II

THE STORY OF EVOLUTION

INTRODUCTORY

THE BEGINNING OF THE EARTH—MAKING A HOME FOR LIFE—THE FIRST LIVING CREATURES

§ 1

THE Evolution-idea is a master-key that opens many doors. It is a luminous interpretation of the world, throwing the light of the past upon the present. Everything is seen to be an antiquity, with a history behind it—a *natural history*, which enables us to understand in some measure how it has come to be as it is. We cannot say more than "understand in some measure," for while the *fact* of evolution is certain, we are only beginning to discern the *factors* that have been at work.

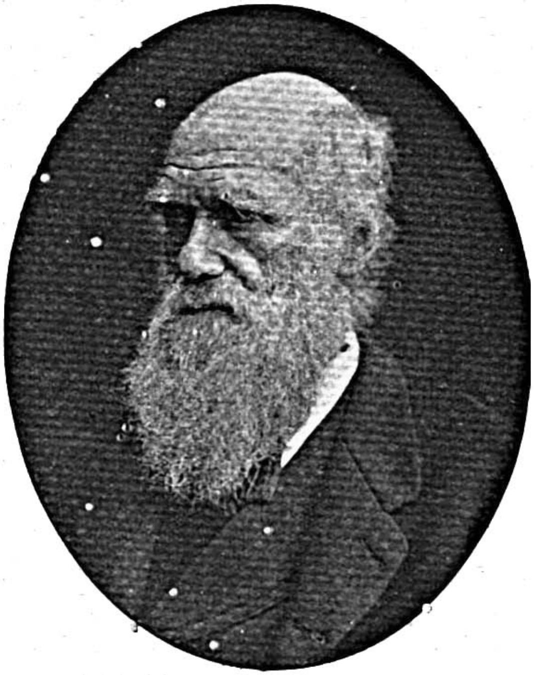


Photo: Rischgitz Collection.

CHARLES DARWIN.

Greatest of naturalists, who made the idea of evolution current intellectual coin, and in his *Origin of Species* (1859) made the whole world new.

The evolution-idea is very old, going back to some of the Greek philosophers, but it is only in modern times that it has become an essential part of our mental equipment. It is now an everyday intellectual tool. It was applied to the origin of the solar system and to the making of the earth before it was applied to plants and animals; it was extended from these to man himself; it spread to language, to folk-ways, to institutions. Within recent years the evolution-idea has been applied to the chemical elements, for it appears that uranium may change into radium, that radium may produce helium, and that lead is the final stable result when the changes of uranium are complete. Perhaps all the elements may be the outcome of an inorganic evolution. Not less important is the extension of the evolution-idea to the world within as well as to the world without. For alongside of the evolution of bodies and brains is the evolution of feelings and emotions, ideas and imagination.

Organic evolution means that the present is the child of the past and the parent of the future. It is not a power or a principle; it is a process—a process of becoming. It means that the present-day animals and plants and all the subtle inter-relations between them have arisen in a natural knowable way from a preceding state of affairs on the whole somewhat simpler, and that again from forms and inter-relations simpler still, and so on backwards and backwards for millions of years till we lose all clues in the thick mist that hangs over life's beginnings.

Our solar system was once represented by a nebula of some sort, and we may speak of the evolution of the sun and the planets. But since it has been *the same material throughout* that has changed in its distribution and forms, it might be clearer to use some word like genesis. Similarly, our human institutions were once very different from what they are now, and we may speak of the evolution of government or of cities. But Man works with a purpose, with ideas and ideals in some measure controlling his actions and guiding his achievements, so that it is probably clearer to keep the good old word history for all processes of social becoming in which man has been a conscious agent. Now between the genesis of the solar system and the history of civilisation there comes the vast process of organic evolution. The word development should be kept for the becoming of the individual, the chick out of the egg, for instance.

Photo: Lick Observatory.

A GIANT SPIRAL NEBULA.

Laplace's famous theory was that the planets and the earth were formed from great whirling nebulæ (see page 17).

Organic evolution is a continuous natural process of racial change, by successive steps in a definite direction, whereby distinctively new individualities arise, take root, and flourish, sometimes alongside of, and sometimes, sooner or later, in place of, the originative stock. Our domesticated breeds of pigeons and poultry are the results of evolutionary change whose origins are still with us in the Rock Dove and the Jungle Fowl; but in most cases in Wild Nature the ancestral stocks of present-day forms are long since extinct, and in many cases they are unknown. Evolution is a long process of coming and going, appearing and disappearing, a long-drawn-out sublime process like a great piece of music.

§ 2

The Beginning of the Earth.

When we speak the language of science we cannot say "In the beginning," for we do not know of and cannot think of any condition of things that did not arise from something that went before. But we may qualify the phrase, and legitimately inquire into the beginning of the earth within the solar system. If the result of this inquiry is to trace the sun and the planets back to a nebula we reach only a relative beginning. The nebula has to be accounted for. And even before matter there may have been a pre-material world. If we say, as was said long ago, "In the beginning was Mind," we may be expressing or trying to express a great truth, but we have gone BEYOND SCIENCE.

The Nebular Hypothesis.

One of the grandest pictures that the scientific mind has ever thrown upon the screen is that of the Nebular Hypothesis. According to Laplace's famous form of this theory (1796), the solar system was once a gigantic glowing mass, spinning slowly and uniformly around its centre. As the incandescent world-cloud of gas cooled, and its speed of rotation increased, the shrinking mass gave off a separate whirling ring, which broke up and gathered together again as the first and most distant planet. The main mass gave off another ring and another till all the planets, including the earth, were formed. The central mass persisted as the sun.

Laplace spoke of his theory, which Kant had anticipated forty-one years before, with scientific caution: "conjectures which I present with all the distrust which everything not the result of observation or of calculation ought to inspire." Subsequent research justified his distrust, for it has been shown that the original nebula need not have been hot and need not have been gaseous. Moreover, there are great difficulties in Laplace's theory of the separation of successive rings from the main mass, and of the condensation of a whirling gaseous ring into a planet.

So it has come about that the picture of a hot gaseous nebula revolving as a unit body has given place to other pictures. Thus Sir Norman Lockyer pointed out (1890) that the earth is gathering to itself millions of meteorites every day; this has been going on for millions of years; in distant ages the accretion may have been vastly more rapid and voluminous; and so the earth has grown! Now the meteoritic contributions are undoubted, but they require a centre to attract them, and the difficulty is to account for the beginning of a collecting centre or planetary nucleus. Moreover, meteorites are sporadic and erratic, scattered hither and thither rather than collecting into unit-bodies. As Professor Chamberlin says, "meteorites have rather the characteristics of the wreckage of some earlier organisation than of the parentage of our planetary system." Several other theories have been propounded to account for the origin of the earth, but the one that has found most favour in the eyes of authorities is that of Chamberlin and Moulton. According to this theory a great nebular mass condensed to form the sun, from which under the attraction of passing stars planet after planet, the earth included, was heaved off in the form of knotted spiral nebulæ, like many of those now observed in the heavens.

Of great importance were the "knots," for they served as collecting centres drawing flying matter into their clutches. Whatever part of the primitive bolt escaped and scattered was drawn out into independent orbits round the sun, forming the "planetesimals" which behave like minute planets. These planetesimals formed the food on which the knots subsequently fed.

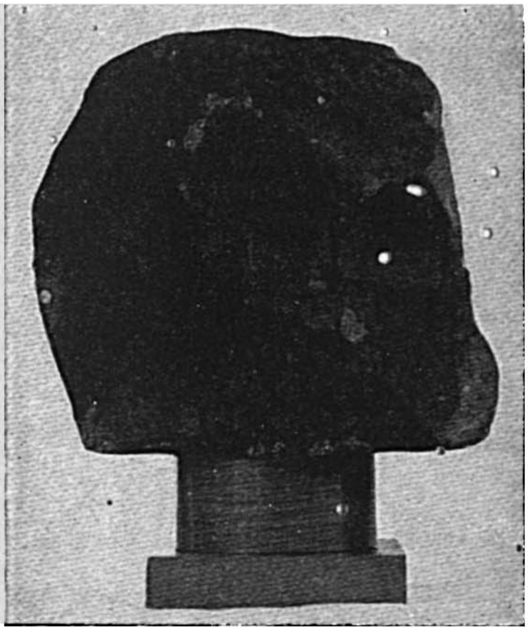


Photo: Natural History Museum.

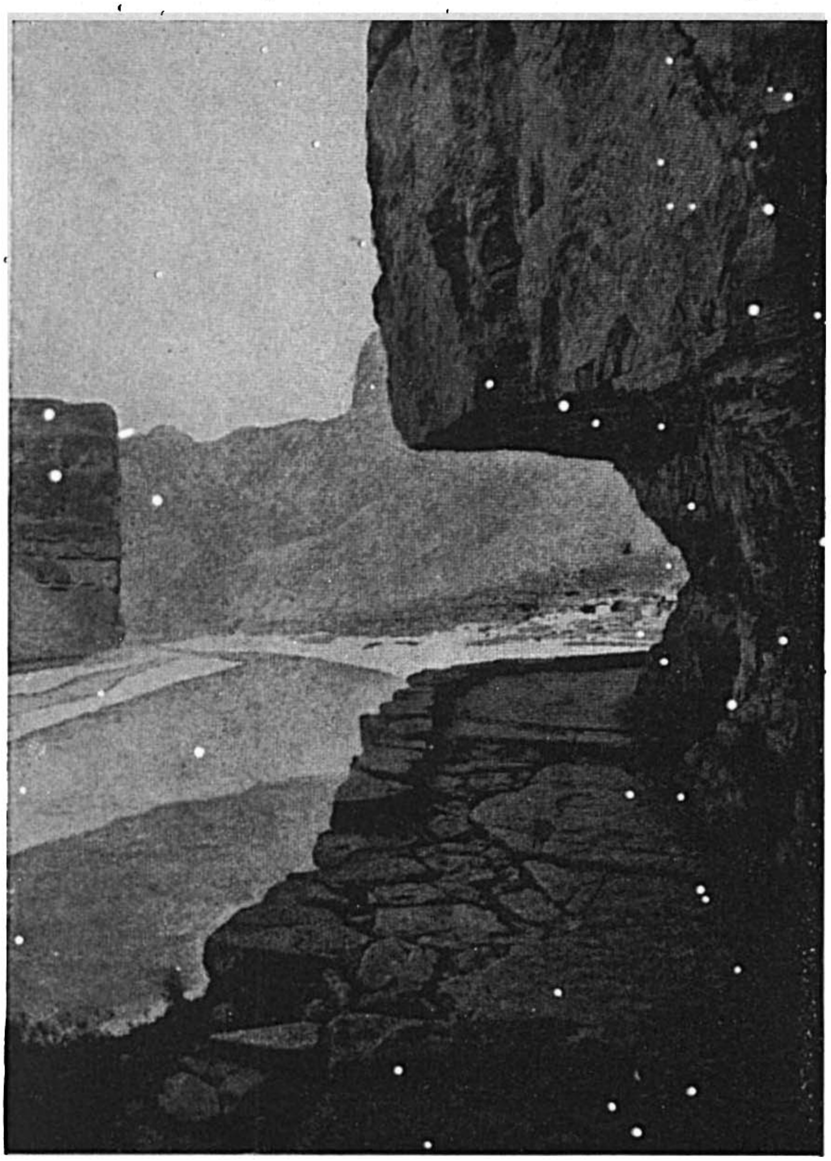
METEORITE WHICH FELL NEAR SCARBOROUGH, AND IS NOW TO BE SEEN IN THE NATURAL HISTORY MUSEUM.

It weighs about 56 lb., and is a "stony" meteorite, i.e. an aerolite.

The Growth of the Earth.

It has been calculated that the newborn earth—the "earth-knot" of Chamberlin's theory—had a diameter of about 5,500 miles. But it grew by drawing planetesimals into itself until it had a diameter of over 8,100 miles at the end of its growing period. Since then it has shrunk, by periodic shrinkages which have meant the buckling up of successive series of mountains, and it has now a diameter of 7,918 miles. But during the shrinking the earth became more varied.

A sort of slow boiling of the internally hot earth often forced molten matter through the cold outer crust, and there came about a gradual assortment of lighter materials nearer the surface and heavier materials deeper down. The continents are built of the lighter materials, such as granites, while the beds of the great oceans are made of the heavier materials such as basalts. In limited areas land has often become sea, and sea has often given place to land, but the probability is that the distinction of the areas corresponding to the great continents and oceans goes back to a very early stage.



Reproduced from the Smithsonian Report, 1915.

A LIMESTONE CANYON.

Many fossils of extinct animals have been found in such rock formations.

The lithosphere is the more or less stable crust of the earth, which may have been, to begin with, about 50 miles in thickness. It seems that the young earth had no atmosphere, and that ages passed before water began to accumulate on its surface—before, in other words, there was any hydrosphere. The water came from the earth itself, to begin with, and it was long before there was any rain dissolving out saline matter from the exposed rocks and making the sea salt. The weathering of the high grounds of the ancient crust by air and water furnished the material which formed the sandstones and mudstones and other sedimentary rocks, which are said to amount to a thickness of over fifty miles in all.

§ 3

Making a Home for Life.

It is interesting to inquire how the callous, rough-and-tumble conditions of the outer world in early days were replaced by others that allowed of the germinaton and growth of that tender plant we call LIFE. There are very tough living creatures, but the average organism is ill suited for violence. Most living creatures are adapted to mild temperatures and gentle reactions.

Hence the fundamental importance of the early atmosphere, heavy with planetesimal dust, in blanketing the earth against intensities of radiance from without, as Chamberlin says, and inequalities of radiance from within. This was the first preparation for life, but it was an atmosphere without free oxygen. Not less important was the appearance of pools and lakelets, of lakes and seas. Perhaps the early waters covered the earth. And water was the second preparation for life—water, that can dissolve a larger variety of substances in greater concentration than any other liquid; water, that in summer does not readily evaporate altogether from a pond, nor in winter freeze throughout its whole extent; water, that is such a mobile vehicle and such a subtle cleaver of substances; water, that forms over 80 per cent. of living matter itself.

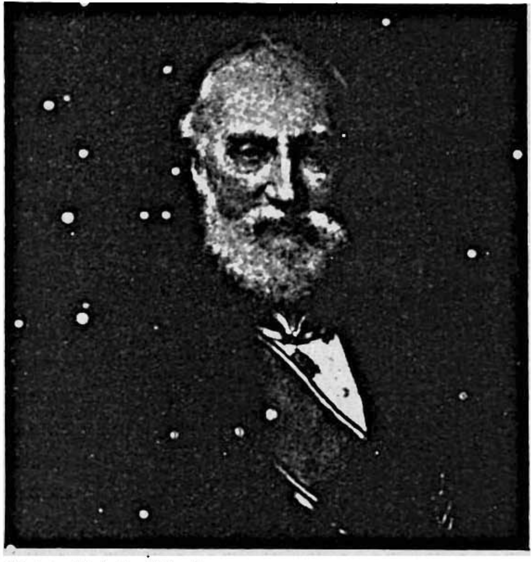


Photo: Rischgitz Collection.

LORD KELVIN.

One of the greatest physicists of the nineteenth century. He estimated the age of the earth at 20,000,000 years. He had not at his disposal, however, the knowledge of recent discoveries, which have resulted in this estimate being very greatly increased.

Of great significance was the abundance of carbon, hydrogen, and oxygen (in the form of carbonic acid and water) in the atmosphere of the cooling earth, for these three wonderful elements have a unique *ensemble* of properties—ready to enter into reactions and relations, making great diversity and complexity possible, favouring the formation of the plastic and permeable materials that build up living creatures. We must not pursue the idea, but it is clear that the stones and mortar of the inanimate world are such that they built a friendly home for life.

Origin of Living Creatures upon the Earth.

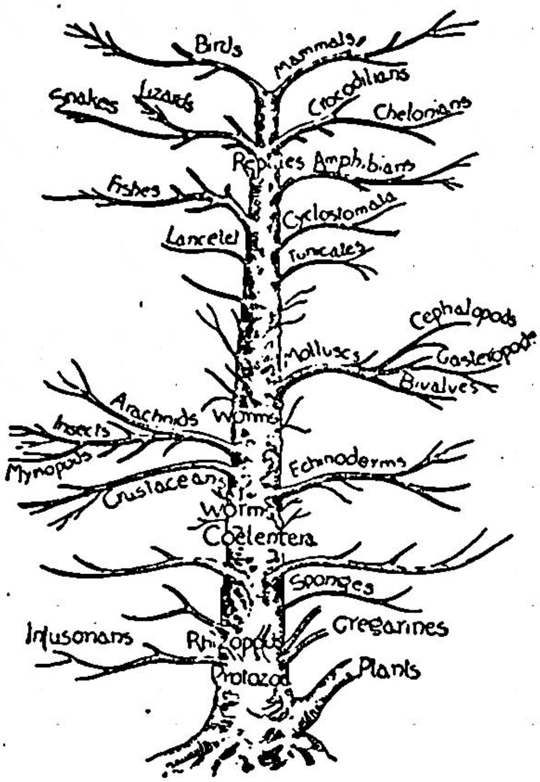
During the early chapters of the earth's history, no living creature that we can imagine could possibly have lived there. The temperature was too high; there was neither atmosphere nor surface water. Therefore it follows that at some uncertain, but inconceivably distant date, living creatures appeared upon the earth. No one knows how, but it is interesting to consider possibilities.

From ancient times it has been a favourite answer that the dust of the earth may have become living in a way which is outside scientific description. This answer forecloses the question, and it is far too soon to do that. Science must often say "Ignoramus": Science should be slow to say "Ignorabimus."

A second position held by Helmholtz, Lord Kelvin, and others, suggests that minute living creatures may have come to the earth from elsewhere, in the cracks of a meteorite or among cosmic dust. It must be remembered that seeds can survive prolonged exposure to very low temperatures; that spores of Bacteria can survive high temperature; that seeds of plants and germs of animals in a state of "latent life" can survive prolonged drought and absence of oxygen. It is possible, according to Berthelot, that as long as there is not molecular disintegration vital activities may be suspended for a time, and may afterwards recommence when appropriate conditions are restored. Therefore, one should be slow to say that a long journey through space is impossible. The obvious limitation of Lord Kelvin's theory is that it only shifts the problem of the origin of organisms (i.e. living creatures) from the earth to elsewhere.

The third answer is that living creatures of a very simple sort may have emerged on the earth's surface from not-living material, e.g. from some semi-fluid carbon compounds activated by ferments. The tenability of this view is suggested by the achievements of the synthetic chemists, who are able artificially to build up substances such as oxalic acid, indigo, salicylic acid, caffeine, and grape-sugar. We do not know, indeed, what in Nature's laboratory would take the place of the clever synthetic chemist, but there seems to be a tendency to complexity. Corpuscles form atoms, atoms form molecules, small molecules large ones.

Various concrete suggestions have been made in regard to the possible origin of living matter, which will be dealt with in a later chapter. So far as we know of what goes on to-day, there is no evidence of spontaneous generation; organisms seem always to arise from pre-existing organisms of the same kind; where any suggestion of the contrary has been fancied, there have been flaws in the experimenting. But it is one thing to accept the verdict "omne vivum e vivo" as a fact to which experiment has not yet discovered an exception, and another thing to maintain that this must always have been true or must always remain true.



GENEALOGICAL TREE OF ANIMALS.

Showing in order of evolution the general relations of the chief classes into which the world of living things is divided. This scheme represents the present stage of our knowledge, but is admittedly provisional.

If the synthetic chemists should go on surpassing themselves, if substances like white of egg should be made artificially, and if we should get more light on possible steps by which simple living creatures may have arisen from not-living materials, this would not greatly affect our general outlook on life, though it would increase our appreciation of what is often libelled as "inert" matter. If the dust of the earth did naturally give rise very long ago to living creatures, if they are in a real sense born of her and of the sunshine, then the whole world becomes more continuous and more vital, and all the inorganic groaning and travailing becomes more intelligible.

§ 4

The first Organisms upon the Earth.

We cannot have more than a speculative picture of the first living creatures upon the earth or, rather, in the waters that covered the earth. A basis for speculation is to be found, however, in the simplest creatures living to-day, such as some of the Bacteria and one-celled animalcules, especially those called Protists, which have not taken any very definite step towards becoming either plants or animals. No one can be sure, but there is much to be said for the theory that the first creatures were microscopic globules of living matter, not unlike the simplest Bacteria of to-day, but able to live on air, water, and dissolved salts. From such a source may have originated a race of one-celled marine organisms which were able to manufacture chlorophyll, or something like chlorophyll, that is to say, the green pigment which makes it possible for plants to utilise the energy of the sunlight in breaking up carbon dioxide and in building up (photosynthesis) carbon compounds like sugars and starch. These little units were probably encased in a cell-wall of cellulose, but their boxed-in energy expressed itself in the undulatory movement of a lash or flagellum, by means of which they propelled themselves energetically through the water. There are many similar organisms to-day, mostly in water, but some of them—simple one-celled plants—paint the tree-stems and even the paving-stones green in wet weather.

