spain under Queen Mary. The entire dress was worn very close, so as to conceal the person as much as possible.

Queen Elizabeth's fondness for dress is well known; she is stated to have left three thousand different habits in her wardrobe. This great number is explained by the royal affectation of wearing by turns the costume of all the nations of Europe, which may be traced to the use of foreign materials made up by foreigners. Bohun, in his character of Elizabeth, tells us that 'when she appeared in public she was richly adorned with the most valuable clothes, set off again with much gold and jewels of inestimable value; and on such occasions she even wore high shoes, that she might seem taller than indeed she was. The first day of the parliament she would appear in a robe embroidered with pearls, and upon her head she had a small crown. She was dressed in white silk, bordered with pearls of the size of beans, and over it a mantle of black silk, shot with silver threads. Her train was very long. Instead of a chain she had an oblong collar of gold and jewels.'

But the glory of the Elizabethan era of female costume, as well as its most remarkable characteristic in the sixteenth century, was the *ruff* of plaited linen or cambric, which now became superb, and rose from the front of the shoulders behind the head nearly to its full height; from the bosom descended a huge stomacher, on each side of which projected the immense fardingale. In this characteristic costume Elizabeth went to St Paul's Cathedral to return thanks for the defeat of the Spanish Armada; though, besides the magnificent ruff, the queen wore a mantle with a large wing-like collar, her hair intertwined with pearls, large pendant jewels on the neck, and a superb lattice-work of pearls over the entire dress.

The ruff must, however, be further noticed: no sooner had its material been changed from Holland to lawn or cambric, than a difficulty arose as to starching or stiffening it, instead of the clumsy mode of supporting it by poking-sticks of ivory, wood, or gilt metal. At length the art of starching was brought from Flanders, and taught in London for a fee of four or five pounds. The fashion next lay in the colour of the starch, of which there were five varieties.

Stockings, which we find mentioned as foreign rarities in the wardrobe accounts of Henry VIII. and Edward VI., became common of home manufacture in the reign of Elizabeth. In the third year a pair of black knit silk stockings, made in England, was presented to her majesty, who was so pleased with the article, that she would never after wear cloth hose. This resolution has been attributed to Elizabeth's desire to encourage English manufactures by her own example, and may be taken as some set-off to her extreme fondness for foreign materials and fashions of dress. Soon after this, a city apprentice having borrowed a pair of knit worsted stockings brought from Mantua, made a pair like them, which he presented to the Earl of Pembroke; and these are the first worsted stockings known to have been knit in England. Mary Queen of Scots, at her execution, wore stockings of blue worsted clocked and topped with silver, and under them another pair of white; and the stockings of this time generally consisted of silk, jarnsey, worsted, crewel, fine yarn, thread, or cloth, of all colours, and with clocks, open seams, &c. The invention of the stocking-frame by Lee at Calverton, near Nottingham, in 1599, must have brought stockings into general use: he or his brother is said to have worked for Queen Elizabeth; but he was driven by the jealousy of the other stocking manufacturers into France, where he died of a broken heart—an end by no means uncommon in the lives of inventors.

The garters of this age were very costly, sometimes of gold or silver, and £4 or £5 a-pair; they are presumed to have been worn by ladies since the time of Edward II., but they must not be confounded with the leg bandages of an earlier date. The ladies wore 'corked shoes, pinsnets, pantoffles, or slippers,' which raised them two inches or more from the ground: these were made of black, white, green, or yellow velvet, or Spanish and English leather, embroidered with gold, silver, or silk, and shaped after the right and left foot, like the Anglo-Saxon sandal. The Elizabethan head-dresses were French hoods, hats, caps, kerchiefs, cauls of net-wire, and lattice caps—the latter, as well as an ermine bonnet, being forbidden by law to all but 'gentlewomen born, having arms.' In Elizabeth's jewel-box is a long list of wigs, or rather head-dresses, among which are cauls of hair set with seed-pearl and gold buttons. The hair was curled, frizzled, and crisped, and under-propped with pins and wires into the most fantastic forms. The finger-rings, earrings, bracelets, and other jewellery, were very splendid; velvet masks and pocket looking-glasses were carried by fashionables, with fans of ostrich feathers set in gold, silver, or ivory handles—the latter introduced from Italy, and used by both sexes.

The male costume in Elizabeth's reign was the large trunk hose, long-waisted doublet, short cloak, hat, band and feather, shoes with roses, and the large ruff; but the great breeches, 'stuffed with hair like woolsacks,' after the separation of the hose into this garment and stockings, appear to have been worn throughout the reign: they were made of silk, velvet, satin, and damask. The doublets were still more costly, and quilted and stuffed, 'slashed, jagged, pinched, and laced;' and over these were worn coats and jerkins in as many varieties as there are days in the year. The cloaks were of the Spanish, French, and Dutch cuts, of cloth, silk, velvet, and taffeta of all colours, trimmed with gold, silver, and silk lace and glass bugles, inside and outside equally superb. The stockings, shoes, slippers, and ruffs resembled those of the ladies.

Hats now began to supersede the bonnets of a former era. Those of beaver were exceedingly expensive, and they were for the most part made of felted wool, dyed. The most remarkable thing about these hats was their numerous shapes: some were steeple-crowned; others were flat and broad, like the battlements of a house; and others with round crowns, and bands of all colours, and ornamented with huge feathers and brooches, clasps, and jewels of great value.

In taking leave of the British costume of the sixteenth century, we may observe that its splendour was almost entirely borrowed from France, 'that country which has since given laws in dress to nearly all Europe.'

Seventeenth Century.

Under James I. the male costume was somewhat more decidedly Spanish, as respects the slashing and ornamenting of the doublet and breeches. Late in the reign, however, the jackets or doublets were shortened, and the breeches reduced in size, and fastened in large bows at the knees; the well-stockinged leg was admired, and the hat worn low in the crown, and with broad brim, as seen in portraits of the date 1619. Beards and whiskers had become almost universal in the reign of Elizabeth; but in that of James, the former was sometimes worn trimmed to a point, hanging down at the division of the ruff.

In the female costume there was little change. The huge fardingale continued to be worn by the nobility; a strong passion for foreign lace was introduced; pearls were the favourite jewels; and the ruff maintained its sway, so as to be anathematised from the pulpit; and the fancies of female costume were glanced at in a sermon preached before the king at Whitehall in 1607–8, as 'her French, her Spanish, and her foolish fashions; her plumes, her fannes, and a silken vizard, with a ruff like a sail, yea, a ruff like a *rainbow*, with a feather in her cap like a flag in her top, to tell which way the wind will blow.'

