# CHAPTER XXVI

## ORGANIC EVOLUTION

### PART I. ADAPTATION

**Introduction.** Adaptation has been defined as the state of being adjusted. Every living form is in a state of adjustment to its surroundings. *No adaptations are absolutely perfect.* Successful adjustments are only relatively adequate. If the organism is not adjusted, death occurs. The biologist looks out on the world of living things and sees adaptations everywhere. That living things are adapted seems almost axiomatic.

**The Test of Fitness.** The environment acts as a sort of examining board. If the organism passes the test, it survives; if not, it perishes. Charles Darwin in his theory of Natural Selection emphasized this aspect. H. C. Bumpus made a collection of English sparrows overcome by a severe winter storm. He found that those that died were extreme variants, either larger or smaller than the average sparrow. Each organic form is exposed to the constant environmental test, the outcome of which is survival or death. In sudden catastrophes, survival possibilities are part of the very constitution of the survivors. Environmental changes of an extensive or severe sort change the face of nature. Volcanic eruptions pour fourth lava streams which destroy all life remaining in their path. Leonardo da Vinci found marine fossils on mountain slopes and concluded that those high places were once beneath sea level. The geologist has confirmed this and also tells us that one-time elevated lands are *now* far *below* sea level.

Could life, as we know it, continue to be, if the force of gravity were permanently altered; if only blue or red light rays shone upon the earth; if the air were permanently dry or, on the other hand, saturated with moisture; if the percentage composition of the ingredients of air were shifted about; if the temperature conditions in our zone were changed considerably, up or down the scale?

Henderson, in his book, "The Fitness of the Environment," shows how the life we know is fitted for the present type of environment. The environment constantly tests the organism as to its fitness for survival.

**Reaction to Environment.** On the other hand, however, the organism does not remain supine but actively responds to external stimuli. We must not look upon the organism merely as helpless clay in the hands of molding forces of nature. The organism is part of nature, so constituted as to react specifically to this or that particular variation in the external world. The organism is stimulated to reactions of adjustment and very often succeeds. The sufferer from disease maintains an optimistic attitude because of this great power of protoplasm. The epidermis at the base of each finger is of moderate thickness when we are engaged in light tasks. But if we wielded a pick or hoe, day in and day out, the epidermis at friction points "grows" thicker, forming callosities protecting the tender structures underneath. It is not the pick which makes the callosities because these are a product of tissue activity. The heavy labor stimulates, it is true, but the adaptation is a reflex reaction on the part of the organism. It sometimes becomes necessary to remove a large vein from the leg. This can be done safely because some other vein enlarges and takes on the function of the diseased vessel. There is only one spleen and it is a useful organ, but it is necessary at times to remove it. This is not fatal because other organs take over the work of the spleen. The legless man who exercises develops strong and effective arms. Trees grow well in fertile soil, but some of the same sort do remarkably well in the crevices of rocks. After all we should not think of natural selection as entirely determining which is fit and which is unfit, because many organisms automatically endeavor to become fit.

**An Example of an Adapted Organism.** A study of any organism will show how fitted it is for its particular mode of existence. The earthworm lives in a burrow and the shape of the body conforms to this. The size is fitted for the use of the setae in crawling in and out of its burrow. They act as a system of levers whose outer ends are in contact with the wall of the burrow. There is no room and no need to turn about in the burrow, for the worm can move easily in either direction. Moreover, it can extend its burrow by "eating" the earth ahead of it. It swallows the excavated earth and secures whatever food there is in it. The earth particles pass through the intestine and, while still there, are carried back up to the burrow entrance, where they are discharged. The skin of the worm must remain moist, otherwise it would die from oxygen starvation. A moist skin is also essential to the functioning of the sense organs in it and so the worm spends most of its time in the ground; and if the surface ground is dry, the worm remains deep in the burrow where the walls are damp. The mouth is adapted for the kind of food the worm eats, and the crop and gizzard are adapted to preparing the food for digestion. The long intestine and its typhosole are well adapted to the slow movement of food, thus giving time for its digestion and absorption. The peristaltic movements of the body churn the coelomic fluid containing absorbed food, back and forth, bringing it into contact with internal tissues that need it. The worm has no eyes nor ears, but is sensitive to light and earth vibrations or jars. It feeds on the surface at night and when all is still. The slightest jar or flash of light will send it scurrying into its burrow. Organisms as a whole appear to be well adapted for their conditions of living.

**Organs Are Adapted.** The broad symmetrical caudal fin of the teleost is adapted to forward-moving locomotion, while the asymmetrical heterocercal tail of the shark enables it, at will, to descend to the bottom after food. The wing of the bird is adapted for aerial navigation, and the wing is modified according to the nature of the flying habits of each particular species. The beak of the seed-eating bird is differently organized from that of the flesh-tearing eagle. The crop of the seed-eating bird is adapted for temporary accumulation of grain during short periods of adventure in the open where the bird may be exposed to the eyes of a possible enemy. The opposable thumb and great toe of the chimpanzee are adapted to arboreal life and the long, strong front limbs are adapted to swinging the body along from limb to limb. Although the hind legs assist in this, they are also used for support. The swiftness of the race horse is made possible by the one-toed organization of the foot and the skeletal, muscular and nervous organizations are directed to this end also.