According to Prof. A. H. Church there was a long chapter in the history of the earth when the sea that covered everything teemed with these green flagellates—the originators of the Vegetable Kingdom.

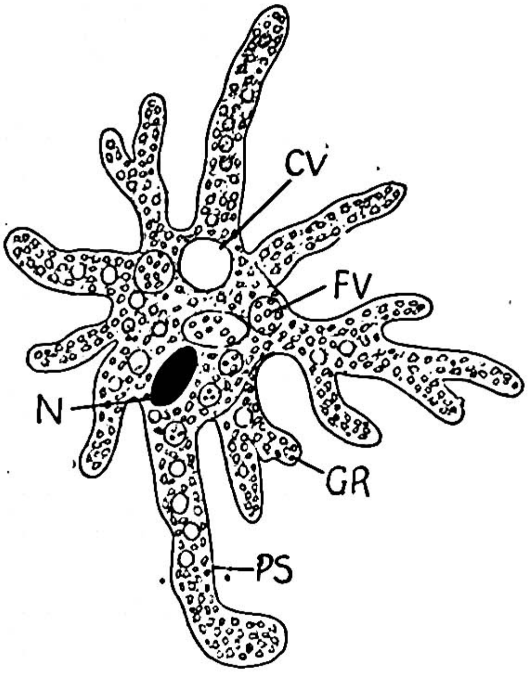


DIAGRAM OF AMŒBA.
(Greatly magnified.)

The amœba is one of the simplest of all animals, and gives us a hint of the original ancestors. It looks like a tiny irregular speck of greyish jelly, about 1/100th of an inch in diameter. It is commonly found gliding on the mud or weeds in ponds, where it engulfs its microscopic food by means of outflowing lobes (PS). The food vacuole (FV) contains ingested food. From the contractile vacuole (CV) the waste matter is discharged. N is the nucleus, GR, granules.

On another tack, however, there probably evolved a series of simple predatory creatures, not able to build up organic matter from air, water, and salts, but devouring their neighbours. These units were not closed in with cellulose, but remained naked, with their living matter or protoplasm flowing out in changeful processes, such as we see in the Amœbæ in the ditch or in our own white blood corpuscles and other amœboid cells. These were the originators of the animal kingdom. Thus from very simple Protists the first animals and the first plants may have arisen. All were still very minute, and it is worth remembering that had there been any scientific spectator after our kind upon the earth during these long ages, he would have lamented the entire absence of life, although the seas were teeming. 'The simplest forms of life' and the protoplasm which Huxley called the physical basis of life will be dealt with in the chapter on Biology in a later section of this work.

FIRST GREAT STEPS IN EVOLUTION

THE FIRST PLANTS—THE FIRST ANIMALS—BEGINNINGS OF BODIES—EVOLUTION OF SEX—BEGINNING OF NATURAL DEATH

§ 1

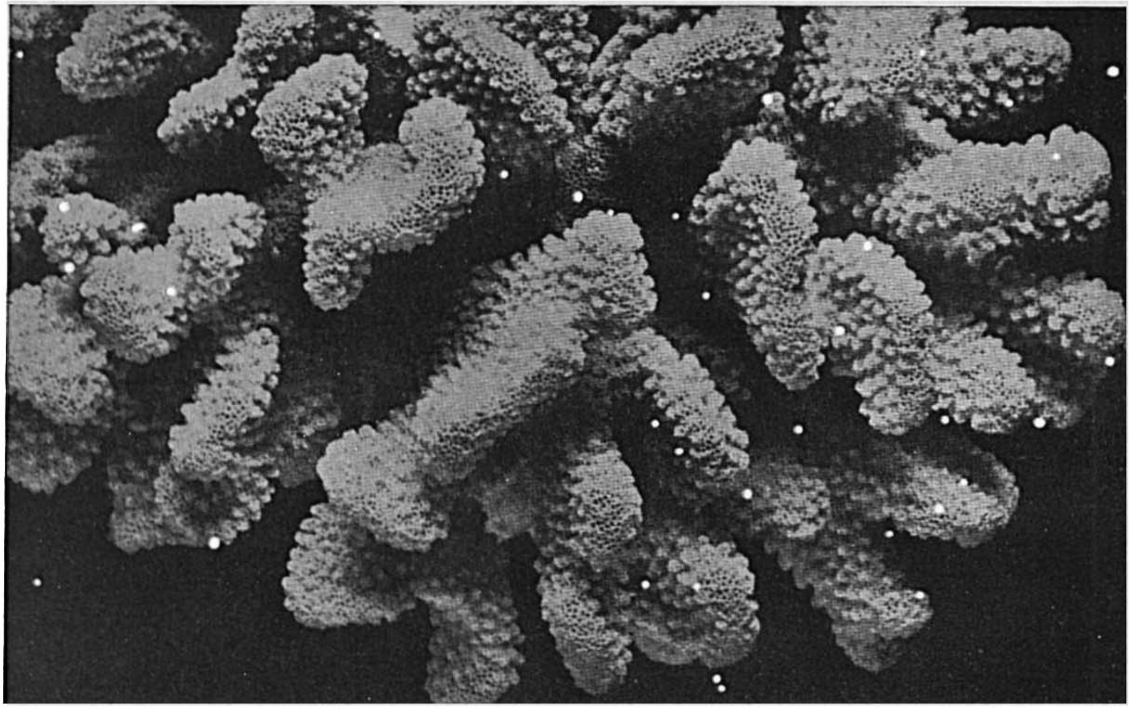
The Contrast between Plants and Animals.

However it may have come about, there is no doubt at all that one of the first great steps in Organic Evolution was the forking of the genealogical tree into Plants and Animals—the most important parting of the ways in the whole history of Nature.

Typical plants have chlorophyll; they are able to feed at a low chemical level on air, water, and salts, using the energy of the sunlight in their photosynthesis. They have their cells boxed in by cellulose walls, so that their opportunities for motility are greatly restricted. They manufacture much more nutritive material than they need, and live far below their income. They have no ready way of getting rid of any nitrogenous waste matter that they may form, and this probably helps to keep them sluggish.

Animals, on the other hand, feed at a high chemical level, on the carbohydrates (e.g. starch and sugar), fats, and proteins (e.g. gluten, albumin, casein) which are manufactured by other animals, or to begin with, by plants. Their cells have not cellulose walls, nor in most cases much wall of any kind, and motility in the majority is unrestricted. Animals live much more nearly up to their income. If we could make for an animal and a plant of equal weight two fractions showing the ratio of the upbuilding, constructive, chemical processes to the down-breaking, disruptive, chemical processes that go on in their respective bodies, the ratio for the plant would be much greater than the corresponding ratio for the animal. In other words, animals take the munitions which plants laboriously manufacture and explode them in locomotion and work; and the entire system of animate nature depends upon the photosynthesis that goes on in green plants.

As the result of much more explosive life, animals have to deal with much in the way of nitrogenous waste products, the ashes of the living fire, but these are usually got rid of very effectively, e.g. in the kidney filters, and do not clog the system by being deposited as crystals and the like, as happens in plants. Sluggish animals like sea-squirts which have no kidneys are exceptions that prove the rule, and it need hardly be said that the statements that have been made in regard to the contrasts between plants and animals are general statements. There is often a good deal of the plant about the animal, as in sedentary sponges, zoophytes, corals, and sea-squirts, and there is often a little of the animal about the plant, as we see in the movements of all shoots and roots and leaves, and occasionally in the parts of the flower. But the important fact is that on the early forking of the genealogical tree, i.e. the divergence of plants and animals, there depended and depends all the higher life of the animal kingdom, not to speak of mankind. The continuance of civilisation, the upkeep of the human and animal population of the globe, and even the supply of oxygen to the air we breathe, depend on the silent laboratories of the green leaves, which are able with the help of the sunlight to use carbonic acid, water, and salts to build up the bread of life.



From the Smithsonian Report, 1917.

A PIECE OF A REEF-BUILDING CORAL, BUILT UP BY A LARGE COLONY OF SMALL SEA-ANEMONE-LIKE POLYPS, EACH OF WHICH FORMS FROM THE SALTS OF THE SEA A SKELETON OR SHELL OF LIME.

The wonderful mass of corals, which are very beautiful, are the skeleton remains of hundreds of these little creatures.

§ 2

The Beginnings of Land Plants.

It is highly probable that for long ages the waters covered the earth, and that all the primeval vegetation consisted of simple Flagellates in the universal Open Sea. But contraction of the earth's crust brought about elevations and depressions of the sea-floor, and in places the solid substratum was brought near enough the surface to allow the floating plants to begin to settle down without getting out of the light.

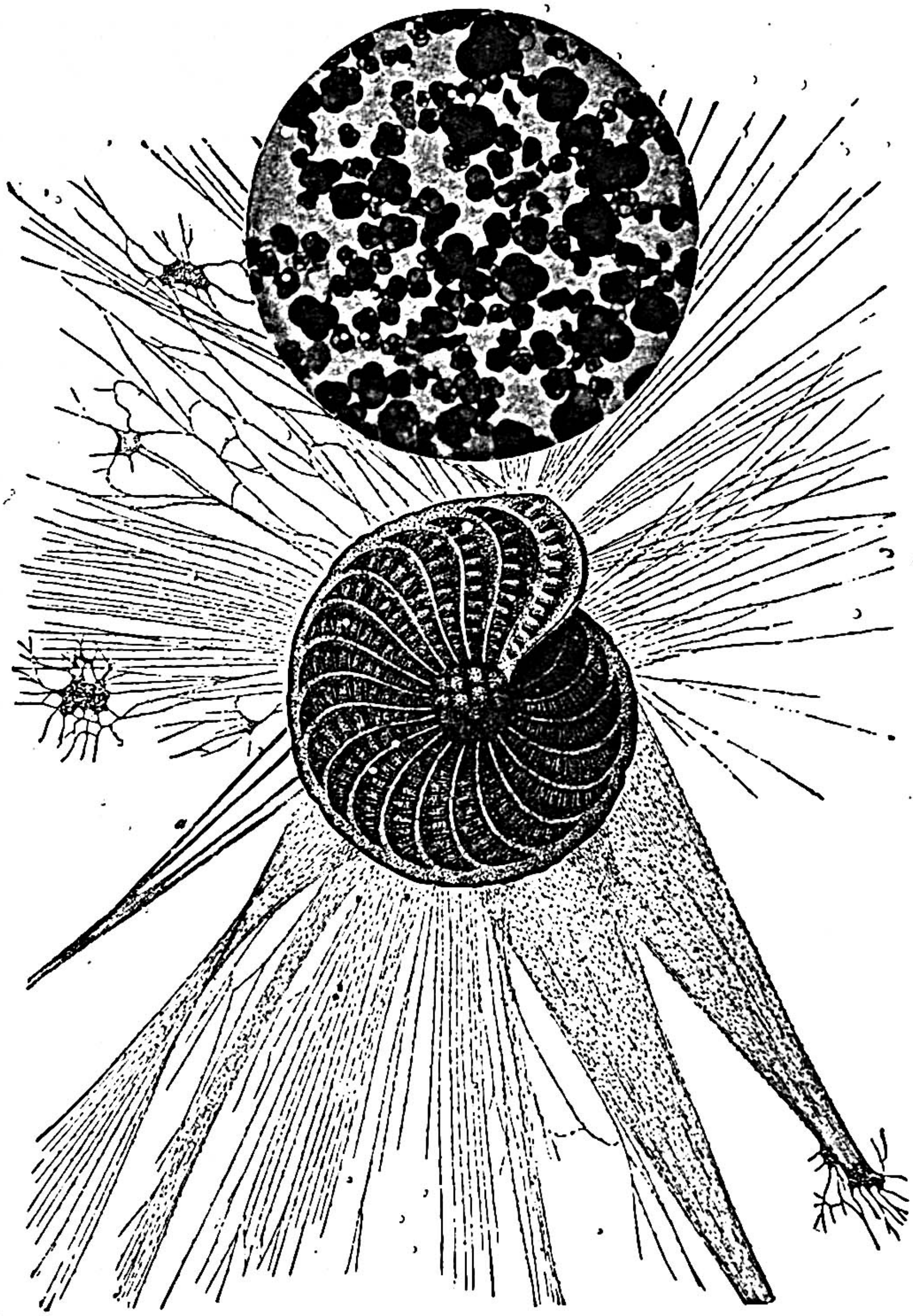


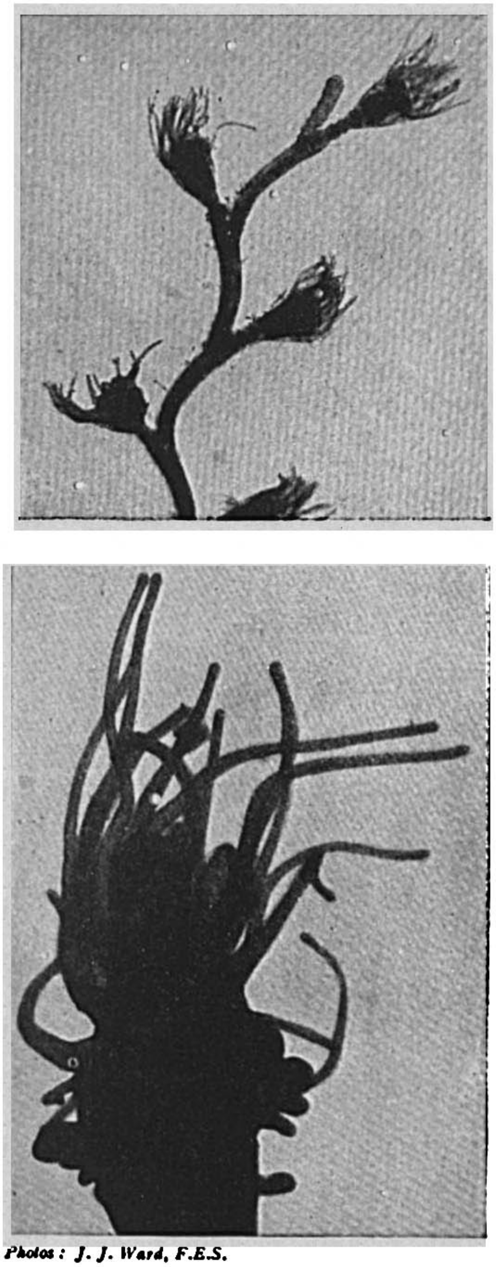
Photo: J. J. Ward, F.E.S.

THE INSET CIRCLE SHOWS A GROUP OF CHALK-FORMING ANIMALS, OR FORAMINIFERA, EACH ABOUT THE SIZE OF A VERY SMALL PIN'S HEAD.

They form a great part of the chalk cliffs of Dover and similar deposits which have been raised from the floor of an ancient sea.

THE ENORMOUSLY ENLARGED ILLUSTRATION IS THAT OF A COMMON FORAMINIFER (POLYSTOMELLA) SHOWING THE SHELL IN THE CENTRE AND THE OUTFLOWING NETWORK OF LIVING MATTER, ALONG WHICH GRANULES ARE CONTINUALLY TRAVELLING, AND BY WHICH FOOD PARTICLES ARE ENTANGLED AND DRAWN IN.

Reproduced by permission of the Natural History Museum (after Max Schultze).



Photos: J. J. Ward, F.E.S.

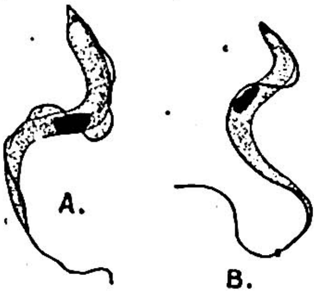
A PLANT-LIKE ANIMAL, OR ZOOPHYTE, CALLED OBELIA.

Consisting of a colony of small polyps, whose stinging tentacles are well shown greatly enlarged in the lower photograph.

This is how Professor Church pictures the beginning of a fixed vegetation—a very momentous step in evolution. It was perhaps among this early vegetation that animals had their first successes. As the floor of the sea in these shallow areas was raised higher and higher there was a beginning of dry land. The sedentary plants already spoken of were the ancestors of the shore seaweeds, and there is no doubt that when we go down at the lowest tide and wade cautiously out among the jungle of vegetation only exposed on such occasions we are getting a glimpse of very ancient days. *This* is the forest primeval.

The Protozoa.

Animals below the level of zoophytes and sponges are called Protozoa. The word obviously means "First Animals," but all that we can say is that the very simplest of them may give us some hint of the simplicity of the original first animals. For it is quite certain that the vast majority of the Protozoa to-day are far too complicated to be thought of as primitive. Though most of them are microscopic, each is an animal complete in itself, with the same fundamental bodily attributes as are manifested in ourselves. They differ from animals of higher degree in not being built up of the unit areas or corpuscles called cells. They have no cells, no tissues, no organs, in the ordinary acceptation of these words, but many of them show a great complexity of internal structure, far exceeding that of the ordinary cells that build up the tissues of higher animals. They are complete living creatures which have not gone in for body-making.



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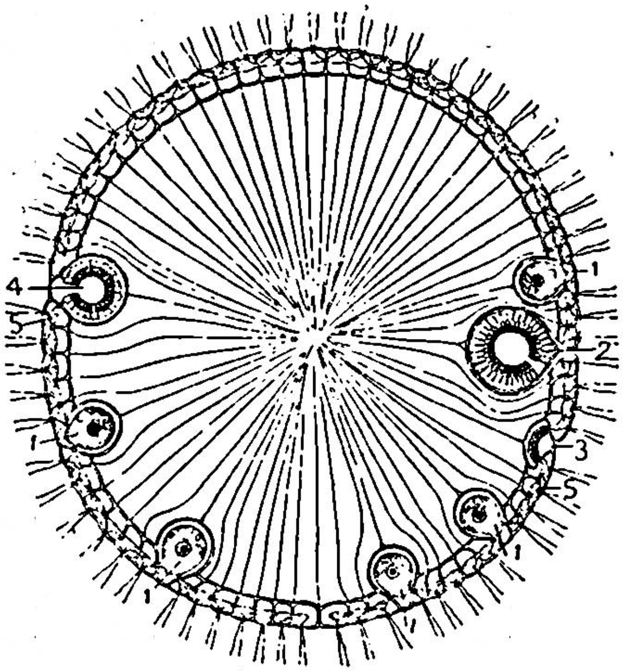
TRYPANOSOMA GAMBIENSE.

(Very highly magnified.)

The microscopic animal Trypanosome, which causes Sleeping Sickness. The study of these organisms has of late years acquired an immense importance on account of the widespread and dangerous maladies to which some of them give rise. It lives in the blood of man, who is infected by the bite of a Tse-tse fly which carries the parasite from some other host.

In the dim and distant past there was a time when the only animals were of the nature of Protozoa, and it is safe to say that one of the great steps in evolution was the establishment of three great types of Protozoa: (*a*) Some were very active, the Infusorians, like the slipper animalcule, the night-light (Noctiluca), which makes the seas phosphorescent at night, and the deadly Trypanosome, which causes



VOLVOX

The Volvox is found in some canals and the like. It is one of the first animals to suggest the beginning of a body. It is a colony of a thousand or even ten thousand cells, but they are all cells of one kind. In *multicellular* animals the cells are of *different* kinds with different functions. Each of the ordinary cells (marked 5) has two lashes or flagella. Daughter colonies inside the parent colony are being formed at 3, 4 and 2. The development of germ cells is shown at 1.

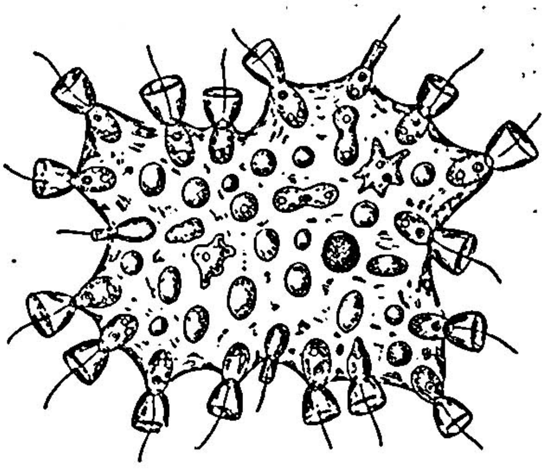
Sleeping Sickness. (*b*) Others were very sluggish, the parasitic Sporozoa, like the malaria organism which the mosquito introduces into man's body. (*c*) Others were neither very active nor very passive, the Rhizopods, with out-flowing processes of living matter. This amœboid line of evolution has been very successful; it is represented by the Rhizopods, such as Amœbæ and the chalk-forming Foraminifera and the exquisitely beautiful flint-shelled Radiolarians of the open sea. They have their counterparts in the amœboid cells of most multicellular animals, such as the phagocytes which migrate about in the body, engulfing and digesting intruding Bacteria, serving as sappers and miners when something has to be broken down and built up again, and performing other useful offices.

§ 3

The great naturalist Louis Agassiz once said that the biggest gulf in Organic Nature was that between the unicellular and the multicellular animals (Protozoa and Metazoa). But the gulf was bridged very long ago when sponges, stinging animals, and simple worms were evolved, and showed, for the first time, a "body." What would one not give to be able to account for the making of a body, one of the great steps in evolution! No one knows, but the problem is not altogether obscure.