The dress worn in the reign of Charles I. is unrivalled for picturesqueness and elegant taste. At this we shall not be surprised, if we recollect that it was copied from the habit of Spain, the most becoming of all European costumes. Early in this reign, however, the motley fashion of the time of James I. prevailed; and the Savoy neck-chain, the ruff and cuffs of Flanders, the Naples hat with the Roman hat-band and Florentine agate, the Milan sword, and the cloak of Geneva set with Brabant buttons, gloves from Madrid, &c. were the characteristics of the beau of 1629. The ruff had almost universally given place to the falling band; and collars of rich point lace, large and hanging down on the shoulders, held by a cord and tassel at the neck, and now called *Vandyke*, from its being the most striking part of the dress in which Vandyke at that time painted portraits.

The principal habits were vests and cloaks of velvet, or silk damask, short trousered breeches terminating in stuffed rolls, and fringes and points, and very rich boots, with large projecting lace tops. A dress of Charles is thus described:—A falling band, green doublet (from the armpits to the shoulders wide and loose), zig-zag turned-up ruffles, long green breeches (like a Dutchman's), tied below the knee with yellow ribbons, red stockings, green shoe-roses, and a short red cloak lined with blue, with a star on the shoulder; the king sometimes wore a large cravat, and at other times a long falling band with tassels. The dress of the gay courtiers or cavaliers consisted of a doublet of velvet, silk, or satin, with large loose sleeves, slashed and embroidered; Vandyke collar and band, and short embroidered cloak, worn on one shoulder; the long breeches, fringed and pointed, met the ruffled tops of the boots; the embroidered sword-belt was worn over the right shoulder, and in it was hung a Spanish rapier; and in the flapping beaver hat was worn a plume of feathers confined by a jewel. A buff coat or jerkin was often worn, as a better defence than the doublet, which it sometimes covered. The engraving represents a citizen of this period more plainly attired.

Citizen in time of Charles I.

The female costume of this period was rather elegant than splendid. Gowns with close bodies and tight sleeves were worn, though the fardingale was retained, with a gorget ruff standing up about the neck like a fan. French hoods were still worn, though with little distinction as to rank. The hair was worn in small curls, and the hoods, of all colours, fastened under the chin with curious effect. Earrings, necklaces, and bracelets were much worn; but the Puritans forbade the females to wear lace, jewels, or even braided hair; and they retained the close hood and high-crowned hat.

Towards the close of the reign of Charles I., the cumbrous fardingale disappeared, with the yellow starched ruff and band. These tasteless fashions having disappeared, the female dress became very elegant, with its rich full skirt and sleeves, and falling collar edged with rich lace, and the hair worn in graceful ringlets; but these vanities were condemned by the Puritan party.

With the Restoration of Charles II. came certain tasteless innovations upon the elegant Vandyke costume of the time of Charles I., which were the first resemblance to the coats and waistcoats of the present day. Thus our most picturesque attire lasted little more than a quarter of a century. Its decline was gradual; its chivalric character soon degenerated into grotesqueness, which in its turn changed to stark meanness. Early in the reign of Charles II. the doublet was much shortened, and worn open in front, where, and at the waistband, the rich shirt was shown; and the loose sleeves and breeches were decked with ribbons and points, and from the knee-bands hung long lace ruffles. At the wrists, too, ruffles were worn; but the lace collar was shorn of its points, designated to this day Vandyke. The cloak was retained upon the left shoulder, and the high-crowned and plumed hat remained for a short time; but the crown of the hat was soon lowered.

The petticoat breeches were another absurdity; although ornamented with ribbons at the sides, the lining strangely appeared below the breeches, and was tied at the knees; to match which the sleeves of the doublet only reached to the elbows, and from under them bulged the ruffled sleeves of the shirt, both being ornamented with ribbons. Meanwhile the skirt of the doublet had been lengthened from above the waist nearly to the knees, and had buttons and button-holes in its entire length, thus becoming a *coat*, and so named in an inventory of 1679; wherein also are the items of *waistcoat*, *breeches*, *pantaloons*, *drawers*, and *trousers*, being the earliest mention of these articles. Stockings of various kinds were common; and 'the lower ends of stockings' are understood as socks. Instead of the lace collar was worn the long square-ended cravat, of the same material, from Brussels and Flanders.

The female costume, as if to compensate for the tasteless additions to that of the men, retained much of its elegance in Charles's reign; indeed from this time 'the stronger sex' appear to have left the art of dress to the ladies. The portraits of the beauties of the court of Charles II., in Windsor Castle and Hampton Court Palace, are familiar illustrations, in which we see only a pearl necklace upon the bosom, and the hair falling in luxuriant ringlets from beneath a string of pearls.

Citizen's wife in the time of Charles II.

The gowns are of the richest satin, low in the bosom, and have long trains, so that the wearers could not 'stir to the next room without a page or two to hold them up.' The annexed engraving represents a citizen's wife performing this office herself.

Passing to the reigns of James II. and William III., we find few noticeable novelties in costume. The coats were often of velvet, without collars, with large hanging sleeves, and button-holes of gold embroidery. The petticoat breeches were exchanged for the close-fitting garments tied below the knee, and therefore called *knee-breeches*; the broad-brimmed hats were turned up on two sides, and edged with feathers or ribbons; the fashion lay in the rich long lace cravat and embroidered waistcoat; the band was now narrowed, so as to resemble that worn at the present time by clergymen. The periwig was worn still longer than hitherto, hanging down in front, or flowing upon the shoulders, though the colour was altered from black to suit the complexion; and combing these wigs was a piece of gallantry, for which purpose a comb was carried, whence the origin of our present pocket-comb: and at court, in the walks of Kensington, the Mall of St James's, or the boxes of the theatre, the beaux curled their wig curls over their fingers whilst in conversation; the effect of these wigs flowing over the cuirass will be seen in the portrait of the great Duke of Marlborough.