The Making of a Body.

When an ordinary Protozoon or one-celled animal divides into two or more, which is its way of multiplying, the daughter-units thus formed float apart and live independent lives. But there are a few Protozoa in which the daughter-units are not quite separated off from one another, but remain coherent. Thus Volvox, a beautiful green ball, found in some canals and the like, is a colony of a thousand or even ten thousand cells. It has almost formed a body! But in this "colony-making" Protozoon, and in others like it, the component cells are all of one kind, whereas in true multicellular animals there are different kinds of cells, showing division of labour. There are some other Protozoa in which the nucleus or kernel divides into many nuclei within the cell. This is seen in the Giant Amœba (Pelomyxa), sometimes found in duck-ponds, or the beautiful Opalina, which always lives in the hind part of the frog's



PROTEROSPONGIA

One of the simplest multicellular animals, illustrating the beginning of a body. There is a setting apart of egg-cells and sperm-cells, distinct from body-cells, the collared lashed cells on the margin are different in kind from those farther in. Thus, as in indubitable multicellular animals, division of labour has begun.

food-canal. If a portion of the living matter of these Protozoa should gather round each of the nuclei, then *that would be the beginning of a body.* It would be still nearer the beginning of a body if division of labour set in, and if there was a setting apart of egg-cells and sperm-cells distinct from body-cells.

It was possibly in some such way that animals and plants with a body were first evolved. Two points should be noticed, that body-making is not essentially a matter of size, though it made large size possible. For the body of a many-celled Wheel Animalcule or Rotifer is no bigger than many a Protozoon. Yet the Rotifer—we are thinking of Hydatina—has nine hundred odd cells, whereas the Protozoon has only one, except in forms like Volvox. Secondly, it is a luminous fact that *every many-celled animal from sponge to man that multiplies in the ordinary way begins at the beginning again as a "single cell,"* the fertilised egg-cell. It is, of course, not an ordinary single cell that develops into an earthworm or a butterfly, an eagle, or a man; it is a cell in which a rich inheritance, the fruition of ages, is somehow condensed; but it is interesting to bear in mind the elementary fact that every many-celled creature, reproduced in the ordinary way and not by budding or the like, starts as a fertilised egg-cell. The coherence of the daughter-cells into which the fertilised egg-cell divides is a reminiscence, as it were, of the primeval coherence of daughter-units that made the first body possible.

Photo: J. J. Ward, F.E.S.

GREEN HYDRA.

A little freshwater polyp, about half an inch long, with a crown of tentacles round the mouth. It is seen giving off a bud, a clear illustration of asexual reproduction. When a tentacle touches some small organism the latter is paralysed and drawn into the mouth.

The Beginning of Sexual Reproduction.

A freshwater Hydra, growing on the duckweed, usually multiplies by budding. It forms daughter-buds, living images of itself; a check comes to nutrition and these daughter-buds go free. A big sea-anemone may divide in two or more parts, which become separate animals. This is asexual reproduction, which means that the multiplication takes place by dividing into two or many portions, and not by liberating egg-cells and sperm-cells. Among animals as among plants, asexual reproduction is very common. But it has great disadvantages, for it is apt to be physiologically expensive, and it is beset with difficulties when the body shows great division of labour, and is very intimately bound into unity. Thus, no one can think of a bee or a bird multiplying by division or by budding. Moreover, if the body of the parent has suffered from injury or deterioration, the result of this is bound to be handed on to the next generation if asexual reproduction is the only method.

Splitting into two or many parts was the old-fashioned way of multiplying, but one of the great steps in evolution was the discovery of a better method, namely, sexual reproduction. The gist of this is simply that during the process of body-building (by the development of the fertilised egg-cell) certain units, *the germ-cells,* do not share in forming ordinary tissues or organs, but remain apart, continuing the full inheritance which was condensed in the fertilised egg-cell. *These cells kept by themselves are the originators of the future reproductive cells of the mature animal;* they give rise to the egg-cells and the sperm-cells.

The advantages of this method are great. (1) The new generation is started less expensively, for it is easier to shed germ-cells into the cradle of the water than to separate off half of the body. (2) It is possible to start a great many new lives at once, and this may be of vital importance when the struggle for existence is very keen, and when parental care is impossible. (3) The germ-cells are little likely to be prejudicially affected by disadvantageous dints impressed on the body of the parent—little likely unless the dints have peculiarly penetrating consequences, as in the case of poisons. (4) A further advantage is implied in the formation of two kinds of germ-cells—the ovum or egg-cell, with a considerable amount of building material and often with a legacy of nutritive yolk; the spermatozoon or sperm-cell, adapted to move in fluids and to find the ovum from a distance, thus securing change-provoking cross-fertilisation.

§ 4

The Evolution of Sex.

Another of the great steps in organic evolution was the differentiation of two different physiological types, the male or sperm-producer and the female or egg-producer. It seems to be a deep-seated difference in constitution, which leads one egg to develop into a male, and another, lying beside it in the nest, into a female. In the case of pigeons it seems almost certain, from the work of Professor Oscar Riddle, that there are two kinds of egg, a male-producing egg and a female-producing egg, which differ in their yolk-forming and other physiological characters.

In sea-urchins we often find two creatures superficially indistinguishable, but the one is a female with large ovaries and the other is a male with equally large testes. Here the physiological difference does not affect the body as a whole, but the reproductive organs or gonads only, though more intimate physiology would doubtless discover differences in the blood or in the chemical routine (metabolism). In a large number of cases, however, there are marked superficial differences between the sexes, and everyone is familiar with such contrasts as peacock and peahen, stag and hind. In such cases the physiological difference between the sperm-producer and the ovum-producer, for this is the essential difference saturates through the body and expresses itself in masculine and feminine structures and modes of behaviour. The expression of the masculine and feminine characters is in some cases under the control of hormones or chemical messengers which are carried by the blood from the reproductive organs throughout the body, and pull the trigger which brings about the development of an antler or a wattle or a decorative plume or a capacity for vocal and saltatory display. In some cases it is certain that the female carries in a latent state the masculine features, but these are kept from expressing themselves by other chemical messengers from the ovary. Of these chemical messengers more must be said later on.

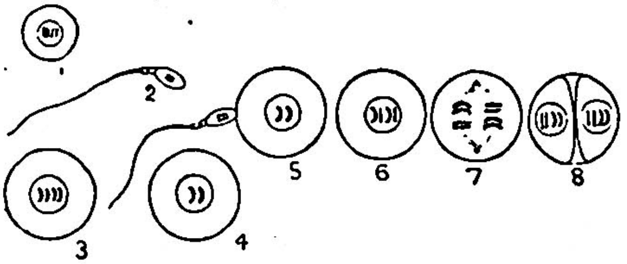


DIAGRAM ILLUSTRATING THE BEGINNING OF INDIVIDUAL LIFE

1 An immature sperm cell, with 4 chromosomes (nuclear bodies) represented as rods.

2 A mature sperm cell, with 2 chromosomes.

3 An immature egg cell, with 4 chromosomes represented as curved bodies.

4 A mature egg-cell with 2 chromosomes.

5 The spermatozoon fertilises the ovum, introducing 2 chromosomes.

6 The fertilised ovum, with 4 chromosomes, 2 of paternal origin and 2 of maternal origin.

7 The chromosomes lie at the equator, and each is split longitudinally. The centrosome introduced by the spermatozoon has divided into two centrosomes, one at each pole of the nucleus. These play an important part in the division or segmentation of the egg.

8 The fertilised egg has divided into two cells. Each cell has 2 paternal and 2 maternal chromosomes.

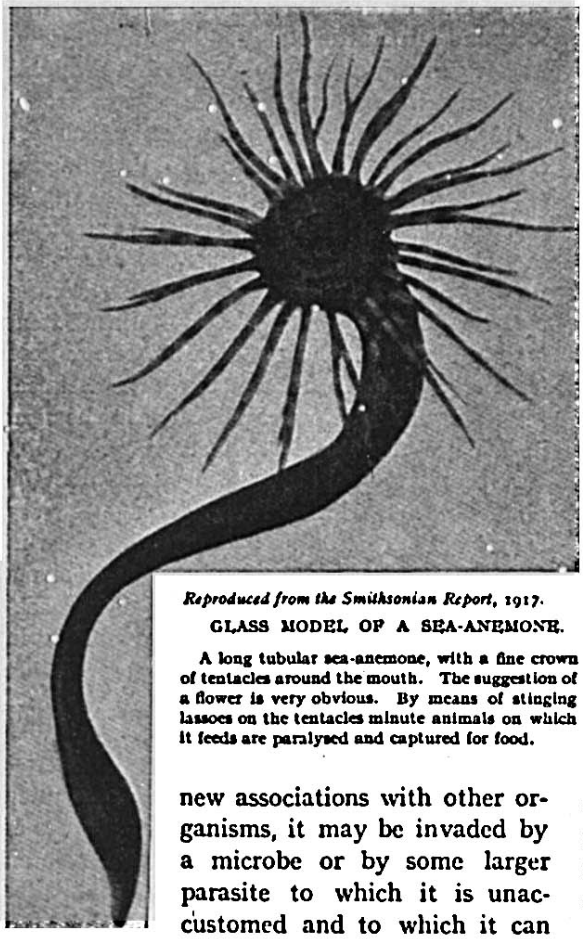
Recent research has shown that while the difference between male and female is very deep-rooted, corresponding to a difference in gearing, it is not always clear-cut. Thus a hen-pigeon may be very masculine, and a cock-pigeon very feminine. The difference is in degree, not in kind.

§ 5

What is the meaning of the universal or almost universal inevitableness of death? A Sequoia or "Big Tree" of California has been known to live for over two thousand years, but eventually it died. A centenarian tortoise has been known, and a sea-anemone sixty years of age; but eventually they die. What is the meaning of this apparently inevitable stoppage of bodily life?

The Beginning of Natural Death.

There are three chief kinds of death. (*a*) The great majority of animals come to a violent end, being devoured by others or killed by sudden and extreme changes in their surroundings. (*b*) When an animal enters a new habitat, or comes into



Reproduced from the Smithsonian Report, 1917.

GLASS MODEL OF A SEA-ANEMONE.

A long tubular sea-anemone, with a fine crown of tentacles around the mouth. The suggestion of a flower is very obvious. By means of stinging lassoes on the tentacles minute animals on which it feeds are paralysed and captured for food.

new associations with other organisms, it may be invaded by a microbe or by some larger parasite to which it is unaccustomed and to which it can offer no resistance. With many parasites a "live-and-let-live" compromise is arrived at, but new parasites are apt to be fatal, as man knows to his cost when he is bitten by a tse-tse fly which infects him with the microscopic animal (a Trypanosome) that causes Sleeping Sickness. In many animals the parasites are not troublesome as long as the host is vigorous, but if the host is out of condition the parasites may get the upper hand, as in the so-called "grouse disease," and become fatal. (*c*) But besides violent death and microbic (or parasitic) death, there is natural death. This is in great part to be regarded as the price paid for a body. A body worth having implies complexity or division of labour, and this implies certain internal furnishings of a more or less stable kind in which the effects of wear and tear are apt to accumulate. It is not the living matter itself that grows old so much as the framework in which it works—the furnishings of the vital laboratory. There are various processes of rejuvenescence, e.g. rest, repair, change, reorganisation, which work against the inevitable processes of senescence, but sooner or later the victory is with ageing. Another deep reason for natural death is to be found in the physiological expensiveness of reproduction, for many animals, from worms to eels, illustrate natural death as the nemesis of starting new lives. Now it is a very striking fact that to a large degree the simplest animals or Protozoa are exempt from natural death. They are so relatively simple that they can continually recuperate by rest and repair; they do not accumulate any bad debts. Moreover, their modes of multiplying, by dividing into two or many units, are very inexpensive physiologically. It seems that in some measure this bodily immortality of the Protozoa is shared by some simple many-celled animals like the freshwater Hydra and Planarian worms. Here is an interesting chapter in evolution, the evolution of means of evading or staving off natural death. Thus there is the well-known case of the Paloloworm of the coral-reefs where the body breaks up in liberating the germ-cells, but the head-end remains fixed in a crevice of the coral, and buds out a new body at leisure.

Along with the evolution of the ways of avoiding death should be considered also the gradual establishment of the length of life best suited to the welfare of the species, and the

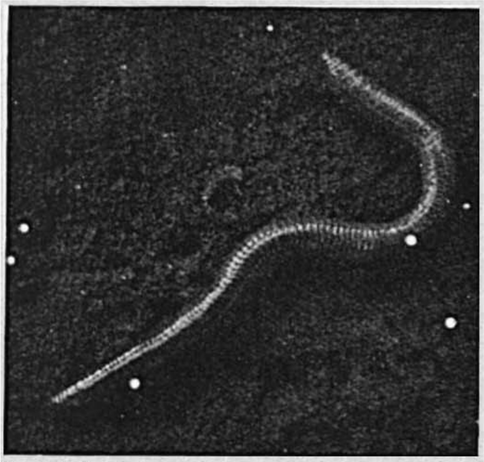


Photo: J. J. Ward, F.E.S.

EARTHWORM.

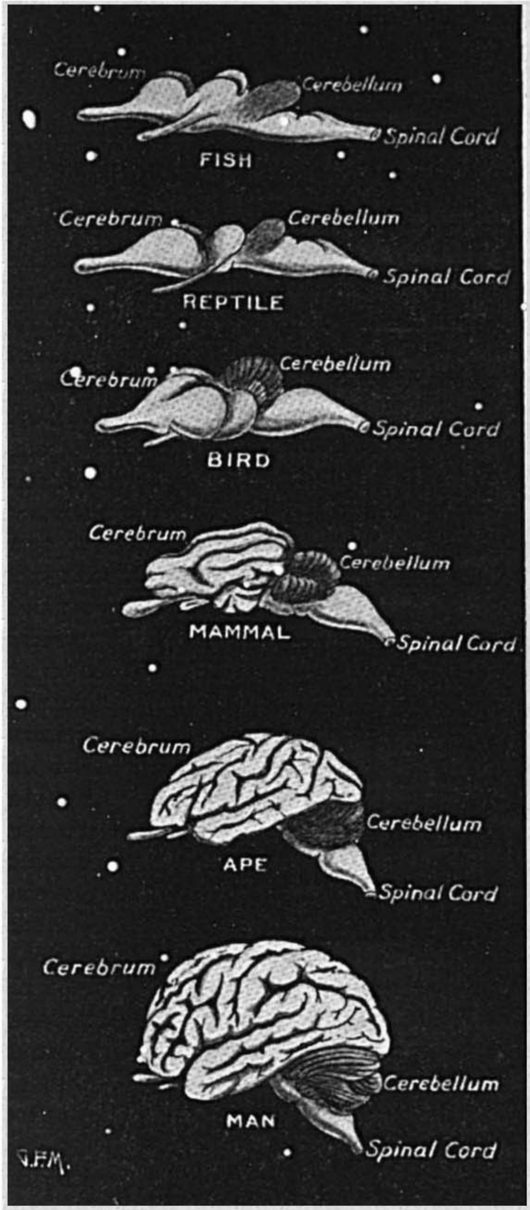
Earthworms began the profitable habit of moving with one end of the body always in front, and from worms to man the great majority of animals have bilateral symmetry.

punctuation of the life-history to suit various conditions.

§ 6

Great Acquisitions.

In animals like sea-anemones and jelly-fishes the general symmetry of the body is radial; that is to say, there is no right or left, and the body might be halved along many planes. It is a kind of symmetry well suited for sedentary or for drifting life. But worms began the profitable habit of moving with one end of the body always in front, and from worms to man the great majority of animals have bilateral symmetry. They have a right and a left side, and there is only one cut that halves the body. This kind of symmetry is suited for a more strenuous life than radial animals show; it is suited for pursuing food, for avoiding enemies, for chasing mates. And *with the establishment of bilateral symmetry must be associated the establishment of head-brains*, the beginning of which is to be found in some simple worm-types.



THIS DRAWING SHOWS THE EVOLUTION OF THE BRAIN FROM FISH TO MAN.

The Cerebrum, the seat of intelligence, increases in proportion to the other parts. In mammals it becomes more and more convoluted. The brain, which lies in one plane in fishes, becomes gradually curved on itself. In birds it is more curved than the drawing shows.

Among the other great acquisitions gradually evolved we may notice: a well-developed head with sense-organs, the establishment of large internal surfaces such as the digestive and absorptive wall of the food-canal, the origin of quickly contracting striped muscle and of muscular appendages, the formation of blood as a distributing medium throughout the body, from which all the parts take what they need and to which they also contribute.

Another very important acquisition, almost confined (so far as is known) to back-boned animals, was the evolution of what are called glands of internal secretion, such as the thyroid and the supra-renal. These manufacture subtle chemical substances which are distributed by the blood throughout the body, and have a manifold influence in regulating and harmonising the vital processes. Some of these chemical messengers are called hormones, which stimulate organs and tissues to greater activity; others are called chalones, which put on a brake. Some regulate growth and others rapidly alter the pressure and composition of the blood. Some of them call into active development certain parts of the body which have been, as it were, waiting for an appropriate trigger-pulling. Thus, at the proper time, the milk-glands of a mammalian mother are awakened from their dormancy. This very interesting outcome of evolution will be dealt with in another portion of this work.

THE INCLINED PLANE OF ANIMAL BEHAVIOUR

§ 1

Before passing to a connected story of the gradual emergence of higher and higher forms of life in the course of the successive ages—the procession of life, as it may be called—it will be useful to consider the evolution of animal behaviour.

A human being begins as a microscopic fertilised egg-cell, within which there is condensed the long result of time—Man's inheritance. The long period of nine months before birth, with its intimate partnership between mother and offspring, is passed as it were in sleep, and no one can make any statement in regard to the mind of the unborn child. Even after birth the dawn of mind is as slow as it is wonderful. To begin with, there is in the ovum and early embryo no nervous system at all, and it develops very gradually from simple beginnings. Yet as mentality cannot come in from outside, we seem bound to conclude that the potentiality of it—whatever that means—resides in the individual from the very first. The particular kind of activity known to us as thinking, feeling, and willing is the most intimate part of our experience, known to us directly apart from our senses, and the possibility of that must be implicit in the germ-cell just as the genius of Newton was implicit in a very miserable specimen of an infant. Now what is true of the individual is true also of the race—there is a gradual evolution of that aspect of the living creature's activity which we call mind. We cannot put our finger on any point and say: Before this stage there was no mind. Indeed, many facts suggest the conclusion that wherever there is life there is some degree of mind—even in the plants. Or it might be more accurate to put the conclusion in another way, that the activity we call life has always in some degree an inner or mental aspect.

Evolution of Mind.

In another part of this book there is an account of the dawn of mind in backboned animals; what we aim at here is an outline of what may be called the inclined plane of animal behaviour.

A very simple animal accumulates a little store of potential energy, and it proceeds to expend this, like an explosive, by acting on its environment. It does so in a very characteristic self-preservative fashion, so that it burns without being consumed and explodes without being blown to bits. It is characteristic of the organism that it remains a going concern for a longer or shorter period—its length of life. Living creatures that expended their energy ineffectively or self-destructively would be eliminated in the struggle for existence. When a simple one-celled organism explores a corner of the field seen under a microscope, behaving to all appearance very like a dog scouring a field seen through a telescope, it seems permissible to think of something corresponding to mental endeavour associated with its activity. This impression is strengthened when an amœba pursues another amœba, overtakes it, engulfs it, loses it, pursues it again, recaptures it, and so on. What is quite certain is that the behaviour of the animalcule is not like that of a potassium pill fizzing about in a basin of water, nor like the lurching movements of a gun that has got loose and "taken charge" on board ship. Another feature is that the locomotor activity of an animalcule often shows a distinct individuality: it may swim, for instance, in a loose spiral.

But there is another side to vital activity besides acting upon the surrounding world; the living creature is acted on by influences from without. The organism acts on its environment; that is the one side of the shield; the environment acts upon the organism; that is the other side. If we are to see life whole we must recognise these two sides of what we call living, and it is missing an important part of the history of animal life if we fail to see that evolution implies becoming more advantageously sensitive to the environment, making more of its influences, shutting out profitless stimuli, and opening more gateways to knowledge. The bird's world is a larger and finer world than an earthworm's; the world means more to the bird than to the worm.

Simple creatures act with a certain degree of spontaneity on their environment, and they likewise react effectively to surrounding stimuli. Animals come to have definite "answers back," sometimes several, sometimes only one, as in

The Trial and Error Method.

OKAPI AND GIRAFFE.

The Okapi is one of the great zoological discoveries. It gives a good idea of what the Giraffe's ancestors were like. The Okapi was unknown until discovered in 1900 by Sir Harry Johnston in Central Africa, where these strange animals have probably lived in dense forests from time immemorial.

the case of the Slipper Animalcule, which reverses its cilia when it comes within the sphere of some disturbing influence, retreats, and, turning upon itself tentatively, sets off again in the same general direction as before, but at an angle to the previous line. If it misses the disturbing influence, well and good; if it strikes it again, the tactics are repeated until a satisfactory way out is discovered or the stimulation proves fatal.

It may be said that the Slipper Animalcule has but one answer to every question, but, there are many Protozoa which have several enregistered reactions. When there are alternative reactions which are tried one after another, the animal is pursuing what is called the trial-and-error method, and a higher note is struck.

There is an endeavour after satisfaction, and a trial of answers. When the creature profits by experience to the extent of giving the right answer first, there is the beginning of learning.

Reflex Actions.

Among simple multicellular animals, such as sea-anemones, we find the beginnings of reflex actions, and a considerable part of the behaviour of the lower animals is reflex. That is to say, there are laid down in the animal in the course of its development certain prearrangements of nerve-cells and muscle-cells which secure that a fit and proper answer is given to a frequently recurrent stimulus. An earthworm half out of its burrow becomes aware of the light tread of a thrush's foot, and jerks itself back into its hole before anyone can say "reflex action." What is it that happens?

Certain sensory nerve-cells in the earthworm's skin are stimulated by vibrations in the earth; the message travels down a sensory nerve-fibre from each of the stimulated cells and enters the nerve-cord. The sensory fibres come into vital connection with branches of intermediary, associative, or communicating cells, which are likewise connected with motor nerve-cells. To these the message is thus shunted. From the motor nerve-cells an impulse or command travels by motor nerve-fibres, one from each cell, to the muscles, which contract. If this took as long to happen as it takes to describe, even in outline, it would not be of much use to the earthworm. But the motor answer follows the sensory stimulus almost instantaneously. The great advantage of establishing or enregistering these reflex chains is that the answers are practically ready-made or inborn, not requiring to be learned. It is not necessary that the brain should be stimulated if there is a brain; nor does the animal will to act, though in certain cases it may by means of higher controlling nerve-centres keep the natural reflex response from being given, as happens, for instance, when we control a cough or a sneeze on some solemn occasion. The evolutionary method, if we may use the expression, has been to enregister ready-made responses; and as we ascend the animal kingdom, we find reflex actions becoming complicated and often linked together, so that the occurrence of one pulls the trigger of another, and so on in a chain. The behaviour of the insectivorous plant called Venus' fly-trap when it shuts on an insect is like a reflex action in an animal, but plants have no definite nervous system.

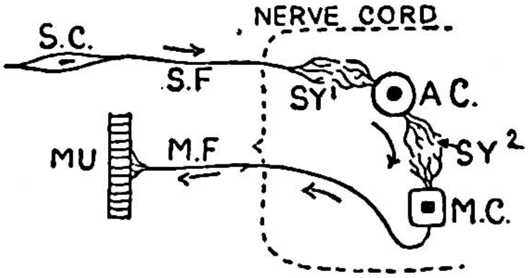


DIAGRAM OF A SIMPLE REFLEX ARC IN A BACKBONELESS ANIMAL LIKE AN EARTHWORM.

1. A sensory nerve-cell (S C.) on the surface receives a stimulus.
2. The stimulus travels along the sensory nerve-fibre (S.F.).
3. The sensory nerve fibre branches in the nerve cord.
4. Its branches come into close contact (SY ¹) with those of an associative or communicating nerve-cell (A C.).
5. Other branches of the associative cell come into close contact (SY²) with the branches or dendrites of a motor nerve-cell (M C.).
6. An impulse or command travels along the motor nerve-fibre or axis cylinder of the motor nerve-cell.
7. The motor nerve-fibre ends on a muscle-fibre (M F.) near the surface. This moves and the reflex action is complete.

What are called Tropisms.

A somewhat higher level on the inclined plane is illustrated by what are called "tropisms," obligatory movements which the animal makes, adjusting its whole body so that physiological equilibrium results in relation to gravity, pressure, currents, moisture, heat, light, electricity, and surfaces of contact. A moth is flying past a candle; the eye next the light is more illumined than the other; a physiological inequilibrium results, affecting nerve-cells and muscle-cells; the outcome is that the moth automatically adjusts its flight so that both eyes become equally illumined; in doing this it often flies into the candle.

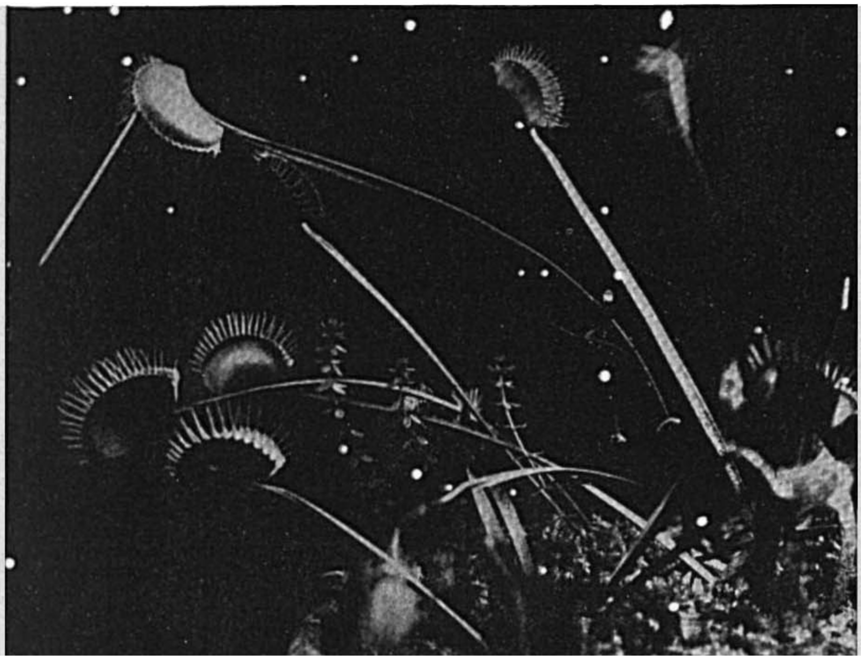


Photo: J. J. Ward, F.E.S.

VENUS' FLY-TRAP.

One of the most remarkable plants in the world, which captures its prey by means of a trap formed from part of its leaf. It has been induced to snap at and hold a bristle. If an insect lighting on the leaf touches one of six very sensitive hairs, which pull the trigger of the movement, the two halves of the leaf close rapidly and the fringing teeth on the margin interlock, preventing the insect's escape. Then follows an exudation of digestive juice.

It may seem bad business that the moth should fly into the candle, but the flame is an utterly artificial item in its environment to which no one can expect it to be adapted. These tropisms play an important rôle in animal behaviour.

Photo: British Museum (Natural History).

THE YUCCA MOTH.

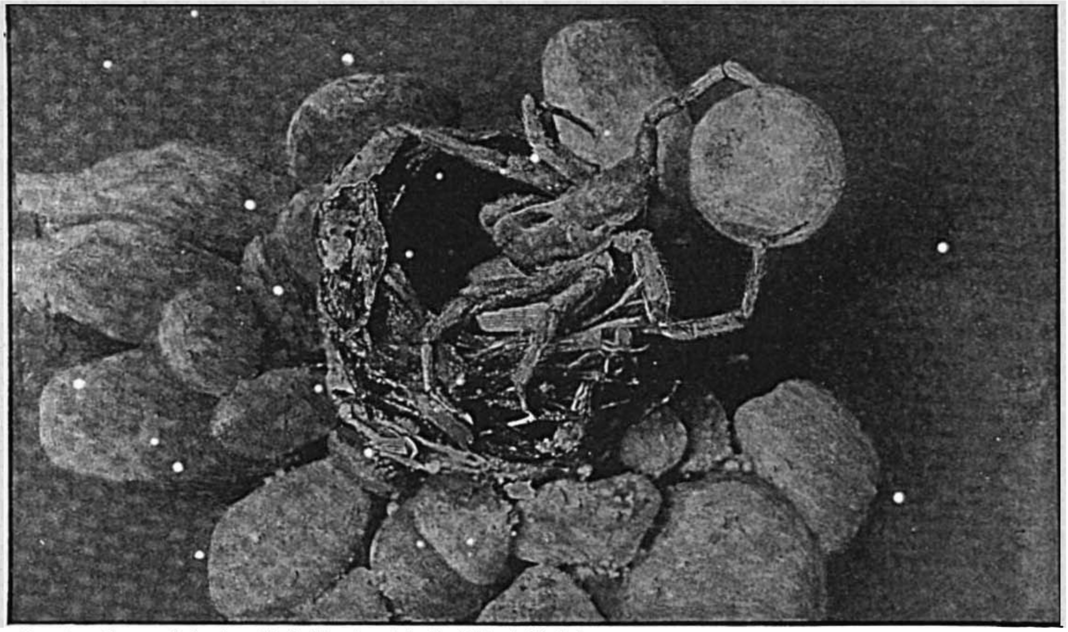
The Yucca Moth, emerging from her cocoon, flies at night to a Yucca flower and collects pollen from the stamens, holding a little ball of it in her mouth-parts. She then visits another flower and lays an egg in the seed-box. After this she applies the pollen to the tip of the pistil, thus securing the fertilisation of the flower and the growth of the ovules in the pod. Yucca flowers in Britain do not produce seeds because there are no Yucca Moths.

§ 2

Instinctive Behaviour.

On a higher level is instinctive behaviour, which reaches such remarkable perfection in ants, bees, and wasps. In its typical expression instinctive behaviour depends on inborn capacities; it does not require to be learned; it is independent of practice or experience, though it may be improved by both; it is shared equally by all members of the species of the same sex (for the female's instincts are often different from the male's); it refers to particular conditions of life that are of vital importance, though they may occur only once in a lifetime. The female Yucca Moth emerges from the cocoon when the Yucca flower puts forth its bell-like blossoms. She flies to a flower, collects some pollen from the stamens, kneads it into a pill-like ball, and stows this away under her chin. She flies to an older Yucca flower and lays her eggs in some of the ovules within the seed-box, but before she does so she has to deposit on the stigma the ball of pollen. From this the pollen-tubes grow down and the pollen-nucleus of a tube fertilises the egg-cell in an ovule, so that the possible seeds become real seeds, for it is only a fraction of them that the Yucca Moth has destroyed by using them as cradles for her eggs. Now it is plain that the Yucca Moth has no individual experience of Yucca flowers, yet she secures the continuance of her race by a concatenation of actions which form part of her instinctive repertory.

From a physiological point of view instinctive behaviour is like a chain of compound reflex actions, but in some cases, at least, there is reason to believe that the behaviour is suffused with awareness and backed by endeavour. This is suggested in exceptional cases where the stereotyped routine is departed from to meet exceptional conditions. It should also be noted that just as ants, hive bees, and wasps exhibit in most cases purely instinctive behaviour, but move on occasion on the main line of trial and error or of experimental initiative, so among birds and mammals the intelligent behaviour is sometimes replaced by instinctive routine. Perhaps there is no instinctive behaviour without a spice of intelligence, and no intelligent behaviour without an instinctive element. The old view that instinctive behaviour was originally intelligent, and that instinct is "lapsed intelligence," is a tempting one, and is suggested by the way in which habitual intelligent actions cease in the individual to require intelligent control, but it rests on the unproved hypothesis that the acquisitions of the individual can be entailed on the race. It is almost certain that instinct is on a line of evolution quite different from intelligence, and that it is nearer to the inborn inspirations of the calculating boy or the musical genius than to the plodding methods of intelligent learning.



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A SPIDER SUNNING HER EGGS.

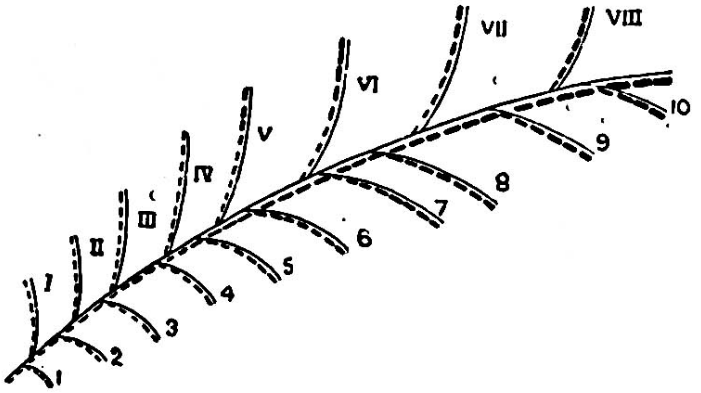
A kind of spider, called Lycosa, lying head downwards at the edge of her nest, and holding her silken cocoon—the bag containing the eggs—up towards the sun in her hindmost pair of legs. This extraordinary proceeding is believed to assist in the hatching.

Animal Intelligence.

The higher reaches of the inclined plane of behaviour show intelligence in the strict sense. They include those kinds of behaviour which cannot be described without the suggestion that the animal makes some sort of perceptual inference, not only profiting by experience but learning by ideas. Such intelligent actions show great individual variability; they are plastic and adjustable in a manner rarely hinted at in connection with instincts where routine cannot be departed from without the creature being nonplussed; they are not bound up with particular circumstances as instinctive actions are, but imply an appreciative awareness of relations.

When there is an experimenting with general ideas, when there is *conceptual* as contrasted with *perceptual* inference, we speak of Reason, but there is no evidence of this below the level of man. It is not, indeed, always that we can credit man with rational conduct, but he has the possibility of it ever within his reach.

Animal instinct and intelligence will be illustrated in another part of this work. We are here concerned simply with the general question of the evolution of behaviour. There is a main line of tentative experimental behaviour both below and above the level of intelligence, and it has been part of the tactics of evolution to bring about the hereditary enregistration of capacities of effective response, the advantages being that the answers come more rapidly and that the creature is left free, if it chooses, for higher adventures.



INCLINED PLANE OF ANIMAL BEHAVIOUR.

Diagram illustrating animal behaviour. The main line represents the general life of the creature. On the upper side are activities implying initiative; on the lower side actions which are almost automatic.

Upper Side.—I. Energetic actions. II. Simple tentatives. III. Trial-and-error methods. IV. Non-intelligent experiments. V. Experiential "learning." VI. Associative "learning." VII. Intelligent behaviour. VIII. Rational conduct (man).

Lower Side.—1. Reactions to environment. 2. Enregistered reactions. 3 Simple reflex actions. 4. Compound reflex actions. 5. Tropisms. 6. Enregistered rhythms. 7. Simple instincts. 8. Chain instincts. 9. Instinctive activities influenced by intelligence. 10 Subconscious cerebration at a high level (man).

There is no doubt as to the big fact that in the course of evolution animals have shown an increasing complexity and masterfulness of behaviour, that they have become at once more controlled and more definitely free agents, and that the inner aspect of the behaviour—experimenting, learning, thinking, feeling, and willing—has come to count for more and more.

§ 3

Evolution of Parental Care.

Mammals furnish a crowning instance of a trend of evolution which expresses itself at many levels—the tendency to bring forth the young at a well-advanced stage and to an increase of parental care associated with a decrease in the number of offspring. There is a British starfish called *Luidia* which has two hundred millions of eggs in a year, and there are said to be several millions of eggs in conger-eels and some other fishes. These illustrate the spawning method of solving the problem of survival. Some animals are naturally prolific, and the number of eggs which they sow broadcast in the waters allows for enormous infantile mortality and obviates any necessity for parental care.

But some other creatures, by nature less prolific, have found an entirely different solution of the problem. They practise parental care and they secure survival with greatly economised reproduction. This is a trend of evolution particularly characteristic of the higher animals. So much so that Herbert Spencer formulated the generalisation that the size and frequency of the animal family is in inverse ratio to the degree of evolution to which the animal has attained.

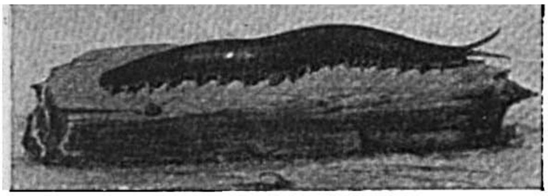
Now there are many different methods of parental care which secure the safety of the young, and one of these is called viviparity. The young ones are not liberated from the parent until they are relatively well advanced and more or less able to look after themselves. This gives the young a good send-off in life, and their chances of death are greatly reduced. In other words, the animals that have varied in the direction of economised reproduction may keep their foothold in the struggle for existence if they have varied at the same time in the direction of parental care. In other cases it may have worked the other way round.

In the interesting archaic animal called *Peripatus*, which has to face a modern world too severe for it, one of the methods of meeting

THE HOATZIN INHABITS BRITISH GUIANA.

The newly-hatched bird has claws on its thumb and first finger and so is enabled to climb on the branches of trees with great dexterity until such time as the wings are strong enough to sustain it in flight.

the environing difficulties is the retention of the offspring for many months within the mother, so that it is born a fully-formed creature. There are only a few offspring at a time, and, although there are exceptional cases like the summer green-flies, which are very prolific though viviparous, the general rule is that viviparity is associated with a very small family. The case of flowering plants stands by itself, for although they illustrate a kind of viviparity, the seeds being embryos, an individual plant may have a large number of flowers and therefore a huge family.



Photograph, from the British Museum (Natural History), of a drawing by Mr. E. Wilson.

PERIPATUS.

A widely-distributed old-fashioned type of animal, somewhat like a permanent caterpillar. It has affinities both with worms and with insects. It has a velvety skin, minute diamond-like eyes, and short stump-like legs. A defenceless, weaponless animal, it comes out at night, and is said to capture small insects by squirting jets of slime from its mouth.

Viviparity naturally finds its best illustrations among terrestrial animals, where the risks to the young life are many, and it finds its climax among mammals.

Now it is an interesting fact that the three lowest mammals, the Duckmole and two Spiny Ant-eaters, lay eggs, i.e. are oviparous; that the Marsupials, on the next grade, bring forth their young, as it were, prematurely, and in most cases stow them away in an external pouch; while all the others—the Placentals—show a more prolonged antenatal life and an intimate partnership between the mother and the unborn young.

§ 4

There is another way of looking at the sublime process of evolution. It has implied a mastery of all the possible haunts of life; it has been a progressive conquest of the environment.

1. It is highly probable that living organisms found their first foothold in the stimulating conditions of the shore of the sea—the shallow water, brightly illumined, seaweed-growing shelf fringing the Continents. This littoral zone was a propitious environment, where sea and fresh water, earth and air all meet, where there is stimulating change, abundant oxygenation, and a copious supply of nutritive material in what the streams bring down and in the rich seaweed vegetation.

It is not an easy haunt of life, but none the worse for that, and it is tenanted to-day by representatives of practically every class of animals, from infusorians to sea-shore birds and mammals.

The Cradle of the Open Sea.

2. The open-sea or pelagic haunt includes all the brightly illumined surface waters beyond the shallow water of the shore area. It is perhaps the easiest of all the haunts of life, for there is no crowding, there is considerable uniformity, and an abundance of food for animals is afforded by the inexhaustible floating "sea-meadows" of microscopic Algæ. These are reincarnated in minute animals like the open-sea crustaceans, which again are utilised by fishes, these in turn making life possible for higher forms like carnivorous turtles and toothed whales. It is quite possible that the open sea was the original cradle of life, and perhaps Professor Church is right in picturing a long period of pelagic life before there was any sufficiently shallow water to allow the floating plants to anchor. It is rather in favour of this view that many shore animals, such as crabs and starfishes, spend their youthful stages in the relatively safe cradle of the open sea, and only return to the more strenuous conditions of their birthplace after

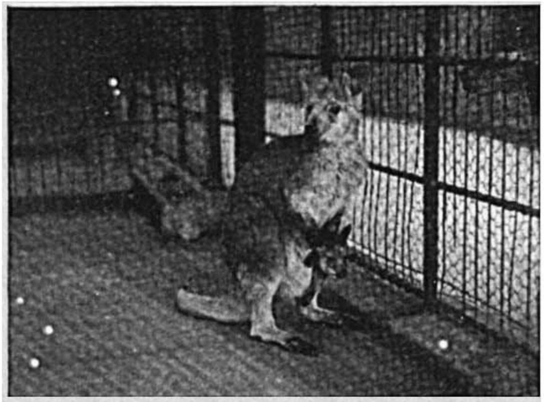


Photo: W. S. Berridge, F.Z.S.

ROCK KANGAROO CARRYING ITS YOUNG IN A POUCH.

The young are born so helpless that they cannot even suck. The mother places them in the external pouch, and fitting their mouths on the teats injects the milk. After a time the young ones go out and in as they please.

they have gained considerable strength of body. It is probably safe to say that the honour of being the original cradle of life lies between the shore of the sea and the open sea.

The Great Deeps.