The female costume was unchanged in the reign of James II.; but it became less luxuriant and more formal in the time of William and Mary, in accordance with Dutch taste. The waists were much lengthened with velvet stomachers, covered with jewels, so as to conceal the bosom, hitherto unsparingly exposed; the sleeve was made tight, and trimmed with lace lappets or ruffles, and long gloves were worn, so as entirely to cover the arm; but the skirts were worn long, full, and flounced; the hair, instead of flowing in ringlets, was gathered up, and strained over a toupee of silk or cotton wool, carried up so high as to be called a tower, covered with a lace scarf or veil that hung in front below the bosom; but this head-dress gradually shrunk into a caul with two lappets, known as a 'mob.' False locks and curls, set on wires to make them stand out, were also worn. Before the Revolution the citizens' wives dressed with becoming plainness, and gentlewomen wore serge gowns, which, after 1688, were rejected by chambermaids.

A few of the fashions and peculiarities of this century may be summed up in conclusion. From the reign of James I., the ladies appear to have dressed their hair in better taste than previously, in curls on each side of the face, and braided in a knot at the back of the head, where it was often ornamented with jewels or pearls, or a single feather. It was next worn in long locks flowing below the shoulders; and the love-lock, ornamented with ribbon and twisted pearls, was worn on one side. From the reign of Charles II. to that of Queen Anne, long hair was much prized, and was often sold by women of inferior fortune to be made into periwigs. About this time the *fontange*, or top-knot, so called from Mademoiselle de Fontange, who first wore it, was driven out of fashion by the fanatical spirit of the time. *Hair powder* was also introduced from France in this century: it was worn of various colours, an absurdity only discontinued at the close of the last century. Towards the close of the century wigs became fashionable, together with false hair; 'a custom contrary to our forefathers, who wore their own hair.'

Under the House of Stuart, the shoe-rose yielded to the shoe-string, the beaux wearing them of silk tagged with silver, and the humbler classes wore laces of plain silk, or even leather thongs—the latter still to be met with in rural life. Shoe-buckles, in size and shape resembling the horse beau, were introduced at the period of the Revolution.

Eighteenth Century.

In the early part of the eighteenth century the costume of the English gentry was greatly affected by that introduced into general usage in France by Louis XIV. About the reign of Queen Anne the new French fashions had been embraced by courtiers, physicians, and other professional persons in England, also the higher order of gentry; and in the following reigns of George I. and II. it became universal.

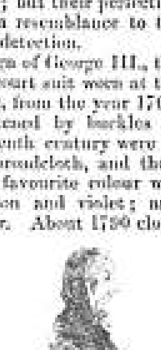
This dress of the old English gentleman, as it afterwards came to be called, consisted at first, during Queen Anne's reign, of a periwig in formal curls, partly contained in a silk bag on the shoulder; a small cocked hat, full bottomed coat, short breeches, blue or scarlet stockings drawn over the knee, and square-toed shoes, with small buckles and high red heels. And this formal costume, relieved only by lace cuffs, ruffles, and neckcloth, and gold or silver clocks in the stockings, remained unmodified through three-quarters of the century. The engraving shows a gentleman of the year 1750, and reminds us that the snuff-box, first carried in the reign of James II., continued indispensable for the 'fine gentleman.' The origin of the cocked-hat is easily explained. The wide flaps or broad brims of the hats in use being found to be inconvenient, they were looped up with a cord and button. At first this was done according to fancy, but latterly there were distinct fashions in cocking the hats. Cocked-hats, richly trimmed with gold-lace and ostrich feathers, occur in Hogarth's pictures, which indeed will furnish a better idea of the entire costume from 1727 to 1760 than many pages of description; and the portraits of Sir Joshua Reynolds will supply the dress of the next forty years.

Gentleman of 1750.

The fashions of wigs were as various as those of hats. A peruke and a plaited and tied tail were called a Ramillies, from the famous battle of that name. The tie-wig became the fashion, from the celebrated Lord Bolingbroke going to court with his wig tied up, upon which Queen Mary observed that he would 'soon come to court in his nightcap,' a royal rebuke which established a fashion. In 1764 wigs went out of wear, and the wig-makers of London petitioned George III. to compel gentlemen to wear wigs by law, for the benefit of their trade! In the present day formal wigs are almost confined to the heads of prelates and law officers; and the latter, to get rid of the powder nuisance, wear wigs made of other materials than hair, as the metal platina. Wigs are, however, much worn, from the greater prevalence of baldness than formerly; but their perfection now consists in bearing so close a resemblance to the natural or living hair as to avoid detection.

Towards the middle of the reign of George III., the male dress took the form of the court suit worn at the present day; the breeches having, from the year 1760, been worn over the knees, fastened by buckles or strings. The coats of the eighteenth century were of velvet, silk, or satin, as well as broadcloth, and their colours very fanciful. Hogarth's favourite colour was sky-blue; Reynold's deep crimson and violet; and Goldsmith rejoiced in plum-colour. About 1790 cloth became the general wear; the waistcoat being of the costlier materials, and embroidered, and sometimes the breeches. Buckles were worn at the knees and in the shoes till the close of the last century; and the large square plaited buckle was the ton until 1791, when shoe-strings became general; though the Prince of Wales and his household endeavoured, by wearing buckles, to retain the fashion.

The female costume of the eighteenth century was as formal and tasteless as that of the men. The most odious piece of attire introduced in the early part of the century was the large whalebone petticoat, which degenerated into the hooped petticoat, and made a lady to appear as if standing in an inverted tub. In the reigns of George I. and II., loose gowns, called *sacques*, and hooded silk cloaks, were worn, and a very small muff, such as have been lately revived. This costume is shown in the annexed portrait of a lady of George II.'s time. Ornamental aprons were also worn, as at the present day, with the watch, necklace, and the fan,



Lady in the time of George II.

which was sometimes from twelve to eighteen inches in length, and beautifully made. Gay sings—

> 'The fan shall flutter in all female hands,
> And various fashions learn from various lands.
> For this shall elephants their ivory shed,
> And polished sticks the waving engines spread:
> His clouded mail the tortoise shall resign,
> And round the rivet pearly circles shine.
> On this shall Indians all their art employ,
> And with bright colours stain the gaudy toy:
> Their paint shall here in wildest fancies flow;
> Their dress, their customs, their religion show.'

Spanish broadcloth, trimmed with gold-lace, was used for ladies' dresses in the reign of George I.; and fur-belowed scarfs were worn from the duchess to the peasant.

Veils of the finest material, as a shroud to the female features, are of great antiquity, and may be traced to Oriental nations, among whom the seclusion of women from general gaze is a point of etiquette. In the eighteenth century, in England, after the disuse of towering head-dresses, veils of an elegant fabric were introduced, and still are not altogether out of date. Female caps of gauze or muslin are of French origin, and have always been multifarious in form. The bonnet, in early times generally made of velvet, cloth, and silk, was in the eighteenth century changed to straw. Gay mentions a new straw-hat lined with green, about 1724, but it was then comparatively rare; for the simple art of plaiting straws together to make bonnets was only practised to any considerable extent about sixty years since; it now employs upwards of 200,000 females in England—Dunstable in Bedfordshire producing the best plait. In our time English straw has been superseded by Leghorn plait, which having declined in fashion, our own straw, silk, and velvet, have been substituted as materials for bonnets; and our home manufactures must have been materially benefited by the change.

Nineteenth Century.

The formalities of the eighteenth century received a terrible blow at the French Revolution; and in the ten years from 1790 to 1800 a more complete change was effected in dress, by the spontaneous action of the people, than had taken place at any previous period in a century. The change began in France, partly to mark a contempt for old court usages, and partly in imitation of certain classes of persons in England, whose costume the French mistook for that of the nation generally. This new French dress was introduced by the party who were styled the Sans Culottes. It consisted of a round hat, a short coat, a light waistcoat, and pantaloons; a handkerchief was tied loosely round the neck, with the ends long and hanging down, and showing the shirt collar above; the hair was cut short, without powder, *à la Titus*, and the shoes were tied with strings.

The comparatively simple form of dress of the Sans Culottes found many admirers in England, and soon became common among young men; the change from antique fashions was also greatly helped by the imposition of a tax on the use of hair-powder, which was henceforth generally abandoned. Pantaloons, which fitted closely to the leg, remained in very common use by those persons who had adopted them till about the year 1814, when the wearing of trousers, already introduced into the army, became fashionable. It is proper, however, to mention that trousers had, for the previous fifteen or twenty years, been used by boys, and were perhaps from them adopted by the army. Previous to the French Revolution, the dress of boys was almost the same as that of men. Although trousers were generally worn after 1815, many elderly persons still held out in knee-breeches against all innovations, and till the present day (1848) an aged gentleman may occasionally be seen clinging to this eighteenth-century piece of dress. The general use of white neckcloths continued, notwithstanding the introduction of the standing collar, till the reign of George IV., when this monarch's taste for wearing a black silk kerchief or stock, and also the use of black stocks in the army, caused a remarkably quick abandonment of white neckcloths, and the adoption of black instead. The year 1825, or thereabouts, was the era of this signal improvement in costume.

While these leading changes were effecting, other alterations of a less conspicuous nature were from time to time taking place. The disbanding of the army after the peace of 1815 led to various transformations besides those we have mentioned. While pantaloons were the fashionable dress, it became customary to wear Hessian boots; these, which had originated among the Hessian troops, were without tops, and were worn with small silk tassels dangling from a cut in front; being drawn over the lower part of the pantaloons, they had a neat appearance, but the keeping of them clean formed a torment that prevented their universal use. When trousers were introduced from the practice of the army, the use of Wellington boots to go beneath them also became common.

Referring to the era of 1815 to 1825, as that in which trousers, Wellington boots, and black neckcloths or stocks came into vogue, we may place the introduction of the surtout in the same period of history. From the time when the collarless and broad-skirted coat had disappeared about the commencement of the century, the fashion of coats had changed in various ways till the above-named era, when the loose frock-coat or surtout was added to the list of garments. We remember seeing French military officers, when in undress, wearing frock-coats as early as 1811; it is probable, therefore, that the modern surtout is only a variety of the loose military greatcoat brought from the continent by the British army; however it originated, it may be allowed to be one of the greatest improvements in the style of dress which has yet occurred in the nineteenth century.

On the whole, the dress of the current age is characterised by simplicity and elegance. The male attire is plain, and in good taste, with the exception of the 'dress-coat' and hat, both of which are as unnatural in cut as they are void of comfort. Female attire was never perhaps more chaste and becoming; the only articles which occasionally merit censure being the square or angular-formed shawl, and the ever-changing but never very classic-looking bonnet. And yet, though convinced of an occasional absurdity in the matter of costume, it is the wiser course rather in so far to follow than attempt to lead in an altogether different direction. 'A man,' says Feltham, and he says wisely, 'ought, in his clothes, to conform something to those that he converses with, to the custom of the nation, and the fashion that is decent and general, to the occasion and to his own condition; for that is best that best suits with one's calling and the rank we live in. And seeing that all men are not Œdipuses, to read the riddle of another man's inside, and that most men judge by appearances, it behoves a man to barter for a good esteem, even from his clothes and outside. We guess the goodness of the pasture by the mantle we see it wears.'

PROVINCIAL PECULIARITIES.

The *Welsh*, as a relict of an ancient Celtic people, possess remarkably few external traits of their original. They have, like the Irish, become Anglicised in costume, and we should in vain search amongst them for the *breacan* or chequered clothing of their Scythian ancestry. The most remarkable part of the Welsh costume is the hat worn by the women. All females in parts of the country not modernised wear round black hats, like those of men; and this fashion is supported to a small extent by ladies of the higher rank. This use of the hat is not Celtic: the fashion is derived from England, and is only two or three centuries old.

The *Irish* at an early period wore the same Celtic fashion of attire as was preserved till recent times in the Scottish Highlands; but, as in Wales, everything of the kind disappeared as the country became Anglicised. A primitive species of attire, including coloured mantles, kirtles, and other fanciful garments, remained in use till the sixteenth century, when laws were passed by Henry VIII. enjoining the use of caps, cloaks, coats, doublets, and hose, of English cut, but of Irish or any other materials. The general dress in Ireland, at the present day, rarely varies from that in England. There are, however, some interesting peculiarities of costume amongst the peasantry of the southern and western counties.

The costume of the Lowland Scotch has generally resembled that of the English in all its changes and vicissitudes. At the present day, Scotland cannot be said to possess any national costume which distinguishes the bulk of the people from their fellow-subjects in South Britain; and however much the fact may surprise the artists and dramatists of England, it is very certain that the inhabitants of Edinburgh, Glasgow, and other cities and towns of Scotland, are dressed in precisely the same fashion of garments as is now seen in the streets of London, Paris, Brussels, or the capital of any other civilised country.