3. A third haunt of life is the floor of the Deep Sea, the abyssal area, which occupies more than a half of the surface of the globe. It is a region of extreme cold—an eternal winter; of utter darkness—an eternal night — relieved only by the fitful gleams of "phosphorescent" animals; of enormous pressure —2½ tons on the square inch at a depth of 2,500 fathoms; of profound calm, unbroken silence, immense monotony. And as there are no plants in the great abysses, the animals must live on one another, and, in the long run, on the rain of moribund animalcules which sink from the surface through the miles of water. It seems a very unpromising haunt of life, but it is abundantly tenanted, and it gives us a glimpse of the insurgent nature of the living creature that the difficulties of the Deep Sea should have been so effectively conquered. It is probable that the colonising of the great abysses took place in relatively recent times, for the fauna does not include many very antique types. It is practically certain that the colonisation was due to littoral animals which followed the food-debris, millennium after millennium, further and further down the long slope from the shore.

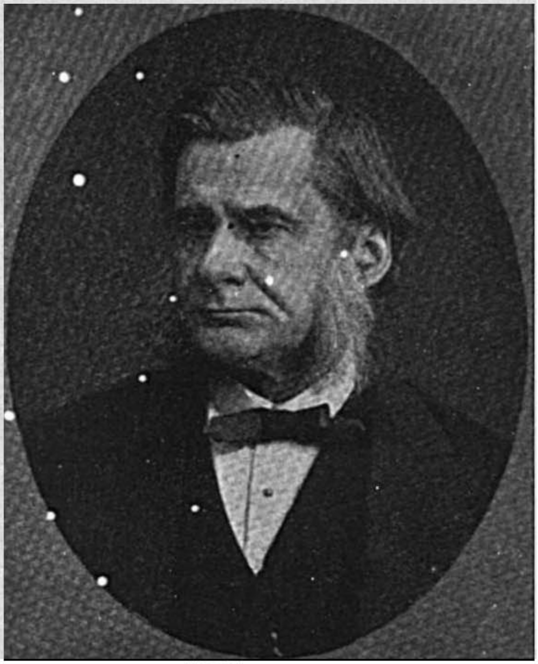


Photo: Kischgus.

PROFESSOR THOMAS HENRY HUXLEY (1825–95).

One of the most distinguished of zoologists, with unsurpassed gifts as a teacher and expositor. He did great service in gaining a place for science in ordinary education and in popular estimation. No one championed Evolutionism with more courage and skill.

The Freshwaters.

4. A fourth haunt of life is that of the freshwaters, including river and lake, pond and pool, swamp and marsh. It may have been colonised by gradual migration up estuaries and rivers, or by more direct passage from the seashore into the brackish swamp. Or it may have been in some cases that landlocked corners of ancient seas became gradually turned into freshwater basins. The animal population of the freshwaters is very representative, and is diversely adapted to meet the characteristic contingencies—the risk of being dried up, the risk of being frozen hard in winter, and the risk of being left high and dry after floods, or of being swept down to the sea.

Conquest of the Dry Land.

5. The terrestrial haunt has been invaded age after age by contingents from the sea or from the freshwaters. We must recognise the worm invasion, which led eventually to the making of the fertile soil, the invasion due to air-breathing Arthropods, which led eventually to the important linkage between flowers and their insect visitors, and the invasion due to air-breathing Amphibians, which led eventually to the higher terrestrial animals and to the development of intelligence and family affection. Besides these three great invasions, there were minor ones such as that leading to land-snails, for there has been a widespread and persistent tendency among aquatic animals to try to possess the dry land.

Getting on to dry land had a manifold significance.

It implied getting into a medium with a much larger supply of oxygen than there is dissolved in the water. But the oxygen of the air is more difficult to capture, especially when the skin becomes hard or well protected, as it is almost bound to become in animals living on dry ground. Thus this leads to the development of *internal surfaces*, such as those of lungs, where the oxygen taken into the body may be absorbed by the blood. In most animals the blood goes to the surface of oxygen-capture; but in insects and their relatives there is a different idea—of taking the air to the blood or in greater part to the area of oxygen-combustion, the living tissues. A system of branching air-tubes takes air into every hole and corner of the insect's body, and this thorough aeration is doubtless in part the secret of the insect's intense activity. The blood never becomes impure.

The conquest of the dry land also implied a predominance of that kind of locomotion which may be compared to punting, when the body is pushed along by pressing a lever against a hard substratum. And it also followed that with few exceptions the body of the terrestrial animal tended to be compact, readily lifted off the ground by the limbs or adjusted in some other way so that there may not be too large a surface trailing on the ground. An animal like a jelly-fish, easily supported in the water, would be impossible on land. Such apparent exceptions as earthworms, centipedes, and snakes are not difficult to explain, for the earthworm is a burrower which eats its way through the soil, the centipede's long body is supported by numerous hard legs, and the snake pushes itself along by means of the large ventral scales to which the lower ends of very numerous ribs are attached.

Methods of Mastering the Difficulties of Terrestrial Life.

A great restriction attendant on the invasion of the dry land is that locomotion becomes limited to one plane, namely, the surface of the earth. This is in great contrast to what is true in the water, where the animal can move up or down, to right or to left, at any angle and in three dimensions. It surely follows from this that the movements of land animals must be rapid and precise, unless, indeed, safety is secured in some other way. Hence it is easy to understand why most land animals have very finely developed striped muscles, and why a beetle running on the ground has far more numerous muscles than a lobster swimming in the sea.

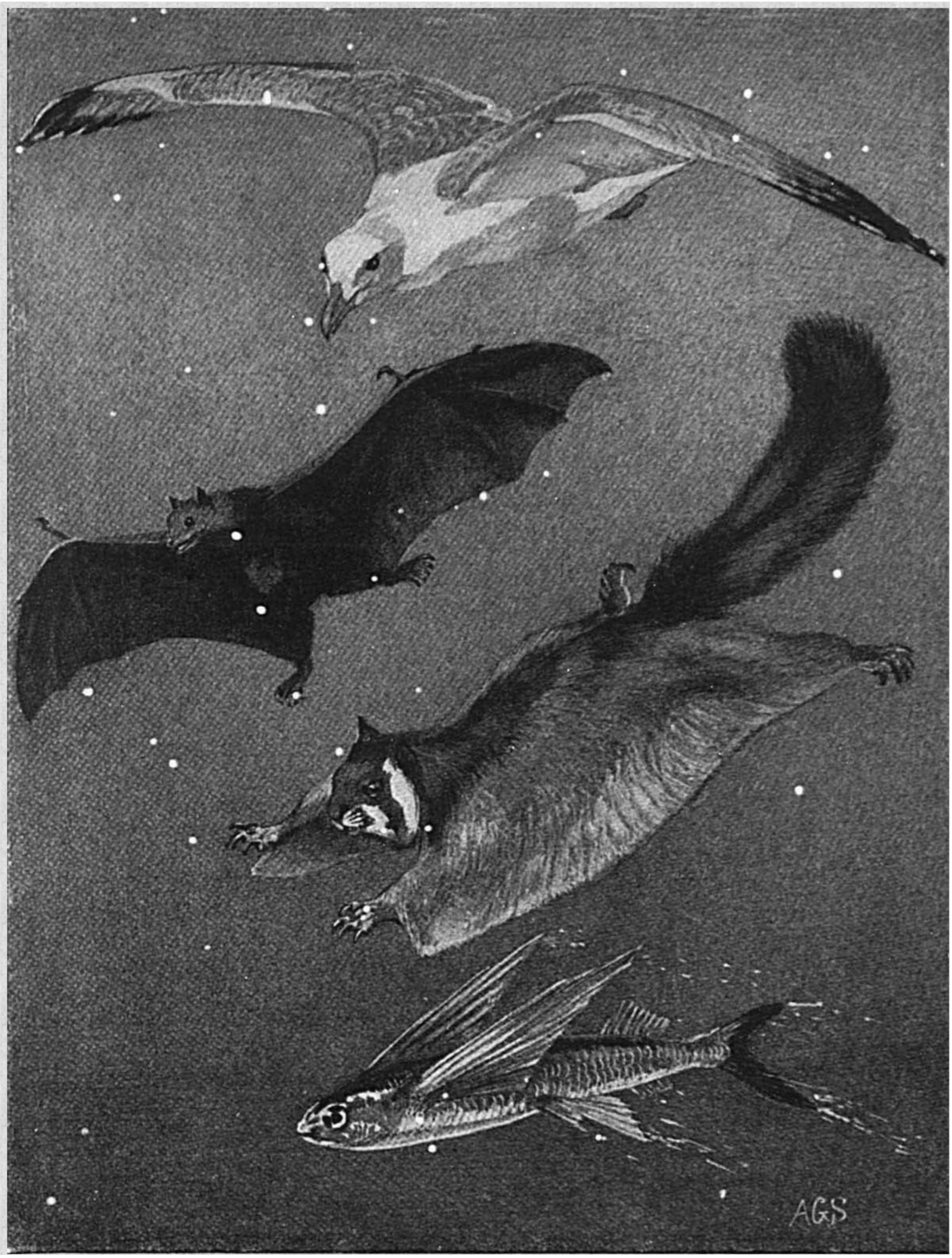
Land animals were also handicapped by the risks of drought and of frost, but these were met by defences of the most diverse description, from the hairs of woolly caterpillars to the fur of mammals, from the carapace of tortoises to the armour of armadillos. In other cases, it is hardly necessary to say, the difficulties may be met in other ways, as frogs meet the winter by falling into a lethargic state in some secluded retreat.

Another consequence of getting on to dry land is that the eggs or young can no longer be set free anyhow, as is possible when the animal is surrounded by water, which is in itself more or less of a cradle. If the eggs were laid or the young liberated on dry ground, the chances are many that they would be dried up or devoured. So there are numerous ways in which land animals secure the safety of their young, e.g. by burying them in the ground, or by hiding them in nests, or by carrying them about for a prolonged period either before or after birth. This may mean great safety for the young, this may make it possible to have only a small family, and this may tend to the evolution of parental care and the kindly emotions. Thus it may be understood that from the conquest of the land many far-reaching consequences have followed.

Finally, it is worth dwelling on the risks of terrestrial life, because they enable us better to understand why so many land animals have become burrowers and others climbers of trees, why some have returned to the water and others have taken to the air. It may be asked, perhaps, why the land should have been colonised at all when the risks and difficulties are so great. The answer must be that necessity and curiosity are the mother and father of invention. Animals left the water because the pools dried up, or because they were overcrowded, or because of inveterate enemies, but also because of that curiosity and spirit of adventure which, from first to last, has been one of the spurs of progress.

Conquering the Air.

6. The last great haunt of life is the air, a mastery of which must be placed to the credit of insects, Pterodactyls, birds, and bats. These have been the successes, but it should be noted that there have been many brilliant failures, which have not attained to much more than parachuting. These include the Flying Fishes, which take leaps from the water and are carried



AN ILLUSTRATION SHOWING VARIOUS METHODS OF FLYING AND SWOOPING.

Gull, with a feather-wing, a true flier. Fox-bat, with a skin-wing, a true flier. Flying Squirrel, with a parachute of skin, able to swoop from tree to tree, but not to fly. Flying Fish, with pectoral fins used as volplanes in a great leap due to the tail. To some extent able to sail in albatross fashion.

for many yards and to considerable heights, holding their enlarged pectoral fins taut or with little more than a slight fluttering. There is a so-called Flying Frog (*Rhacophorus*) that skims from branch to branch, and the much more effective Flying Dragon (*Draco volans*) of the Far East, which has been mentioned already. Among mammals there are Flying Phalangers, Flying Lemurs, and more besides, all attaining to great skill as parachutists, and illustrating the endeavour to master the air which man has realised in a way of his own.

The power of flight brings obvious advantages. A bird feeding on the ground is able to evade the stalking carnivore by suddenly rising into the air; food and water can be followed rapidly and to great distances; the eggs or the young can be placed in safe situations; and birds in their migrations have made a brilliant conquest both of time and space. Many of them know no winter in their year, and the migratory flight of the Pacific Golden Plover from Hawaii to Alaska and back again does not stand alone.

THE PROCESSION OF LIFE THROUGH THE AGES

§ 1

The Rock Record.

How do we know when the various classes of animals and plants were established on the earth? How do we know the order of their appearance and the succession of their advances? The answer is: by reading the Rock Record. In the course of time the crust of the earth has been elevated into continents and depressed into ocean-troughs, and the surface of the land has been buckled up into mountain ranges and folded in gentler hills and valleys. The high places of the land have been weathered by air and water in many forms, and the results of the weathering have been borne away by rivers and seas, to be laid down again elsewhere as deposits which eventually formed sandstones, mudstones, and similar sedimentary rocks. Much of the material of the original crust has thus been broken down and worked up again many times over, and if the total thickness of the sedimentary rocks is added up it amounts, according to some geologists, to a total of 67 miles. In most cases, however, only a small part of this thickness is to be seen in one place, for the deposits were usually formed in limited areas at any one time.

The Use of Fossils.

When the sediments were accumulating age after age, it naturally came about that remains of the plants and animals living at the time were buried, and these formed the fossils by the aid of which it is possible to read the story of the past. By careful piecing together of evidence the geologist is able to determine the order in which the different sedimentary rocks were laid down, and thus to say, for instance, that the Devonian period was the time of the origin of Amphibians. In other cases the geologist utilises the fossils in his attempt to work out the order of the strata when these have been much disarranged. For the simpler fossil forms of any type must be older than those that are more complex. There is no vicious circle here, for the general succession of strata is clear, and it is quite certain that there were fishes before there were amphibians, and amphibians before there were reptiles, and reptiles before there were birds and mammals. In certain cases, e.g. of fossil horses and elephants, the actual historical succession has been clearly worked out.

If the successive strata contained good samples of all the plants and animals living at the time when the beds were formed, then it would be easy to read the record of the rocks, but many animals were too soft to become satisfactory fossils, many were eaten or dissolved away, many were destroyed by heat and pressure, so that the rock record is like a library very much damaged by fire and looting and decay.

§ 2

The long history of the earth and its inhabitants is conveniently divided into eras. Thus,

BARON CUVIER, 1769-1832.

One of the founders of modern Comparative Anatomy. A man of gigantic intellect, who came to Paris as a youth from the provinces, and became the director of the higher education of France and a peer of the Empire. He was opposed to Evolutionist ideas, but he had anatomical genius.

The Geological Time-table.

just as we speak of the ancient, mediæval, and modern history of mankind, so we may speak of Palæozoic, Mesozoic, and Cenozoic eras in the history of the earth as a whole.

Geologists cannot tell us except in an approximate way how long the process of evolution has taken. One of the methods is to estimate how long has been required for the accumulation of the salts of the sea, for all these have been dissolved out of the rocks since rain began to fall on the earth. Dividing the total amount of saline matter by what is contributed every year in modern times, we get about a hundred million years as the age of the sea. But as the present rate of salt-accumulation is probably much greater than it was during many of the geological periods, the prodigious age just mentioned is in all likelihood far below the mark. Another method is to calculate how long it would take to form the sedimentary rocks, like sandstones and mudstones, which have a *total* thickness of over fifty miles, though the *local* thickness is rarely over a mile. As most of the materials have come from the weathering of the earth's crust, and as the annual amount of weathering now going on can be estimated, the time required for the formation of the sedimentary rocks of the world can be approximately calculated. There are some other ways of trying to tell the earth's age and the length of the successive periods, but no certainty has been reached.

The eras marked on the table (page 52) as *before the Cambrian* correspond to about thirty-two miles of thickness of strata; and all the subsequent eras with fossil-bearing rocks to a thickness of about twenty-one miles—in itself an astounding fact. Perhaps thirty million years must be allotted to the Pre-Cambrian eras, eighteen to the Palæozoic, nine to the Mesozoic, three to the Cenozoic, making a grand total of sixty millions.

The Establishment of Invertebrate Stocks.

It is an astounding fact that at least half of geological time (the Archæozoic and Proterozoic eras) passed before there were living creatures with parts sufficiently hard to form fossils. In the latter part of the Proterozoic era there are traces of one-celled marine animals (Radiolarians) with shells of flint, and of worms that wallowed in the primal mud. It is plain that as regards the most primitive creatures the rock record tells us little.

The rarity of direct traces of life in the oldest rocks is partly due to the fact that the primitive animals would be of delicate build, but it must also be remembered that the ancient rocks have been profoundly and repeatedly changed by pressure and heat, so that the traces which did exist would be very liable to obliteration. And if it be asked what right we have to suppose the presence of living creatures in the absence or extreme rarity of fossils, we must point to great accumulations of limestone which indicate the existence of calcareous algæ, and to deposits of iron which probably indicate the activity of iron-forming Bacteria. Ancient beds of graphite similarly suggest that green plants flourished in these ancient days.

§ 3

The *Cambrian* period was the time of the establishment of the chief stocks of backboneless animals, such as sponges, jellyfishes, worms,

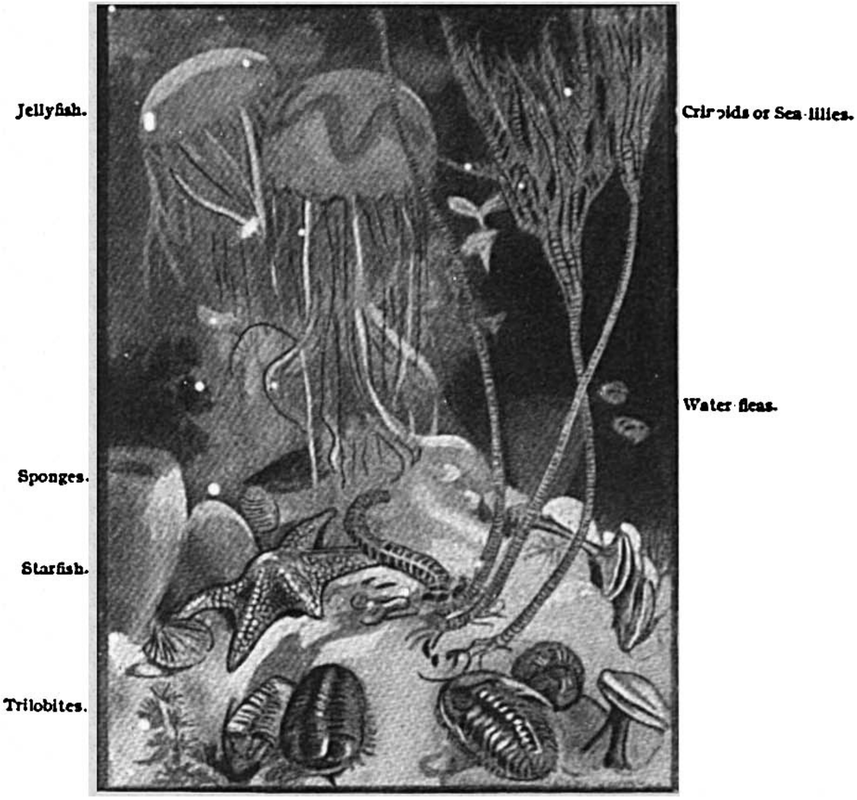
The Era of Ancient Life (Palæozoic).

sea-cucumbers, lamp-shells, trilobites, crustaceans, and molluscs. There is something very eloquent in the broad fact that the peopling of the seas had definitely begun some thirty million years ago, for Professor H. F. Osborn points out that in the Cambrian period there was already a colonisation of the shore of the sea, the open sea, and the deep waters.

The *Ordovician* period was marked by abundant representation of the once very successful class of Trilobites—jointed-footed, antenna-bearing, segmented marine animals, with numerous appendages and a covering of chitin. They died away entirely with the end of the Palæozoic era. Also very notable was the abundance of predatory cuttlefishes, the bullies of the ancient seas. But it was in this period that the first backboned animals made their appearance—an epoch-making step in evolution. In other words, true fishes were evolved—destined in the course of ages to replace the cuttlefishes (which are mere molluscs) in dominating the seas.

RECENT TIMES		Human civilisation.
CENOZOIC ERA	PLEISTOCENE OR GLACIAL TIME	Last Great Ice Age.
	MIOCENE AND PLIOCENE TIMES	Emergence of Man.
	EOCENE AND OLIGOCENE TIMES	Rise of higher mammals.
MESOZOIC ERA	CRETACEOUS PERIOD	Rise of primitive mammals, flowering plants, and higher insects.
	JURASSIC PERIOD	Rise of birds and flying reptiles.
	TRIASSIC PERIOD	Rise of dinosaur reptiles.
PALÆOZOIC ERA	PERMIAN PERIOD	Rise of reptiles.
	CARBONIFEROUS PERIOD	Rise of insects.
	DEVONIAN PERIOD	First amphibians.
	SILURIAN PERIOD	Land animals began.
	ORDOVICIAN PERIOD	First fishes.
	CAMBRIAN PERIOD	Peopling of the sea.
PROTEROZOIC AGES		Many of the Backboneless stocks began.
ARCHÆOZOIC AGES		Living creatures began to be upon the earth.
FORMATIVE TIMES		Making of continents and ocean-basins. Beginnings of atmosphere and hydrosphere. Cooling of the earth. Establishment of the solar system.

In the *Silurian* period, in which the peopling of the seas went on apace, there was the first known attempt at colonising the dry land. For in Silurian rocks there are fossil scorpions, and that implies ability to breathe dry air—by means of internal surfaces, in this case known as lung-books. It was also towards the end of the Silurian, when a period of great aridity set in, that fishes appeared related to our mud-fishes or double-breathers (Dipnoi), which have lungs as well as gills. This, again, meant utilising dry air, just as the present-day mud-fishes do when the water disappears from the pools in hot weather. The lung-fishes or mud-fishes of to-day are but three in number, one in Queensland, one in



From Knipe's "Nebula to Man."