Anciently, the dress of the Scotch, both those of the Highlands and Lowlands, was distinguished by party-colours, woven in cheques, according to taste or ancient usage. By the Celtic race in the Highlands, this species of variegating cloth with colours was called *Breacan*, which signifies spotted, and by the Teutonic population of the Lowlands it received the name of *Tartan*, a word whose origin has defied the researches of etymologists, but which it is not unlikely may have been derived from the ancient Tartar races, who used a similar kind of colouring in their attire. Till the present day, cloths checked in various colours are worn by the Calmucs and other tribes in the north of Europe. Tartan for clothing disappeared in the Lowlands of Scotland in the course of the seventeenth century; but even as late as the beginning of the eighteenth century, party-coloured plaids were pretty generally worn; and young women were in the habit of using a 'tartan screen'—that is, a small plaid of variegated colours. The tartan screen, which was worn in the fashion of a covering for the head and shoulders, so as to combine in some measure the properties of a modern bonnet and shawl, was formed of costly materials; the ladies of the higher classes employing silk, and those of inferior station fine worsted, the colours in each case being remarkably brilliant. Being often employed with a degree of real or affected modesty to conceal a part of the features, it may be said to have performed the office of a veil to Scottish maidens; and hence its appellation of *screen*. Perhaps the use of this species of coif was a consequence of a point of etiquette, which rendered it indecorous for young unmarried women to wear any regular garment on the head.

While tartan disappeared from the Lowlands, except in the screens of the women and the plaids of the shepherds, it continued to be in universal use in the Highlands, where it may be said to have been always associated with the manners of the people; and this leads us to say a few words respecting

Highland Costume.—Originally, the costume of the Highlanders resembled that of other Celtic tribes, and consisted of little else than a woollen garment of variegated colours wrapped round the body and loins, with a portion hanging down to cover the upper part of the legs. In progress of time this rude fashion was superseded by a distinct piece of cloth forming a philibeg or kilt, while another piece was thrown loosely as a mantle or plaid over the body and shoulders. In either case the cloth was variegated in conformity with the prescribed *breacan*, or symbol of the clan; and hence the tartan was sometimes called *cath-dath*, or battle colours, in token of forming a distinction of clans in the field of battle.

According to the author of the 'Vestiarium Scoticum,' the following, in the reign of James VI., was the list of chief and subordinate clans, each possessing its own tartan; among these clans, it will be observed, are included certain Lowland families or houses, who had also adopted the same kind of cognisance:—

Clan Stewart—six colours, chiefly red, chequed with green, purple, black, white, and yellow.
Prince of Rothsay—three colours, chequed with green and white.
Royal Stewart—chiefly white, chequed with green, red, purple, and black.
Macdonald of the Isles—chiefly green, chequed with black, purple, red, and white.
Ranald—chiefly green, chequed with black, purple, red, and white.
Macgregor—chiefly red, chequed with green and white.
Ross—chiefly red, chequed with green and purple.
Macduff—chiefly red, chequed with green, black, and purple.
Macpherson—equal portions of black and white, with small lines of red and yellow.
Grant—chiefly red, with cheques of green and purple.
Munro—chiefly red, chequed with black and white.
Macleod—chiefly yellow, chequed with black and red.
Campbell—chiefly green, chequed with black, purple, yellow, and white.
Sutherland—chiefly green, with black, purple, red, and white.
Cameron—chiefly red, chequed with green and yellow.
Macneil—chiefly green, with purple, black, white, and red.
Macfarlane—very dark, being chiefly black chequed with white.
Machlachlan—chiefly yellow, with cheques of brown.
Gillean or Maclean—chiefly green, chequed with black and white.
Mackenzie—nearly equal portions of green and purple, chequed with black, white, and red.
Fraser—chiefly red, chequed with purple, green, and white.
Menzies—equal portions of red and white.
Chisholm—chiefly red, chequed with purple, green, and white.
Buchanan—chiefly red and white, with small black stripes.
Lamont—chiefly green, chequed with black, purple, and white.
Macdougall—chiefly red, chequed with black, purple, and green.
Mackintyre—chiefly green, chequed with purple, red, and white.
Robertson—chiefly red, chequed with purple and green.
Macnab—chiefly red, chequed with crimson, green, and black.
Mackinnon—chiefly red, chequed with green, black, and white.
Mackintosh—chiefly red, chequed with green, black, and white.
Farquharson—chiefly green, with purple, black, red, and yellow.
Gun—chiefly green, chequed with black and red.
Macarthur—chiefly green, chequed with black and yellow.
Mackay—chiefly a bluish-purple, with black and red cheques.
Macquean—nearly equal portions of red and black, with yellow.
Bruce—chiefly red, with green, yellow, and white.
Douglas—very dark, being equal cheques of black and slate colour.
Crawford—equal portions of red and green, with white.
Ruthven—chiefly red, with purple and green.
Montgomery—chiefly light green, chequed with purple.
Hamilton—chiefly red, with purple and white.
Wemyss—chiefly red, chequed with black, white, and green.
Cumyn—chiefly red, with green, black, and white.
Sinclair—chiefly green, chequed with black, purple, red, and white.
Dunbar—chiefly red, chequed with green and black.
Leslie—chiefly red, chequed with purple, black, and yellow.
Lauder—chiefly green, with purple, black, and red.
Cunningham—chiefly red, with black, purple, and white.
Lindsay—chiefly red, with purple and green.
Hay—chiefly red, with green, yellow, white, and black.
Dundas—chiefly green, with purple, black, and red.
Ogilvie—chiefly green, beautifully chequed with purple, black, yellow, and red.
Oliphant—equal portions of green and purple, with black and white.
Seton—chiefly red, with small lines of green, black, purple, and white.
Ramsay—chiefly red, with black squares chequed with white.
Erskine—red and green.
Wallace—red and black, chequed with yellow.
Brodie—chiefly red, with black and yellow.
Barclay—chiefly light-green and purple, chequed with red.
Murray—chiefly green, chequed with black, purple, and red.
Urquhart—chiefly green, with black, purple, white, and red.
Rose—chiefly red, with small cheques of purple, green, and white.

Colquhoun—green, purple, black, red, and white.
Drummond—chiefly red, with green and dark red.
Forbes—chiefly green, with black, red, and yellow.
Scott—chiefly red, with green, red, and black.
Armstrong—chiefly green, with black, purple, and red.
Gordon—chiefly green, with purple, black, and yellow.
Cranstoun—yellowish-green, with purple and red.
Graham—chiefly green, with black chequers.
Maxwell—chiefly red, with green and black.
Home—dark purple, with black, red, and green.
Johnstone—chiefly green, with purple, black, and yellow.
Ker—chiefly red, with black and green.

To this list the names of other Scottish families who have adopted a peculiar set of tartan as a cognisance could be added, and probably the entire number of tartans now fabricated for indiscriminate sale is not fewer than a hundred. One of the most commonly used patterns of tartan is that adopted by the 42d regiment—dark-green, chequed with purple. Some of what are called fancy tartans are gaudy, but not in good harmony or contrast of colour.

Suddenly in 1747, with the view of breaking the spirit of the clans, a law was enacted proscribing the use of the Highland dress, including the tartan in all its varieties. The following is the provision in the act of parliament on the subject:—'That from and after the 1st day of August 1747, no man nor boy, within that part of Great Britain called Scotland, other than such as shall be employed as officers and soldiers in his majesty's forces, shall, on any pretence whatever, wear or put on the clothes commonly called Highland clothes—that is to say, the plaid, philibeg, or little kilt, trowse, shoulder-belts, or any part whatsoever of what peculiarly belongs to the Highland garb; and that no tartan or party-coloured plaid or stuff shall be used for greatcoats or for uppercoats; and if any such person shall presume, after the said first day, to wear or put on the aforesaid garments, or any part of them, every such person offending, being convicted by the oath of one or more credible witnesses before any court of justiciary, "shall suffer imprisonment, without bail, during the space of six months;" and being convicted for a second offence, shall be transported to any of his majesty's plantations beyond seas, there to remain the space of seven years.' This contemptible law was repealed in the year 1782; but before that time the tartan and the 'garb of old Gaul' had been generally abandoned, except among Highland regiments, and it is chiefly copies from their attire that have guided modern attempts at reviving the costume.

As modernised and improved by the Highland regiments, the 'belted plaid,' worn as the philibeg or small kilt, with a separate drapery depending from the shoulder in imitation of the ancient garb, is one of the most picturesque and graceful costumes to be seen in any part of the world; and although it leaves the legs bare at and a short way above the knee, we are assured that it is by no means too meagre an attire for cold weather. Anciently, the Gael wore no shoes or garments for the legs. The feet were only on occasions covered with pieces of hide, tied with a thong, called *brogs*, which, though slender, were very lasting, and were well suited for walking or running on heathy mountains. The introduction of shoes, and also hose, formed from the same tartan cloth as the kilt, is comparatively modern. The hose of the common men in the Highland regiments are still not knitted or wove like stockings, but cut from the web and sewed. It appears that even in ancient times the Celtic tribes did not always wear the loose garments we have described; but that they also, or at least some of them, wore the *triughas* or *trius*, a species of vestment 'formed of tartan cloth, nicely fitted to the shape, and fringed down the leg.'

The coat, in which the upper part of the body and arms of the Highlanders are now invested, is of course quite modern, having come into use when the old form of the plaid dress was laid aside. Made, as it usually is, with short skirts and small round buttons, it cannot be considered in harmony with the rest of the attire; but it is nevertheless convenient.

The bonnet has for ages been a part of the Highland costume, as it was formerly also of the Lowlanders, and of the English, previous to the introduction of felt hats. The English gave up bonnets sooner than the Scotch; and ultimately the cry that 'the blue bonnets had come over the Border,' was equivalent to saying that a party of Scotch marauders had entered England on one of their usual hostile excursions. The Highlanders, with whom the bonnet has remained longest as a part of ordinary dress, have adopted very many shapes and modes of ornamenting their head-gear. The heavy plume of black feathers used in the army is quite modern, and in exceedingly bad taste, besides being totally unconformable to the idea of a primitive and light costume. The true bonnet of the Highlands is small, either round or peaked in front, as in the adjoining cut, dark blue or gray in colour, and without any tartan or chequering. In fancy dress, however, the bonnet is somewhat larger, and occasionally has a band of tartan. Highland chiefs were distinguished by three pinion feathers of the native eagle stuck in the bonnet; and those who enjoyed the rank of gentlemen were entitled to wear a single feather. It was customary also for the members of each clan to wear in the bonnet a peculiar badge formed of some native shrub. Authorities differ as to the precise shrubs worn for this purpose. The Buchanans used a sprig of bilberry; the Camerons, crowberry; the Campbells, fir-club-moss; the Forbeses, broom; Frasers, yew; &c.

The full dress of Highland chiefs and gentlemen has always been liberally ornamented with sword, baldrick, dirk, large brooches, buckler, shot pouch, and purse. The purse or sporan is a most important part of the costume; it is formed of the skin of a wild animal with the hair on, and tied to the waist by a band, hangs down in front, so as to fall easily upon the lap, and not incommode the legs in walking. It is usually ornamented with silver tags and tassels, and a flap covering the mouth of the purse is sometimes decorated with the visard of a fox. 'In many cases,' says Logan in his 'Scottish Gael,' 'the purse is composed of leather, like a modern reticule. It is formed into several distinct pockets, in which the Gael carried their money, watch, &c. and sometimes also their shot; but anciently they bore a similar wallet or *baily* at the right side, for the shot, or for a quantity of meal or other provision. This was termed *dorlach*, and was the knapsack of the Highland soldier; and small as that of the present military is, among the Gael it was still more portable. "Those of the English who visited our camp," says an author quoted by Jameson, "did gaze with admiration upon these supple fellows, the Highlanders, with their plaids, targets [shields], and dorlachs." The purse admits of much ornament, but according to my taste, when too large, it hides the beauty of the kilt.'

After a period of indifference to the preservation of the Highland dress, there has latterly sprung up a better tone of feeling on the subject among Lowlanders as well as Highlanders. At the same time, it is employed only as a fancy costume on festive or gala occasions; and in the Highlands, the ordinary dress of the English is in common use.

INDEX, AND GLOSSARY OF TERMS.

*** The Figures in the columns indicate the pages of the Text in which the particular term or subject is fully explained.

Abacus (Gr. *abax*, a slab), in Architecture, the upper part or crowning member of the capital of a column.

Abbatoir (Fr. *abbatre*, to knock down), a building appropriated to the slaughtering of cattle. See requirements of, 479.