ANIMALS OF THE CAMBRIAN PERIOD.

e.g. Sponges, Jellyfish, Starfish, Sea-lilies, Water-fleas, and Trilobites.

South America, and one in Africa, but they are extremely interesting "living fossils," binding the class of fishes to that of amphibians. It is highly probable that the first invasion of the dry land should be put to the credit of some adventurous worms, but the second great invasion was certainly due to air-breathing Arthropods, like the pioneer scorpion we mentioned.

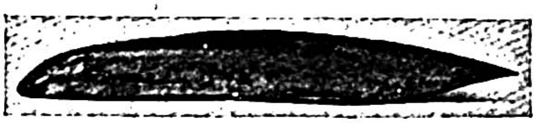


Photo: British Museum (Natural History).

THE GAMBIAN MUD-FISH, PROTOPTERUS.

It can breathe oxygen dissolved in water by its gills; it can also breathe dry air by means of its swim-bladder, which has become a lung. It is a *double-breather*, showing evolution in process. For seven months of the year, the dry season, it can remain inert in the mud, getting air through an open pipe to the surface. When water fills the pools it can use its gills again. Mud-nests or mud encasements with the lung-fish inside have often been brought to Britain and the fish when liberated were quite lively.

The *Devonian* period, including that of the Old Red Sandstone, was one of the most significant periods in the earth's history. For it was the time of the establishment of flowering plants upon the earth and of terrestrial backboned animals. One would like to have been the discoverer of the Devonian footprint of *Thinopus*, the first known Amphibian foot-print—an eloquent vestige of the third great invasion of the dry land. It was probably from a stock of Devonian lung-fishes that the first Amphibians sprang, but it was not till the next period that they came to their own. While they were still feeling their way, there was a remarkable exuberance of shark-like and heavily armoured fishes in the Devonian seas.

EVOLUTION OF LAND ANIMALS

§ 1

Giant Amphibians and Coal-measures.

The *Carboniferous* period was marked by a mild moist climate and a luxuriant vegetation in the swampy low grounds. It was a much less strenuous time than the Devonian period; it was like a very long summer. There were no trees of the type we see now, but there were forests of club-mosses and horse-tails which grew to a gigantic size compared with their pigmy representatives of to-day. In these forests the jointed-footed invaders of the dry land ran riot in the form of centipedes, spiders, scorpions, and insects, and on these the primeval Amphibians fed. The appearance of insects made possible a new linkage of far-reaching importance, namely, the cross-fertilisation of flowering plants by their insect visitors, and from this time onwards it may be said that flowers and their visitors have evolved hand in hand. Cross-fertilisation is much surer by insects than by the wind, and cross-fertilisation is more advantageous than self-fertilisation because it promotes both fertility and plasticity. It was probably in this period that *coloured* flowers—attractive to insect-visitors—began to justify themselves as beauty become useful, and began to relieve the monotonous green of the horsetail and club-moss forests, which covered great tracts of the earth for millions of years. In the Carboniferous forests there were also land-snails, representing one of the minor invasions of the dry land, tending on the whole to check vegetation. They, too, were probably preyed upon by the Amphibians, some of which attained a large size. Each age has had its giants, and those of the Carboniferous were Amphibians called Labyrinthodonts, some of which were almost as big as donkeys. It need hardly be said that it was in this period that most of the Coal-measures were laid down by the immense accumulation of the spores and debris of the club-moss forests. Ages afterwards, it was given to man to tap this great source of energy—traceable back to the sunshine of millions of years ago. Even then it was true that no plant or animal lives or dies to itself!

The Acquisition of Amphibians.

As Amphibians had their Golden Age in the Carboniferous period we may fitly use this opportunity of indicating the advances in evolution which the emergence of Amphibians implied. (1) In the first place the passage from water to dry land was the beginning of a higher and more promiseful life, taxed no doubt by increased difficulties. The natural question rises why animals should have migrated from water to dry land at all when great difficulties were involved in the transition. The answers must be: (*a*) that local drying up of water-basins or elevations of the land surface often made the old haunts untenable; (*b*) that there may have been great congestion and competition in the old quarters; and (*c*) that there has been an undeniable endeavour after well-being throughout the history of animal life. In the same way with mankind, migrations were prompted by the setting in of prolonged drought, by over-population, and by the spirit of adventure. (2) In Amphibians for the first time the non-digitate paired fins of fishes were replaced by limbs with fingers and toes. This implied an advantageous power of grasping, of holding firm, of putting food into the mouth, of feeling things in three dimensions. (3) We cannot be positive in regard to the soft parts of the ancient Amphibians known only as fossils, but if they were in a general way like the frogs and toads, newts and salamanders of the present day, we may say that they made among other acquisitions the following: true ventral lungs, a three-chambered heart, a movable tongue, a drum to the ear, and lids to the eyes. It is very interesting to find that though the tongue of the tadpole has some muscle-fibres in it, they are not strong enough to effect movement, recalling the tongue of fishes, which has not any muscles at all. Gradually, as the tadpole becomes a frog, the muscle-fibres grow in strength, and make it possible for the full-grown creature to shoot out its tongue upon insects. This is probably a recapitulation of what was accomplished in the course of millennia in the history of the Amphibian race.

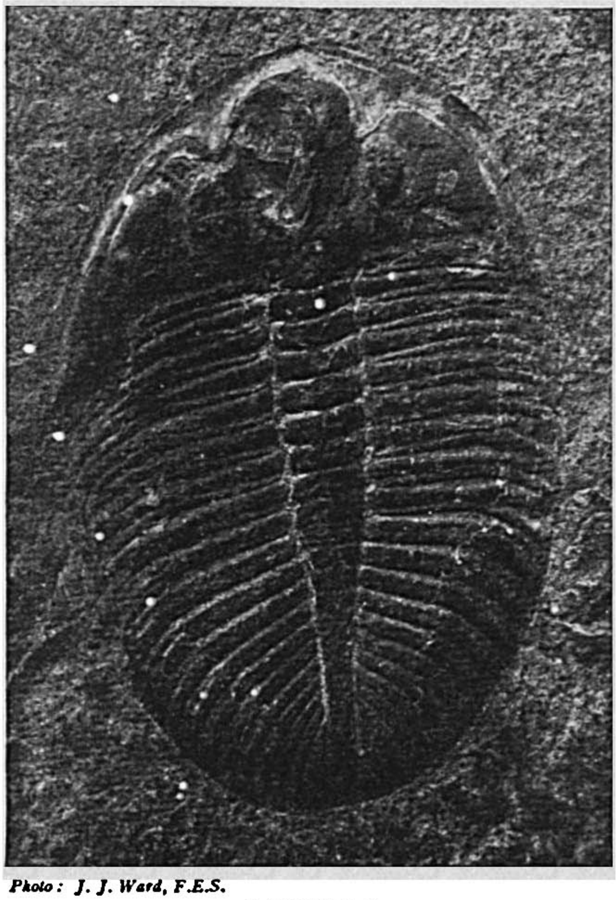


Photo: J. J. Ward, F.E.S.

A TRILOBITE.

Trilobites were ancient seashore animals, abundant from the Upper Cambrian to the Carboniferous eras. They have no direct descendants to-day. They were jointed-footed animals, allied to Crustaceans and perhaps also to King-crabs. They were able to roll themselves up in their ring-armour.

(4) Another acquisition made by Amphibians was a voice, due, as in ourselves, to the rapid passage of air over taut membranes (vocal cords) stretched in the larynx. It is an interesting fact that for millions of years there was upon the earth no sound of life at all, only the noise of wind and wave, thunder and avalanche. Apart from the instrumental music of some insects, perhaps beginning in the Carboniferous, the first vital sounds were due to Amphibians, and theirs certainly was the first voice—surely one of the great steps in organic evolution.

The first use of the voice was probably that indicated by our frogs and toads—it serves as a sex-call. That is the meaning of the trumpeting with which frogs herald the spring, and it is often only in the males that the voice is well developed. But if we look forward, past Amphibians altogether, we find the voice becoming a maternal call helping to secure the safety of the young—a use very obvious when young birds squat motionless at the sound of the parent's danger-note. Later on, probably, the voice became an infantile call, as when the unhatched

Evolution of the Voice.

crocodile pipes from within the deeply buried egg, signalling to the mother that it is time to be unearthed. Higher still the voice expresses emotion, as in the song of birds, often outside the limits of the breeding time. Later still, particular sounds become *words*, signifying particular things or feelings, such as "food," "danger," "home," "anger," and "joy." Finally words become a medium of social intercourse and as symbols help to make it possible for man to reason.

§ 2

The Early Reptiles.

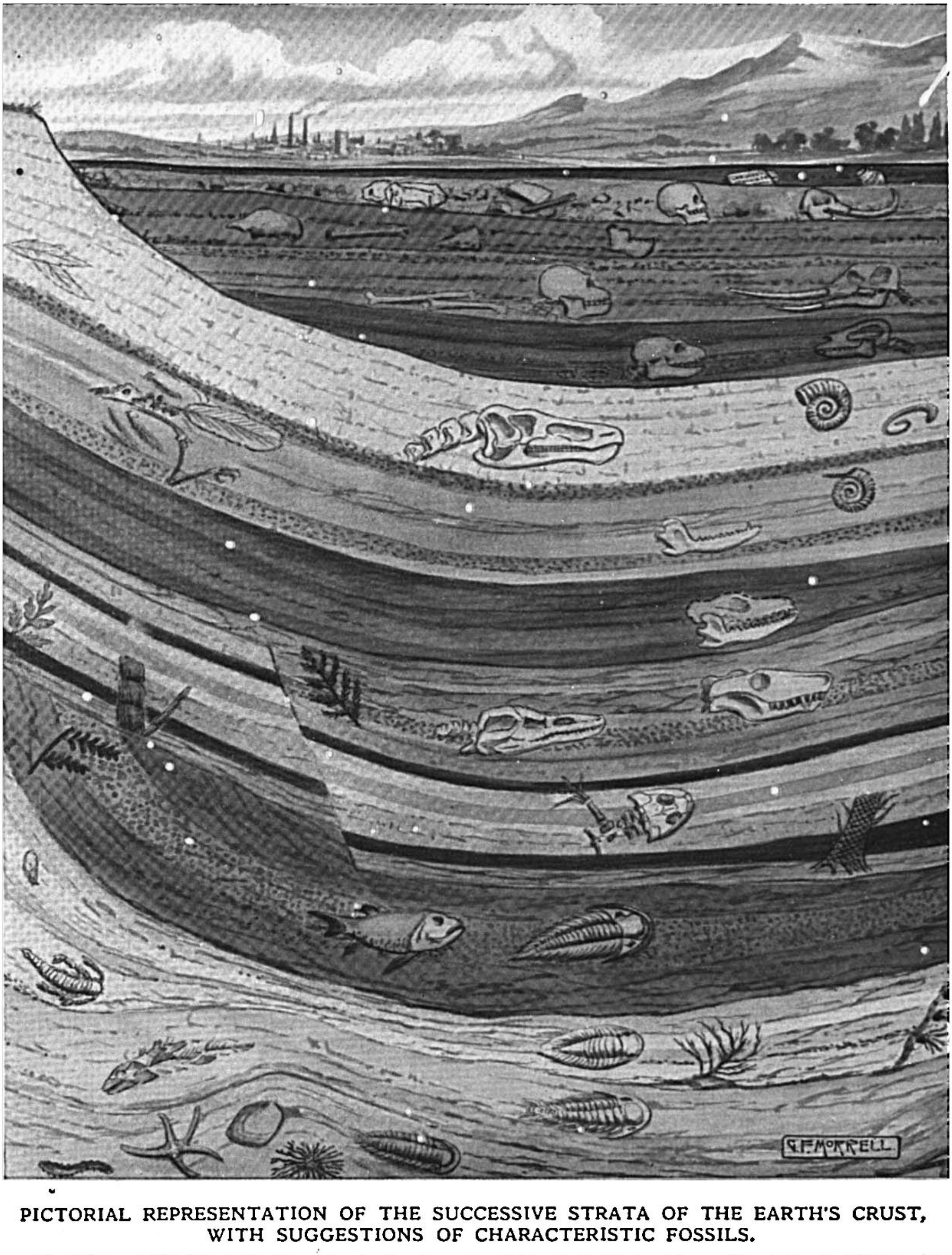
In the *Permian* period reptiles appeared, or perhaps one should say, began to assert themselves. That is to say, there was an emergence of backboned animals which were free from water and relinquished the method of breathing by gills, which Amphibians retained in their young stages at least. The unhatched or unborn reptile breathes by means of a vascular hood spread underneath the egg-shell and absorbing dry air from without. It is an interesting point that this vascular hood, called the allantois, is represented in the Amphibians by an unimportant bladder growing out from the hind end of the food-canal. A great step in evolution was implied in the origin of this antenatal hood or fœtal membrane and another one—of protective significance—called the amnion, which forms a water-bag over the delicate embryo. The step meant total emancipation from the water and from gill-breathing, and the two fœtal membranes, the amnion and the allantois, persist not only in all reptiles but in birds and mammals as well. These higher Vertebrates are therefore called Amniota in contrast to the Lower Vertebrates or Anamnia (the Amphibians, Fishes, and primitive types).

It is a suggestive fact that the embryos of all reptiles, birds, and mammals show gill-clefts *—a tell-tale evidence of their distant aquatic ancestry.* But these embryonic gill-clefts are not used for respiration and show no trace of gills except in a few embryonic reptiles and birds where their dwindled vestiges have been recently discovered. As to the gill-clefts, they are of no use in higher Vertebrates except that the first becomes the Eustachian tube leading from the ear-passage to the back of the mouth. The reason why they persist when only one is of any use, and that in a transformed guise, would be difficult to interpret except in terms of the Evolution theory. They illustrate the lingering influence of a long pedigree, the living hand of the past, the tendency that individual development has to recapitulate racial evolution. In a condensed and telescoped manner, of course, for what took the race a million years may be recapitulated by the individual in a week!

In the Permian period the warm moist climate of most of the Carboniferous period was replaced by severe conditions, culminating in an Ice Age which spread from the Southern Hemisphere throughout the world. With this was associated a waning of the Carboniferous flora, and the appearance of a new one, consisting of ferns, conifers, ginkgos, and cycads, which persisted until near the end of the Mesozoic era. The Permian Ice Age lasted for millions of years, and was most severe in the Far South. Of course, it was a very different world then, for North Europe was joined to North America, Africa to South America, and Australia to Asia. It was probably during the Permian Ice Age that many of the insects divided their life-history into two main chapters—the feeding, growing, moulting, immature, larval stages, e.g. caterpillars, and the more ascetic, non-growing, non-moulting, winged phase, adapted for reproduction. Between these there intervened the quiescent, well-protected pupa stage or chrysalis, probably adapted to begin with as a means of surviving the severe winter. For it is easier for an animal to survive when the vital processes are more or less in abeyance.

Disappearance of many Ancient Types.

We cannot leave the last period of the Palæozoic era and its prolonged ice age without noticing that it meant the entire cessation of a large number of ancient types, especially among plants and backboneless animals, which now disappear for ever. It is necessary to understand that the animals of ancient days stand in three different relations to those of to-day. (*a*) There are ancient types that have living representatives, sometimes few and sometimes many, sometimes



PICTORIAL REPRESENTATION OF THE SUCCESSIVE STRATA OF THE EARTH'S CRUST, WITH SUGGESTIONS OF CHARACTERISTIC FOSSILS.

E.g. Fish and Trilobite in the Devonian (red), a large Amphibian in the Carboniferous (blue), Reptiles in Permian (light red), the first Mammal in the Triassic (blue), the first bird in the Jurassic (yellow), Giant Reptiles in the Cretaceous (white), then follow the Tertiary strata with progressive mammals, and Quaternary at the top with man and mammoth.

much changed and sometimes but slightly changed. The lamp-shell, *Lingulella*, of the Cambrian and Ordovician period has a very near relative in the *Lingula* of to-day. There are a few extremely conservative animals. (*b*) There are ancient types which have no living representatives, except in the guise of transformed descendants, as the King-crab (*Limulus*) may be said to be a transformed descendant of the otherwise quite extinct race to which Eurypterids or Sea-scorpions belonged. (*c*) There are altogether extinct types—*lost races*—which have left not a wrack behind. For there is not any representation to-day of such races as Graptolites and Trilobites.

Looking backwards over the many millions of years comprised in the Palæozoic era, what may we emphasise as the most salient features? There was in the *Cambrian* the establishment of the chief classes of backboneless animals: in the *Ordovician* the first fishes and perhaps the first terrestrial plants; in the *Silurian* the emergence of air-breathing Invertebrates and mud-fishes: in the *Devonian* the appearance of the first Amphibians, from which all higher land animals are descended, and the establishment of a land flora; in the *Carboniferous* the great Club-moss forests and an exuberance of air-breathing insects and their allies; in the *Permian* the first reptiles and a new flora.

THE GEOLOGICAL MIDDLE AGES

§ 1

The Mesozoic Era.

In a broad way the Mesozoic era corresponds with the Golden Age of reptiles, and with the climax of the Conifer and Cycad flora, which was established in the Permian. But among the Conifers and Cycads our modern flowering plants were beginning to show face tentatively, just like birds and mammals among the great reptiles.

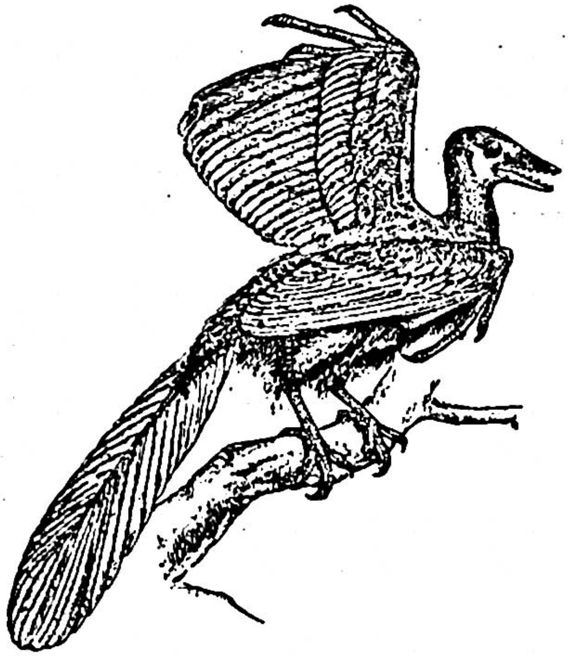
In the *Triassic* period the exuberance of reptilian life which marked the Permian was continued. Besides Turtles which still persist, there were Ichthyosaurs, Plesiosaurs, Dinosaurs, and Pterosaurs, none of which lasted beyond the Mesozoic era. Of great importance was the rise of the Dinosaurs in the Triassic, for it is highly probable that within the limits of this vigorous and plastic stock—some of them bipeds—we must look for the ancestors of both birds and mammals. Both land and water were dominated by reptiles, some of which attained to gigantic size. Had there been any zoologist in those days, he would have been very sagacious indeed if he had suspected that reptiles did not represent the climax of creation.

The Flying Dragons.

The *Jurassic* period showed a continuance of the reptilian splendour. They radiated in many directions, becoming adapted to many haunts. Thus there were many Fish Lizards paddling in the seas, many types of terrestrial dragons stalking about on land, many swiftly gliding alligator-like forms, and the Flying Dragons which began in the Triassic attained to remarkable success and variety. Their wing was formed by the extension of a great fold of skin on the enormously elongated outermost finger, and they varied from the size of a sparrow to a spread of over five feet. A soldering of the dorsal vertebræ as in our Flying Birds was an adaptation to striking the air with some force, but as there is not more than a slight keel, if any, on the breast-bone, it is unlikely that they could fly far. For we know from our modern birds that the power of flight may be to some extent gauged from the degree of development of the keel, which is simply a great ridge for the better insertion of the muscles of flight. It is absent, of course, in the Running Birds, like the ostrich, and it has degenerated in an interesting way in the burrowing parrot (*Stringops*) and a few other birds that have "gone back."

The First Known Bird.