Abdomen (Lat. *abdo*, I hide or cover), the large cavity, commonly known as the belly, containing the organs more immediately concerned in the process of digestion, as the stomach, liver, spleen, bowels, &c.

Abductor (Lat. *abducere*, to lead or draw from), the term given to those muscles which serve to open or draw back parts of the body; their opposites or antagonists are termed Adductor.

Aberration of light (Lat. *ab*, from, and *erro*, I wander), in Astronomy, 13; and in Optics, 249.

Abracadabra, a celebrated term of incantation, used as a spell against fevers. It was written thus,

A B R A C A D A B R A
A B R A C A D A B R
A B R A C A D A B
A B R A C A D A
A B R A C A D
A B R A C A
A B R A C
A B R A
A B R
A B
A

and suspended from the neck of the patient.

Abranchia (Gr. *a*, not—*branchia*, gills), animals destitute of gills, and having no apparent external organs of respiration.

Abstergent, abstersive (Lat. *abstergere*, to cleanse from), having the property of cleansing.

Acanthopterygii, a Cuvierian order of fishes, 157.

Acanthus, acanthads, acanthaceæ, in Botany, 106.

Acaridæ (Gr. *acari*, a mite), the mite family, 172.

Acclimatise, to accustom to a foreign climate; to inure to the temperature of a new climate: a term applied alike to plants and animals.

Achromatic (Gr. *a*, without, and *chroma*, colour), in Optics, applied to lenses, 252.

Acids, in Chemistry, 292; acidulous, slightly acid; acidulated, made slightly acid.

Acotyledon, acotyledonous (Gr. *a*, not—*cotyledon*, seed-lobe), plants whose seeds have no cotyledons or seed-lobes, in Botany, 91.

Acoustics, 254-256.

Acrogens, acrogenous (Gr. *acros*, the point or apex, and *gennao*, I produce), a term applied to those plants which, like the tree-ferns, increase by additions to the growing point, and never augment in thickness after once formed, 111-112.

Actinia or sea-anemone, its structure, 189.

Actinometer (Gr. *actin*, a ray—*metron*, measure), an instrument invented by Sir John Herschel for measuring the intensity of the sun's rays.

Action and reaction, in Natural Philosophy, 203.

Adamant, adamantine (Gr. *a*, not, and *damaō*, I break or conquer), a name given to different minerals of excessive hardness, as diamond and adamantine spar.

Adipocere (Lat. *adeps*, fat, and *cera*, wax), a fatty or waxen substance produced by the decomposition of the flesh of animals in moist situations or under water, resembling in some of its properties a mixture of fat and wax. It is found in damp grave-yards, in peat-bogs where animals have been accidentally entombed, and is also occasionally thrown up on the sea-shore after a storm. It has a chalky aspect, a soapy feel, is inflammable, and swims in water.

Aeliopyle (*Æolus*, the god of the winds, and *pila*, a ball), figured and described, 309.

Aërography (Gr. *aër*, the air, *grapho*, I write), the science which describes the composition, properties, uses, &c. of the air: seldom used as a technical term.

Aërolites (meteoric stones), theories respecting, 48.

Aërology (Gr. *aër*, the air, and *logos*, discourse), the doctrine of air—a term generally applied to medical discussions respecting its salubrity.

Aeronautics (Gr. *aër*, and *nautikos*, of or belonging to ships), the art of sailing in and navigating the air; aëronaut, one who so sails.

Aerostation (Gr. *aër*, and *stao*, I stand), means simply the weighing of the air; but has been employed (incorrectly) in the science of aëronautics, as the art of raising substances into the atmosphere by means of heated air or light gases. Hydrogen gas, or common coal-gas (carburetted hydrogen), is now generally used for this purpose. See p. 240.

Affinity or attraction, in Chemistry, 304.

Aftermath, in Agriculture; grass which is mown after the first crop of hay has been taken away, instead of being eaten off by stock.

Agate, varieties of in Mineralogy, 360.

Agriculture, 481-496; history of British, 481; implements and practice of, 480-485.

Air, laws of, 235; pressure of, 235-237; air-pump, 236; as necessary to health, 705.

Alabaster economically considered, 358.

Albino (Lat. *albus*, white), a term originally applied by the Portuguese to negroes who were born mottled or discoloured with white spots. It is now generally applied to persons and animals of a preternatural whiteness of the skin and hair, and a peculiar redness of the pupil of the eye, which is so weak as to be of little use in broad daylight. The disease appears to depend upon a deficiency or morbid state of the *rete mucosum* over the whole body.

Alcohol, in Dietetics, 736; in Medicine, 760.

Alder-tree, character and cultivation of, 108, 567.

Alembic, in Applied Chemistry, 308.

Alkalies, alkaline substances, in Chemistry, 292.

Alkalimeter, an instrument for ascertaining the proportion of alkali contained in any substance.

Alkanet (Fr.), a kind of reddish-purple dye of a resinous nature, obtained from the roots of the *Anchusa tinctoria*—a native of Southern Europe.

Alligators or caymans, family of, 153.

Alloy (Fr.), in Chemistry and Metallurgy, a term generally applied to all combinations obtained by fusing metals with each other: thus brass is an alloy of copper and zinc; bronze of copper and tin. When mercury is one of the combining metals, the compound is called an amalgam.

All-spice, or Jamaica pepper, in Cookery, the dried immature berry of the *Myrtus pimenta*. It is supposed to possess the mixed flavour of several spices.

Alluvium, alluvial (Lat. *ad*, to, *luo*, I wash); earth, sand, gravel, or other transported matter, which has been washed away and deposited by water upon land not permanently submerged beneath the waters of lakes or seas, is known by this term, 18. Most of the *straths* and *carses* in Scotland, and the *dales* in

Suppuration, the generation of *pus*, a thick diseased secretion, of yellowish hue.

Surgery, Household, 765-768.

Suture (Lat. *sutura*, a seam), in anatomy, the junction of the bones of the head by an irregularly-jagged zig-zag line, resembling the cross stitches of a seam.

Swallow family (*Hirundinidæ*), in Zoology, 146.

Swans, in Zoology, 152; domesticated, 637.

Swarming of the honey-bee, 643, 651.

Swine (Lat. *sus*); hence *Suidæ*, the pig family, 140.

Sword-fish, *Xiphias*, its habits, 157.

Sycamore or plane, nature and culture of, 565.