But the Jurassic is particularly memorable because its strata have yielded two fine specimens of the first known bird, *Archæopteryx*. These were entombed in the deposits which formed the fine-grained lithographic stones of Bavaria, and practically every bone in the body is preserved except the breast-bone. Even the feathers have left their marks with distinctness. This oldest known bird—too far advanced to be



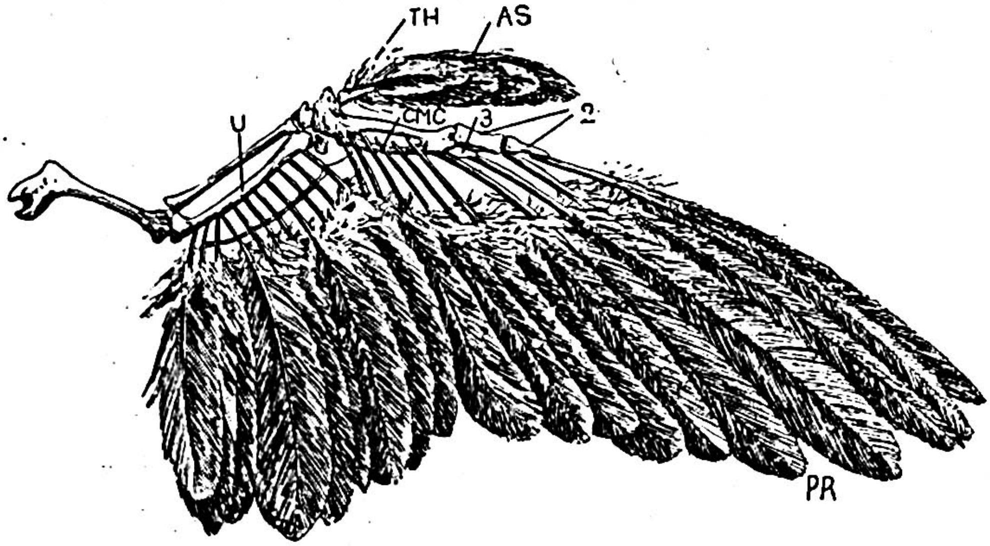
THE ARCHÆOPTERYX.

(After William Leche of Stockholm.)

A good restoration of the oldest known bird, Archæopteryx (Jurassic Era). It was about the size of a crow; it had teeth on both jaws; it had claws on the thumb and two fingers; and it had a long lizard-like tail. But it had feathers, proving itself a true bird.

the first bird—was about the size of a crow and was probably of arboreal habits. Of great interest are its reptilian features, so pronounced that one cannot evade the evolutionist suggestion. It had teeth in both jaws, which no modern bird has; it had a long lizard-like tail, which no modern bird has; it had claws on three fingers, and a sort of half-made wing. That is to say, it does not show, what all modern birds show, a fusion of half the wrist-bones with the whole of the palm-bones, the well-known carpo-metacarpus bone which forms a basis for the longest pinions. In many reptiles, such as Crocodiles, there are peculiar bones running across the abdomen beneath the skin, the so-called "abdominal ribs," and it seems an eloquent detail to find these represented in *Archæopteryx*, the earliest known bird. No modern bird shows any trace of them.

There is no warrant for supposing that the flying reptiles or Pterodactyls gave rise to birds, for the two groups are on different lines, and the structure of the wings is entirely different. Thus the long-fingered Pterodactyl wing was a parachute wing, while the secret of the bird's wing has its centre in the feathers. It is highly probable that birds evolved from certain Dinosaurs which had become bipeds, and it is possible that they were for a time swift runners that took "flying jumps" along the ground. Thereafter, perhaps, came a period of arboreal apprenticeship during which there was much gliding from tree to tree before true flight was achieved. It is an interesting fact that the



WING OF A BIRD, SHOWING THE ARRANGEMENT OF THE FEATHERS.

The longest feathers or primaries (PR) are borne by the two fingers (2 and 3), and their palm-bones (CMC); the second longest or secondaries are borne by the ulna bone (U) of the fore-arm; there is a separate tuft (AS) on the thumb (TH).

problem of flight has been solved four times among animals—by insects, by Pterodactyls, by birds, and by bats; and that the four solutions are on entirely different lines.

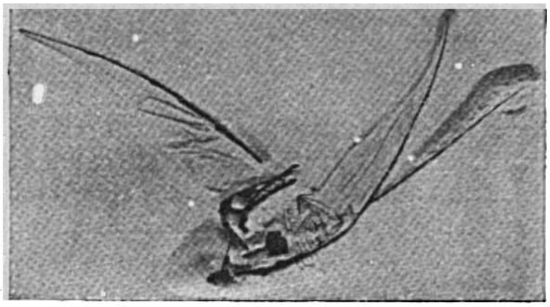


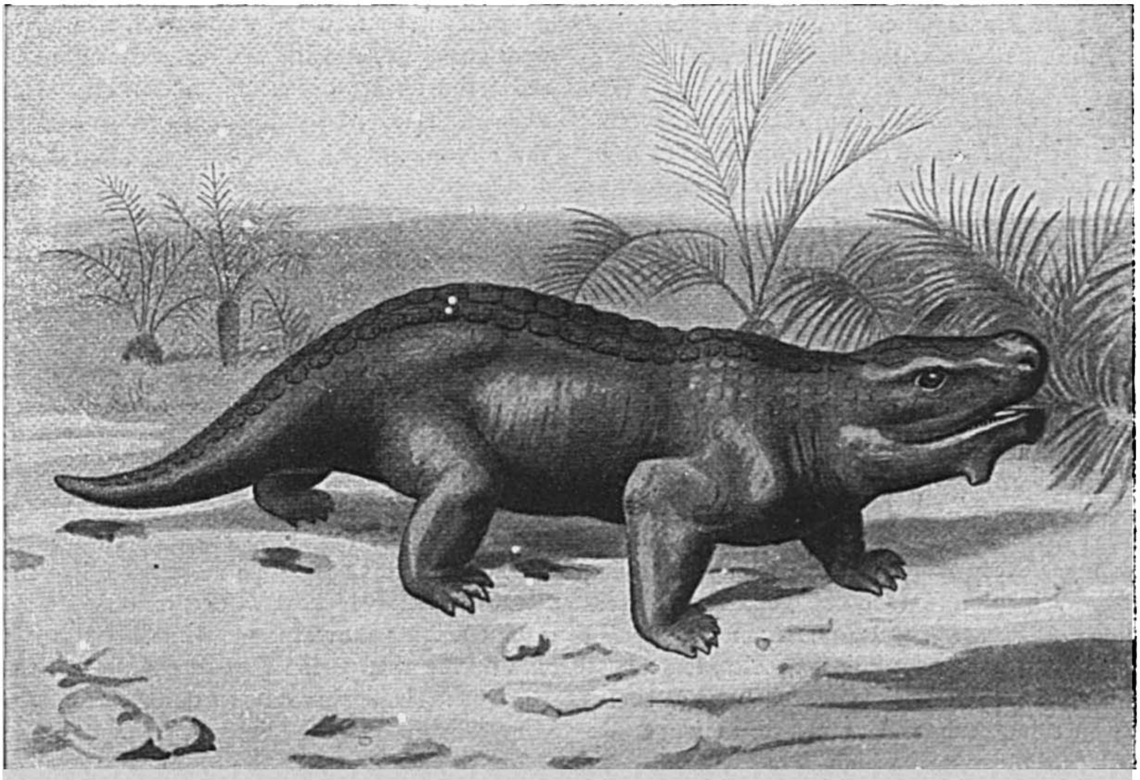
Photo: British Museum (Natural History).

FOSSIL OF A PTERODACTYL OR EXTINCT FLYING DRAGON.

The wing is made of a web of skin extended on the enormously elongated outermost finger. The long tail served for balancing and steering. The Pterodactyls varied from the size of sparrows to a wing-span of fifteen feet—the largest flying creatures.

In the *Cretaceous* period the outstanding events included the waning of giant reptiles, the modernising of the flowering plants, and the multiplication of small mammals. Some of the Permian reptiles, such as the dog-toothed Cynodonts, were extraordinarily mammal-like, and it was probably from among them that definite mammals emerged in the Triassic. Comparatively little is known of the early Triassic mammals save that their back-teeth were marked by numerous tubercles on the crown, but they were gaining strength in the late Triassic when small arboreal insectivores, not very distant from the modern tree-shrews (*Tupaia*), began to branch out in many directions indicative of the great divisions of modern mammals, such as the clawed mammals, hoofed mammals, and the race of monkeys or Primates. In the Upper Cretaceous there was an exuberant "radiation" of mammals, adaptive to the conquest of all sorts of haunts, and this was vigorously continued in Tertiary times.

There is no difficulty in the fact that the earliest remains of definite mammals in the Triassic precede the first-known bird in the Jurassic. For although we usually rank mam-



From Knipe's "Nebula to Man."

PARIASAURUS: AN EXTINCT VEGETARIAN TRIASSIC REPTILE.

Total length about 9 feet. (Remains found in Cape Colony, South Africa.)

mals as higher than birds (being mammals ourselves, how could we do otherwise?), there are many ways in which birds are pre-eminent, e.g. in skeleton, musculature, integumentary structures, and respiratory system. The fact is that birds and mammals are on two quite different tacks of evolution, not related to one another, save in having a common ancestry in extinct reptiles. Moreover, there is no reason to believe that the Jurassic *Archæopteryx* was the first bird in any sense except that it is the first of which we have any record. In any case it is safe to say that birds came to their own before mammals did.

Looking backwards, we may perhaps sum up what is most essential in the Mesozoic era in Professor Schuchert's sentence: "The Mesozoic is the Age of Reptiles, and yet the little mammals and the toothed birds are storing up intelligence and strength to replace the reptiles when the cycads and conifers shall give way to the higher flowering plants."

§ 2

The Cenozoic or Tertiary Era.

In the *Eocene* period there was a replacement of the small-brained archaic mammals by big-brained modernised types, and with this must be associated the covering of the earth with a garment of grass and dry pasture. Marshes were replaced by meadows and browsing by grazing mammals. In the spreading meadows an opportunity was also offered for a richer evolution of insects and birds.

During the *Oligocene* the elevation of the land continued, the climate became much less moist, and the grazing herds extended their range.

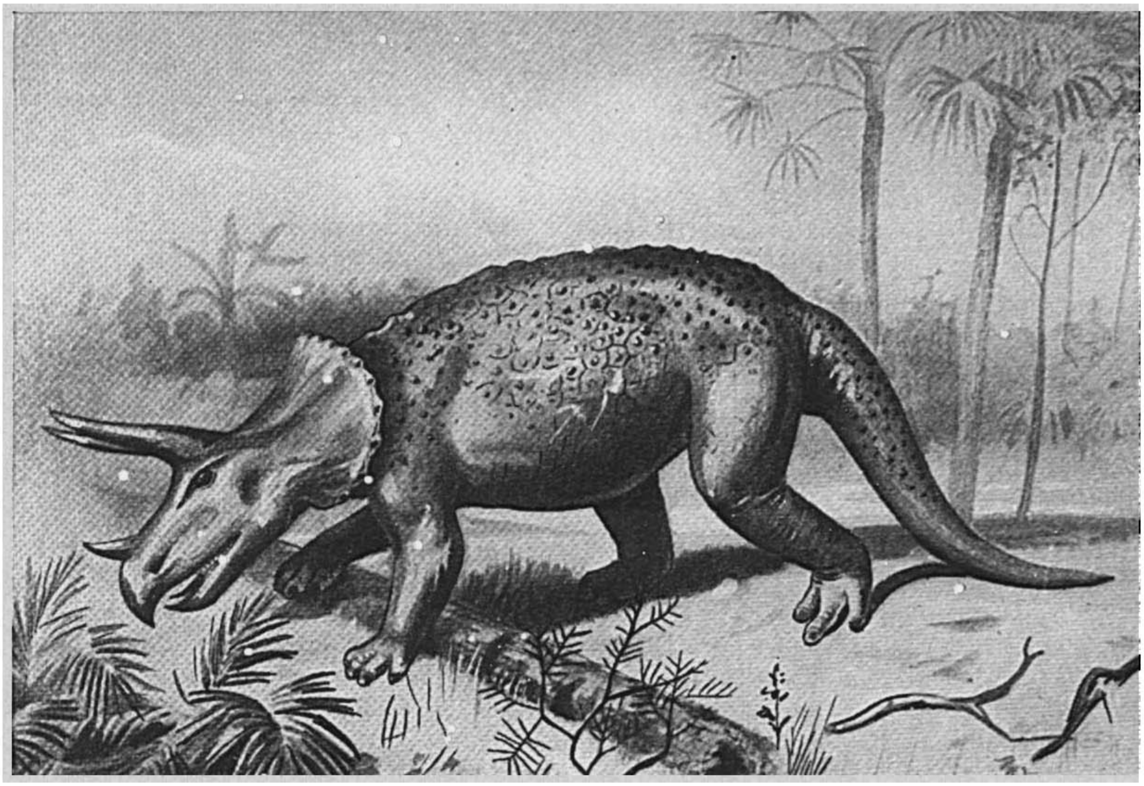
The *Miocene* was the mammalian Golden Age, and there were crowning examples of what Osborn calls "adaptive radiation." That is to say, mammals, like the reptiles before them, conquer every haunt of life. There are flying bats, volplaning parachutists, climbers in trees like sloths and squirrels, quickly moving hoofed mammals, burrowers like the moles, freshwater mammals, like duckmole and beaver, shore-frequenting seals and manatees, and open-sea cetaceans, some of which dive far more than full fathoms five. It is important to realise the perennial tendency of animals to conquer every corner and to fill every niche of opportunity, and to notice that this has been done by successive sets of animals in succeeding ages. *Most notably the mammals repeat all the experiments of reptiles on a higher turn of the spiral.* Thus arises what is called convergence, the superficial resemblance of unrelated types, like whales and fishes, the resemblance being due to the fact that the different types are similarly adapted to similar conditions of life. Professor H. F. Osborn points out that mammals may seek any one of the twelve different habitat-zones, and that in each of these there may be six quite different kinds of food. Living creatures penetrate everywhere like the overflowing waters of a great river in flood.

§ 3

The *Pliocene* period was a more strenuous time, with less genial climatic conditions, and with more intense competition. Old land bridges were broken and new ones made, and the geographical distribution underwent great changes. Professor R. S. Lull describes the *Pliocene* as "a period of great unrest." "Many migrations occurred the world over, new competitions arose, and the weaker stocks began to show the effects of the strenuous life. One momentous event seems to have occurred in the Pliocene, and that was the transformation of the precursor of humanity into man—the culmination of the highest line of evolution."

The *Pleistocene* period was a time of sifting. There was a continued elevation of the continental masses, and Ice Ages set in, relieved by less severe interglacial times when the ice-sheets retreated northwards for a time. Many types, like the mammoth, the woolly rhinoceros, the sabre-toothed tiger, the cave-lion, and the cave-bear, became extinct. Others which formerly had a wide range became restricted to the Far North or were left isolated here and there on the high mountains, like the Snow Mouse, which now occurs on isolated Alpine heights above the snow-line. Perhaps it was during this period that many birds of the Northern Hemisphere learned to evade the winter by the sublime device of migration.

Looking backwards we may quote Professor Schuchert again: "The lands in the Cenozoic begin to bloom with more and more flowering plants and grand hardwood forests, the atmosphere is scented with sweet odours, a vast crowd of new kinds of insects appear, and the places of the once dominant reptiles of the lands and seas are taken by the mammals. Out of these struggles there rises a greater intelligence, seen in nearly all of the mammal stocks, but particularly in one, the monkey-apé-man line. Brute man appears on the scene with the introduction of the last glacial climate, a most trying time for all things endowed with life, and finally there results the dominance of reasoning man over all his brute associates." In man and human society the story of evolution has its climax.



From Knipe's "Nebula to Man."

TRICERATOPS: A HUGE EXTINCT REPTILE.

(From remains found in Cretaceous strata of Wyoming, U.S.A.)

This Dinosaur, about the size of a large rhinoceros, had a huge three-horned skull with a remarkable bony collar over the neck. But, as in many other cases, its brain was so small that it could have passed down the spinal canal in which the spinal cord lies. Perhaps this partly accounts for the extinction of giant reptiles.

The Ascent of Man.

Man stands apart from animals in his power of building up general ideas and of using these in the guidance of his behaviour and the control of his conduct. This is essentially wrapped up with his development of language as an instrument of thought. Some animals have words, but man has language (Logos). Some animals show evidence of *perceptual* inference, but man often gets beyond this to *conceptual* inference (Reason). Many animals are affectionate and brave, self-forgetful and industrious, but man "thinks the ought," definitely guiding his conduct in the light of ideals, which in turn are wrapped up with the fact that he is "a social person."

Besides his big brain, which may be three times as heavy as that of a gorilla, Man has various physical peculiarities. He walks erect, he plants the sole of his foot flat on the ground. he has a chin and a good heel, a big forehead and a non-protrusive face, a relatively uniform set of teeth without conspicuous canines, and a relatively naked body.

But in spite of Man's undeniable apartness, there is no doubt as to his solidarity with the rest of creation. There is an "all-pervading similitude of structure" between man and the Anthropoid Apes, though it is certain that it is not from any living form that he took his origin.

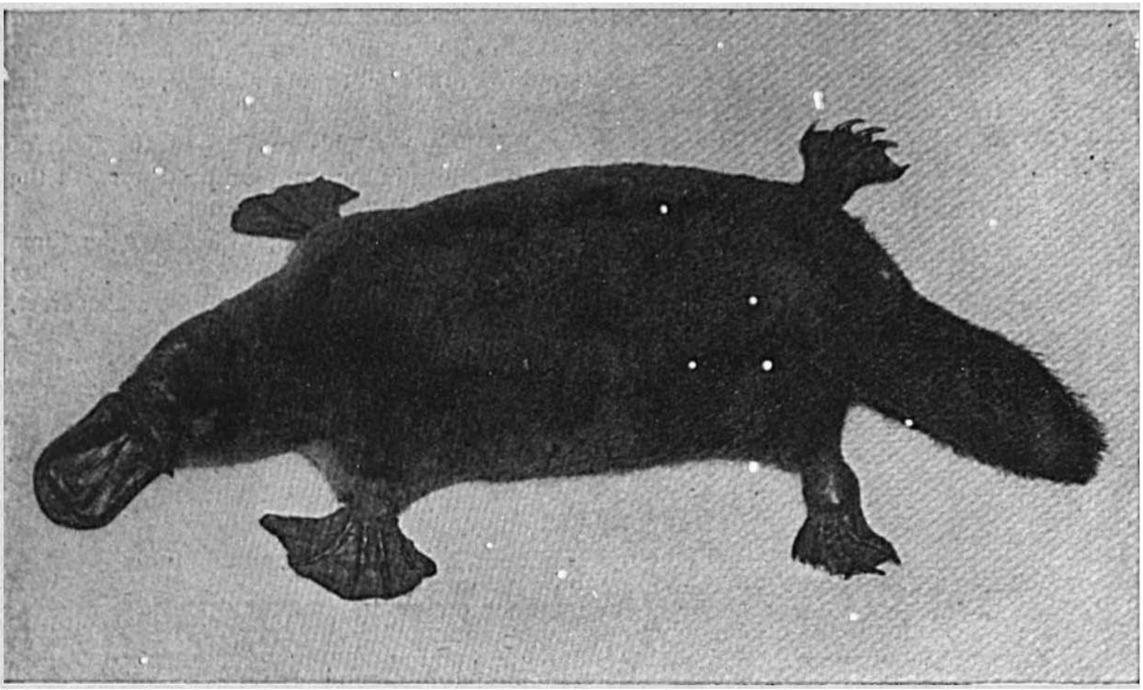


Photo: "Daily Mail."

THE DUCKMOLE OR DUCK-BILLED PLATYPUS OF AUSTRALIA.

The Duckmole or Duck-billed Platypus of Australia is a survivor of the most primitive mammals. It harks back to reptiles, e.g. in being an egg-layer, in having comparatively large eggs, and in being imperfectly warm-blooded. It swims well and feeds on small water-animals. It can also burrow.

None of the anatomical distinctions, except the heavy brain, could be called momentous. Man's body is a veritable museum of relics (vestigial structures) inherited from pre-human ancestors. In his everyday bodily life and in some of its disturbances, man's pedigree is often revealed. Even his facial expression, as Darwin showed, is not always human. Some fossil remains bring modern man nearer the anthropoid type.