Syenite (Syene in Egypt), a variety of granite, 22.

Synchronal, synchronous (Gr.), occurring at the same period of time; simultaneous.

Synchronism, a word expressing the simultaneous occurrence of two events.

Synclinal (Gr. *syn*, together, and *clino*, I bend), bending together, or towards one point, such as the sides of a basin towards the bottom.

Syncopé, a faint or swoon, in Surgery, 766.

Synthesis (Gr. a joining or putting together). In chemistry, p. 290, the operation of joining or uniting simple substances; opposed to analysis. Water is proved to consist of oxygen and hydrogen by *analysis*—that is, by decomposing water, and ascertaining its constituents; it may, however, be proved to consist of oxygen and hydrogen by *synthesis*—that is, by uniting the relative proportions of oxygen and hydrogen, which form water.

Syphons (Gr. *siphōn*, a tube), in Pneumatics, 230; syphon-pipes, in supply of water, 467.

Syrups, preparation of, in Medicine, 754.

System (Gr. *systema*), a composition; a composition of many things acting harmoniously together. 'In science and philosophy, a system is a whole plan or scheme, consisting of many parts, connected in such a manner as to create a chain of natural dependencies; or a regular union of principles or parts, forming one entire thing. Thus we say the planetary *system*, or the whole of the bodies supposed to belong to each other; a *system* of botany, or that which comprehends the whole science of plants; a *system* of philosophy, or a theory or doctrine which embraces the whole of philosophy. The great utility of *systems* is to classify the individual subjects of our knowledge in such a way as to enable us readily to retain and employ them, and at the same time to illustrate each by showing its connection with all.'

Tabasheer, a siliceous concretion found in the joints of the bamboo, 19.

Table-lands and mountains of the globe, 56.

Tadpole, a young frog, before it has disengaged itself from the membranes, which envelope it in its first or aquatic stage of existence.

Talc and mica, in mineral economy, 361.

Talpidæ (Lat. *talpa*, mole), the mole family, 133.

Talus; when fragments are broken off by the action of the weather from the face of a steep rock, as they accumulate at its base, they form a sloping bank, called a *talus*.

Tannin, and tanning in leather manufacture, 313.

Tape-worm (*Tænia*), in Zoology, 176.

Tapestry, manufacture of, 347.

Tapioca, manufacture and dietetic uses, 725.

Tardigrada (Lat. *tardus*, slow, *gradus*, a pace), the technical term for the sloth family, 139.

Tartans, in Highland costume, 763.

Taste, sense of, physiologically considered, 123.

Tatooing, barbarous practice of, 774.

Taxodon, the name given by Professor Owen to a fossil animal discovered by Mr Darwin in the upper tertiaries of South America. The name is assigned from the curvature of the teeth, which seem to indicate that the animal belonged to the order Rodentia, though fully as large as the hippopotamus.

Tea, in Botany, 94; in dietetics, 735.

Teazle, use of, in woollen manufacture, 346.

Technology (Gr. *technē*, art, and *logos*, a discourse), a treatise on the arts. Hence the epithet *technical*, denoting something belonging to art.

Teeth, of man and other animals, 119.

Telegraph, a word signifying 'writing to or for a distant point, and applied to the various inventions by which news are communicated between distant spots by flags or other means.'

Telescopes, refracting and reflecting, 252.

Tellurium, one of the metallic elements, 301.

Temperaments, physiologically considered, 125.

Temperature, internal, of the globe, 63.

Temperature of the body, in hygiene, 715.

Tempering, the term applied to the hardening of steel by suddenly plunging it while red-hot into cold water. No other metal possesses this property, 376.

Tentacles, tentacula, the organs of feeling, prehension, and motion, in various insects and other animals, and sometimes viewed also as organs of hearing.

Terbium, a recently-discovered metallic element, 300.

Teredo navalis, structure of, in Zoology, 183.

Termites, or white ants, in Zoology, 166.

Terra-cotta, an Italian word signifying baked clay, and applied to a class of relics of art, such as vases and the like, formed from that substance, and found in considerable quantities in Tuscany. In pottery, 327.

Terrier dog, varieties of, 663.

Tertian, an ague of which there are two paroxysms every three days.

Tertiary formation, in Geology, described, 29-30.

Tesselated (*tessera*), formed in little squares or mosaic work, as a tesselated pavement.

Tests and test tubes, in Applied Chemistry, 306.

Testudo, the tortoise tribe of Animals.

Tetanus, the technical term for *locked jaw*.

Textile Manufactures, 337-352.

Thallus (Gr. *thallus*, a green leaf), in botany, a name given to the frond, or leaf-like part, of certain plants. Lichens are stemless, leafless plants, consisting of a tough wrinkled substance, called a *thallus*; hence the term *Thallogens*, in systematic classification.

Theatrical representations as an amusement, 717.

Theca, a spore-case or sheath, in botany, 75.

Theory, 'a doctrine which confines itself to the speculative parts of a subject without regard to its practical application or illustration. An exposition of the principles of any science, as the theory of music. The philosophical explanation of phenomena, either physical or moral, as Newton's *theory* of optics; Smith's *theory* of moral sentiments. *Theory* is distinguished from *hypothesis*, thus: a theory is founded on inferences drawn from the principles which have been established on independent evidence; a hypothesis is a proposition assumed to account for certain phenomena, and has no other evidence of its truth, than that it affords a satisfactory explanation of those phenomena.'

Therapeutics, a term applied to the study of the symptoms of disease and its remedies, and denoting, in short, the healing art generally.

Thermal (Gr. *therme*, heat), warm or hot. Thermal and igneous are sometimes used indiscriminately; but it is more accurate to make a distinction. Thus, in treating of volcanoes, we speak of *igneous agency*; in treating of hot-springs, *thermal* is the more appropriate term. *Thermæ*, hot baths.

Thermometer, principles and construction of, 34.

Theroid animals. The termination *therium* (Gr. *therion*, a wild beast) is adopted in geology to designate certain classes of fossil mammalia whose structure and habits have not yet been fully established by anatomists. The individual animals are characterised by a prefix which applies to some peculiarity of form, the place where found, or the name of the discoverer. Thus we have the *deinotherium* (terrible wild beast); the *palæotherium* (ancient); the *anoplotherium* (unarmed, having no weapons of defence); the *megatherium* (great); the *elasmotherium* (from the laminated structure of its teeth); the *anthracotherium* (found

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