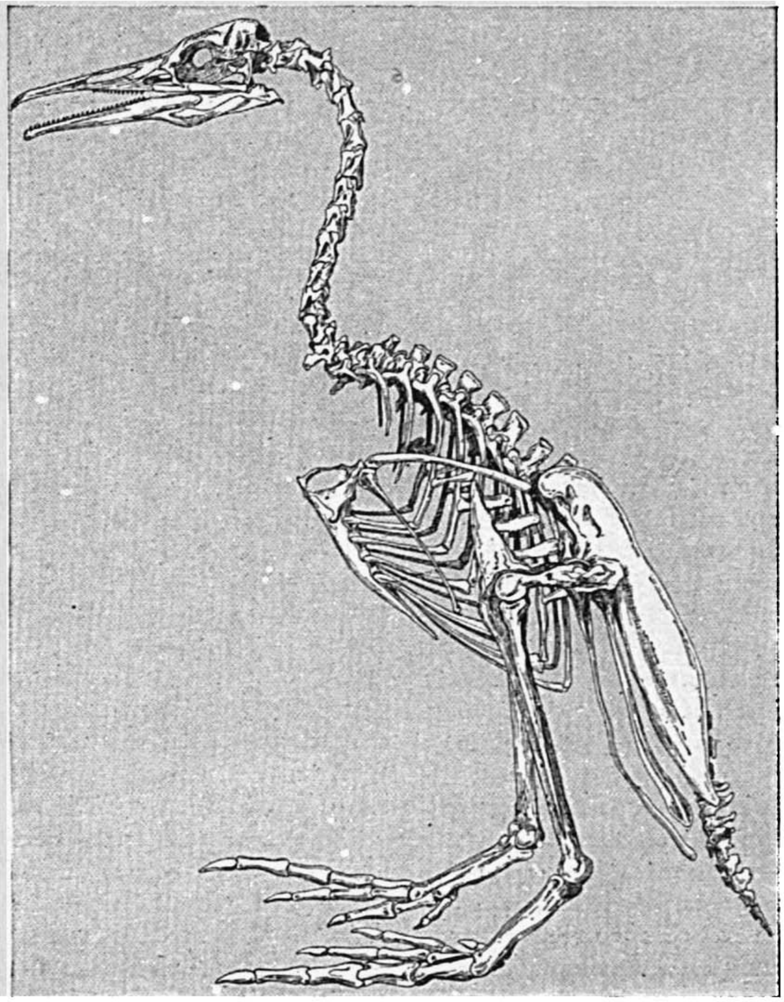
It is difficult not to admit the ring of truth in the closing words of Darwin's *Descent of Man*: "We must, however, acknowledge, as it seems to me, that man, with all his noble qualities, with sympathy which feels for the most debased, with benevolence which extends not only to other men but to the humblest living creature, with his God-like intellect which has penetrated into the movements and constitution of the solar system—with all these exalted powers—man still bears in his bodily frame the indelible stamp of his lowly origin."

THE EVOLVING SYSTEM OF NATURE

There is another side of evolution so obvious that it is often overlooked, the tendency to link lives together in vital inter-relations. Thus flowers and their insect visitors are often vitally interlinked in mutual dependence. Many birds feed on berries and distribute the seeds. The tiny freshwater snail is the host of the juvenile stages of the liver-fluke of the sheep. The mosquito is the vehicle of malaria from man to man, and the tse-tse fly spreads sleeping sickness. The freshwater mussel cannot continue its race without the unconscious co-operation of the minnow, and the freshwater fish called the bitterling cannot continue its race without the unconscious co-operation of the mussel. There are numerous mutually beneficial partnerships between different kinds of creatures, and other inter-relations where the benefit is one-sided, as in the case of insects that make galls on plants. There are also among kindred animals many forms of colonies, communities, and societies. Nutritive chains bind long series of animals together, the cod feeding on the whelk, the whelk on the worm, the worm on the organic dust of the sea. There is a system of successive incarnations and matter is continually passing from one embodiment to another. These instances must suffice to illustrate the central biological idea of the web of life, the interlinked System of Animate Nature. Linnæus spoke of the Systema Naturæ, meaning the orderly hierarchy of classes, orders, families, genera, and species; but we owe to Darwin in particular some knowledge of a more dynamic Systema Naturæ, the network of vital inter-relations. This has become more and more complex as evolution has continued, and man's web is most complex of all. It means making Animate Nature more of a unity; it means an external method of registering steps of progress; it means an evolving set of sieves by which new variations are sifted, and living creatures are kept from slipping down the steep ladder of evolution.

Parasitism.

It sometimes happens that the inter-relation established between one living creature and another works in a retrograde direction. This is the case with many thoroughgoing internal parasites which have sunk into an easygoing kind of life, utterly dependent on their host for food, requiring no exertions, running no risks, and receiving no spur to effort. Thus we see that evolution is not necessarily progressive; everything



SKELETON OF AN EXTINCT FLIGHTLESS TOOTHED BIRD, HESPERORNIS.

(*After Marsh.*)

The bird was five or six feet high, something like a swimming ostrich, with a very powerful leg but only a vestige of a wing. There were sharp teeth in a groove. The modern divers come nearest to this ancient type.

depends on the conditions in reference to which the living creatures have been evolved. When the conditions are too easygoing, the animal may be thoroughly well adapted to them—as a tapeworm certainly is—but it slips down the rungs of the ladder of evolution.

This is an interesting minor chapter in the story of evolution—the establishment of different kinds of parasites, casual and constant, temporary and lifelong, external hangers-on and internal unpaying boarders, those that live in the food-canal and depend on the host's food and those that inhabit the blood or the tissues and find their food there. It seems clear that ichneumon grubs and the like which hatch inside a caterpillar and eat it alive are not so much parasites as "beasts of prey" working from within.

But there are two sides to this minor chapter: there is the evolution of the parasite, and there is also the evolution of counteractive measures on the part of the host. Thus there is the maintenance of a bodyguard of wandering amœboid cells, which tackle the microbes invading the body and often succeed in overpowering and digesting them. Thus, again, there is the protective capacity the blood has of making antagonistic substances or "anti-bodies" which counteract poisons, including the poisons which the intruding parasites often make.

THE EVIDENCES OF EVOLUTION—HOW IT CAME ABOUT

§ 1

Progress in Evolution.

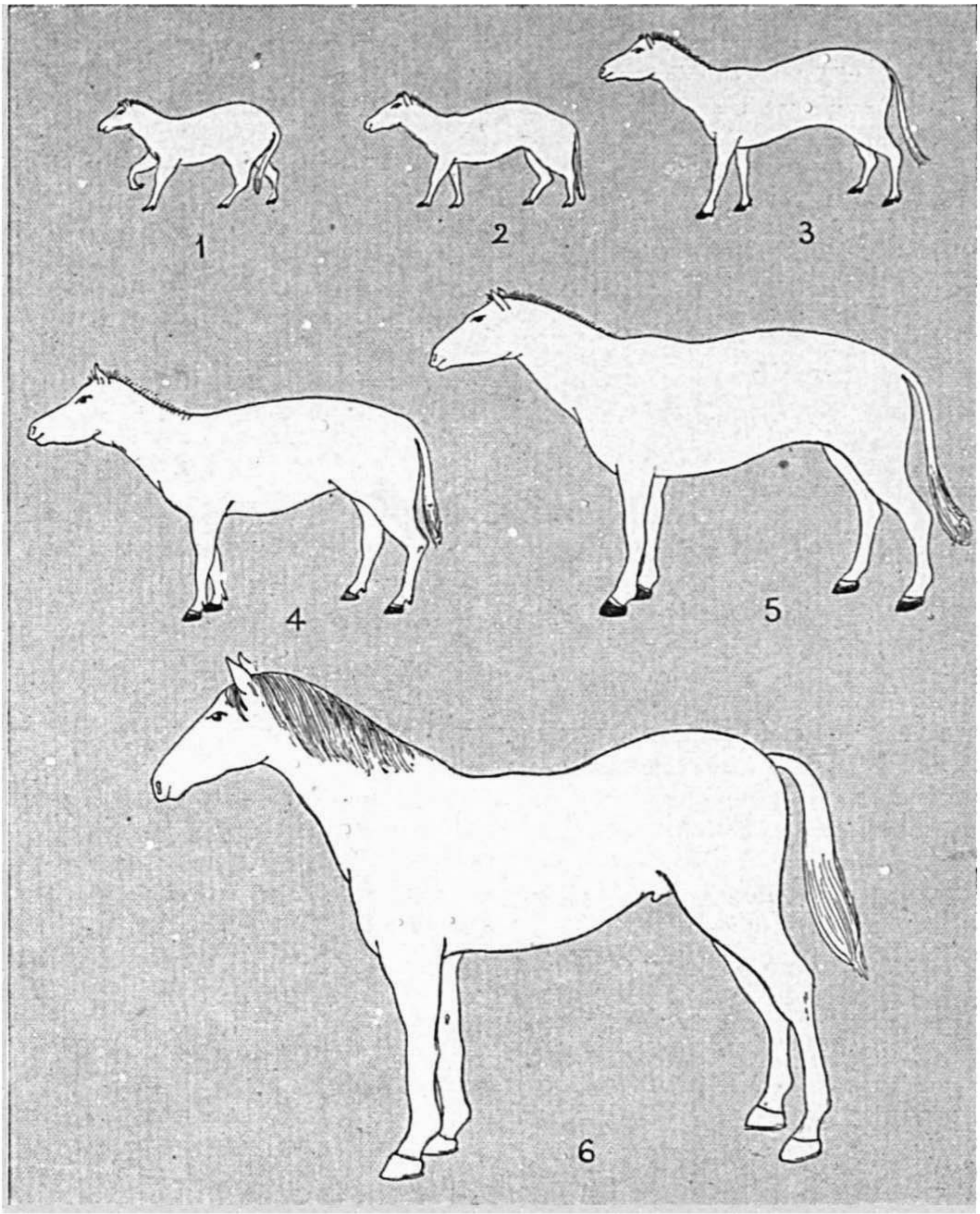
There has often been slipping back and degeneracy in the course of evolution, but the big fact is that there has been progress. For millions of years Life has been slowly creeping upwards, and if we compare the highest animals—Birds and Mammals—with their predecessors, we must admit that they are more controlled, more masters of their fate, with more mentality. Evolution is on the whole *integrative*; that is to say, it makes against instability and disorder, and towards harmony and progress. Even in the rise of Birds and Mammals we can discern that the evolutionary process was making towards a fuller embodiment or expression of what Man values most—control, freedom, understanding, and love. The advance of animal life through the ages has been chequered, but on the whole it has been an advance towards increasing fullness, freedom, and fitness of life. In the study of this advance—the central fact of Organic Evolution—there is assuredly much for Man's instruction and much for his encouragement.

Evidences of Evolution.

In all this, it may be said, the fact of evolution has been taken for granted, but what are the evidences? Perhaps it should be frankly answered that the idea of evolution, that the present is the child of the past and the parent of the future, cannot be *proved* as one may prove the Law of Gravitation. All that can be done is to show that it is a key—a way of looking at things—that fits the facts. There is no lock that it does not open.

But if the facts that the evolution theory vividly interprets be called the evidences of its validity, there is no lack of them. There is *historical* evidence; and what is more eloquent than the general fact that fishes emerge before amphibians, and these before reptiles, and these before birds, and so on? There are wonderfully complete fossil series, e.g. among cuttlefishes, in which we can almost see evolution in process. The pedigree of horse and elephant and crocodile is in general very convincing, though it is to be confessed that there are other cases in regard to which we have no light. Who can tell, for instance, how Vertebrates arose or from what origin?

There is *embryological* evidence, for the individual development often reads like an abbreviated recapitulation of the presumed evolution of the race. The mammal's visceral clefts are tell-tale evidences of remote aquatic ancestors, breathing by gills. Something is known in regard to the historical evolution of antlers in bygone ages; the Red Deer of to-day recapitulates at least the general outlines of the history. The individual development of an



SIX STAGES IN THE EVOLUTION OF THE HORSE, SHOWING GRADUAL INCREASE IN SIZE.

(After Lull and Matthew.)

1. Four-toed horse, Eohippus, about one foot high. Lower Eocene, N America.
2. Another four-toed horse, Orohippus, a little over a foot high. Middle Eocene, N. America.
3. Three-toed horse, Mesohippus, about the size of a sheep. Middle Oligocene, N. America.
4. Three-toed horse, Merychippus, Miocene, N. America. Only one toe reaches the ground on each foot, but the remains of two others are prominent.
5. The first one-toed horse, Pliohippus, about forty inches high at the shoulder. Pliocene, N. America.
6. The modern horse, running on the third digit of each foot.

asymmetrical flat-fish, like a plaice or sole, which rests and swims on one side, tells us plainly that its ancestors were symmetrical fishes.

There is what might be called *physiological* evidence, for many plants and animals are variable before our eyes, and evolution is going on around us to-day. This is familiarly seen among domesticated animals and cultivated plants, but there is abundant flux in Wild Nature. It need hardly be said that some organisms are very conservative, and that change need not be expected when a position of stable equilibrium has been secured.

There is also *anatomical* evidence of a most convincing quality. In the fore-limbs of back-boned animals, say, the paddle of a turtle, the wing of a bird, the flipper of a whale, the foreleg of a horse, and the arm of a man; the same essential bones and muscles are used to such diverse results! What could it mean save blood relationship? And as to the two sets of teeth in whalebone whales, which never even cut the gum, is there any alternative but to regard them as relics of useful teeth which ancestral forms possessed? In short, the evolution theory is justified by the way in which it works.

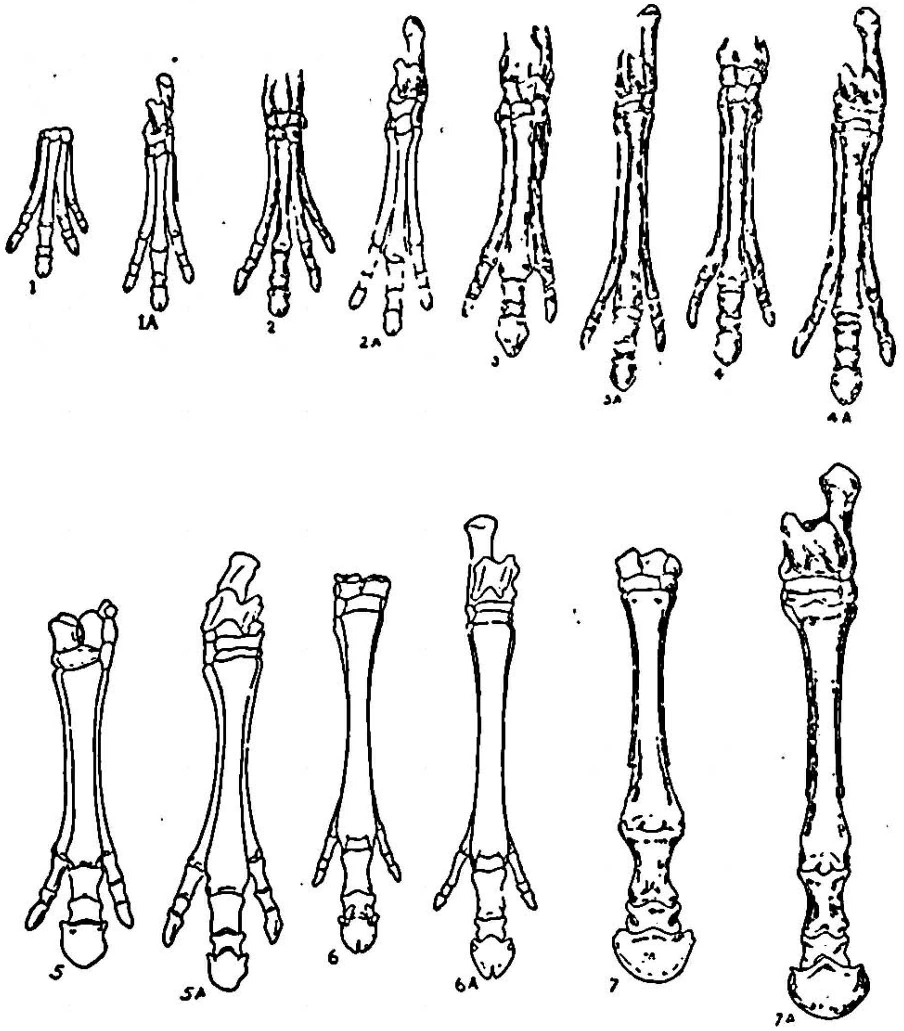
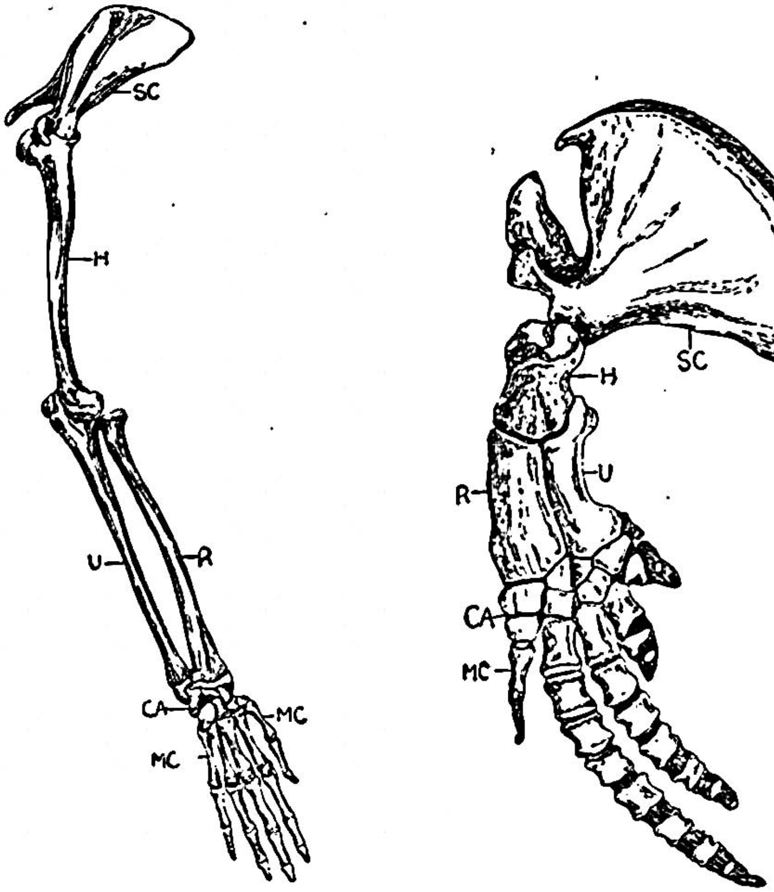


DIAGRAM SHOWING SEVEN STAGES IN THE EVOLUTION OF THE FORE-LIMBS AND HIND-LIMBS OF THE ANCESTORS OF THE MODERN HORSE, BEGINNING WITH THE EARLIEST KNOWN PREDECESSORS OF THE HORSE AND CULMINATING WITH THE HORSE OF TO DAY.

(After Marsh and Lull.)

1 and 1A, fore-limb and hind limb of Eohippus; 2 and 2A, Orohippus; 3 and 3A, Mesohippus; 4 and 4A, Hypohippus; 5 and 5A, Merychippus, 6 and 6A, Hipparion; 7 and 7A, the modern horse. Note how the toes shorten and disappear.



A Fore limb of Monkey.

B. Fore-limb of Whale.

WHAT IS MEANT BY HOMOLOGY? ESSENTIAL SIMILARITY OF ARCHITECTURE, THOUGH THE APPEARANCES MAY BE VERY DIFFERENT.

This is seen in comparing these two fore limbs, A, of Monkey, B of Whale. They are as different as possible, yet they show the same bones, e g SC, the scapula or shoulder blade, H, the humerus or upper arm; R and U, the radius and ulna of the fore arm; CA, the wrist; MC, the palm; and then the fingers.

§ 2

Factors in Evolution.

If it be said " So much for the *fact* of evolution, but what of the *factors*? " the answer is not easy. For not only is the problem the greatest of all scientific problems, but the inquiry is still very young. The scientific study of evolution practically dates from the publication of *The Origin of Species* in 1859.

Heritable novelties or variations often crop up in living creatures, and these form the raw material of evolution. These variations are the outcome of expression of changes in the germ-cells that develop into organisms. But why should there be changes in the constitution of the germ-cells? Perhaps because the living material is very complex and inherently liable to change; perhaps because it is the vehicle of a multitude of hereditary items among which there are very likely to be reshufflings or rearrangements; perhaps because the germ-cells have very changeful surroundings (the blood, the body-cavity fluid, the sea-water); perhaps because deeply saturating outside influences, such as change of climate and habitat, penetrate through the body to its germ-cells and provoke them to vary. But we must be patient with the wearisome reiteration of " perhaps." Moreover, every many-celled organism, reproduced in the usual way, arises from an egg-cell fertilised by a sperm-cell, and the changes involved in and preparatory to this fertilisation may make new permutations and combinations of the living items and hereditary qualities not only possible but necessary. It is something like shuffling a pack of cards, but the cards are living. As to the changes wrought on the body during its lifetime by peculiarities in nurture, habits, and surroundings, these dents or modifications are often very important for the individual, but it does not follow that they are directly important for the race, since it is not certain that they are transmissible.

Given a crop of variations or new departures or mutations, whatever the inborn novelties may be called, we have then to inquire how these are sifted. The sifting, which means the elimination of the relatively less fit variations and the selection of the relatively more fit, is effected in many different ways in the course of the struggle for existence. The organism plays its new card in the game of life, and the consequences may determine survival. The relatively less fit to given conditions will tend to be eliminated, while the relatively more fit will tend to survive. If the variations are hereditary and reappear, perhaps increased in amount, generation after generation, and if the process of sifting continue consistently, the result will be the evolution of the species. The sifting process may be helped by various forms of "isolation" which lessen the range of free intercrossing between members of a species, e.g. by geographical barriers. Interbreeding of similar forms tends to make a stable stock; outbreeding among dissimilars tends to promote variability. But for an outline like this it is enough to suggest the general method of organic evolution: Throughout the ages organisms have been making tentatives—new departures of varying magnitude—and these tentatives have been tested. The method is that of testing all things and holding fast that which is good.

BIBLIOGRAPHY

(The following short list may be useful to readers who desire to have further books recommended to them.)

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