**Functions Are Adapted.** Think of the different and special functions of the front limbs of the bat, the camel, the horse, the cat and the chimpanzee. The organization in each case fits the function which is performed. We examine the skeletal structures of all and compare them. We find a similar underlying pattern. It is the function which determines the specialization in structure in each case. A piece of the tendon of Achilles, which connects the calf (gastrocnemius) muscle of the leg to the heel, is torn away by accident. If the leg is prevented from being used, a sort of connective tissue regenerates and fills the space thus formed and the use of the leg is greatly impaired. But if the movement of the leg is permitted and encouraged, useful tendon tissue regenerates to repair the wounded tendon and so in time restore the leg apparatus to a normal functioning condition. If the spleen is removed, the function is taken over by other glands. If the thyroid gland does not deliver sufficient thyroxin to the body, it may grow larger, forming a goiter, in an endeavor to salvage every trace of iodine ingested. When the color of the background changes with the seasons, certain physiological activities change the plumage of certain birds accordingly. The breeding period of the frog and other animals is in the spring and the young appear when the food and climatic conditions are favorable for successful development.

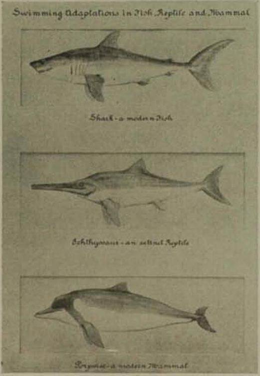


FIG. 377. — Illustrating the Law of Convergence of Form — Osborn. (Courtesy Am. Mus. Nat. Hist.)

**Embryological Processes Are Adaptive.** The gastrula of the starfish and Amphioxus are adapted to a freely moving life so that they can obtain the necessary food for the completion of their development. The embryos of fish, frog, reptile, bird and mammal look alike at an early stage. Different developmental processes in each result in a special type of adult. Both pairs of legs of Necturus, an amphibian, are about equal in size. The embryonic legs of a kangaroo at an early stage are equal in size, but later the front limbs develop very slowly and very little, while the hind legs develop rapidly and become very powerful organs. The nose of the elephant develops more rapidly and differently than the nose of a tapir and the neck of a giraffe develops more rapidly than the neck of a cow, while the brain of a scholar develops differently than the brain of an idiot.

**Law of Convergence.** H. F. Osborn maintains that two great laws of adaptation are evident. One he calls the *Law of Convergence of Form* (Fig. 377). This is illustrated by adaptations for rapid swimming. The internal anatomy of the shark is that of an elasmobranch; that of the ichthyosaur is reptilian; that of the porpoise is mammalian. The shark, the ichthyosaur and porpoise all have a spindle-shaped body, bulky in front, a pointed nose, a propelling tail, a dorsal fin which acts as a keel and anterior appendages used for balancing. Structures somewhat similar in form are seen in adaptations for flight illustrated by the "wings" of insects, and of pterodactyls, the flying reptiles of the Mesozoic Era and by bats and birds.

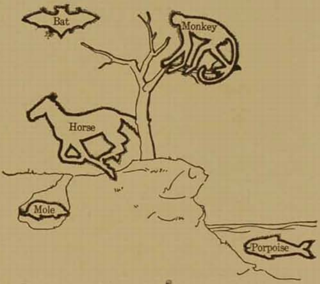

Fig. 378. — Illustrating the Law of Adaptive Radiation — Osborn.

**The Law of Adaptive Radiation** (Fig. 378). This appears to be just the opposite of the preceding. Animals of the same sort take up different modes of life and, becoming adaptively modified for each particular mode of life, assume different forms. Mammals which have a similar fundamental organization are adaptively modified to different life conditions. We find running or cursorial types, such as the horse; burrowing or fossorial types, such as the mole; climbing or arboreal types, such as the monkey; swimming or natatorial types, such as the porpoise, and flying or aerial types, such as the bat.

**Protective Resemblance.** Protective resemblance is a sort of convergence of form and color exhibited by many animals in particular habitats. The polar bear and other animals in the same regions are white, living as they do midst arctic snow and ice. The ptarmigan assumes a white coat in winter, the flounder changes its color to blend with the color of the bottom; Kallima, a butterfly (Fig. 379) from India, folds its wings as it rests on certain twigs, and then looks like a dead leaf. Certain moths are so colored as to blend in with the color of the bark of the tree on which they rest. A certain insect resembles a thorn and rests on thorny branches. According to some observers, the striped tiger blends in with the jungle through which it courses, the tawny lion fits in with its background of tall dried grass and the leopard's spots cause it to be unseen among the lights and shades of leafy branches. The belly of the fish is light in color and is unnoticeable from below, while the back is so colored as to blend in with the surrounding water in the dim light from above. Protective resemblance is agreement in color, form or both, between an organism and some part of its environment.

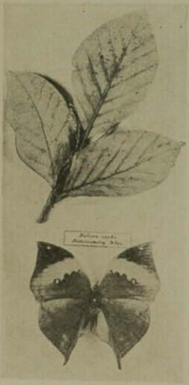

Fig. 379.—Kallima Butterfly of India. Lower figure with wings outspread. In upper figure, the butterfly is at the lower left and at rest. (Photo by Schechter.)

**Mimicry.** No less striking is mimicry, which is a special kind of protective resemblance. In this sort of adaptation, a defenseless species apparently secures protection by possessing a close resemblance to a form that is well protected. The defenseless form *mimics* certain rather *immune* models (Fig. 380). The models have distinctive colors or markings by which they are recognized, with the result that they are avoided. Certain harmless flies, moths and beetles look like, *i.e., mimic* protected forms. Some flies "buzz" and have the appearance of bees. Some edible butterflies imitate, in appearance, nauseating forms. Mimicry is not a conscious reaction on the part of the mimics. The idea of mimicry is a human conception. One naturally asks, "How did it come about?" The student of mimicry and protective resemblance and convergence of form holds that such adaptations were perfected by a process of the survival of the fittest.

**Adaptive Modifications.** Organs and tissues are modified to become special adaptations. Tissues and organs used once for one purpose are modified for functioning differently. The muscle tissue of the pectoral fin of the electric ray is now an electric organ, giving its enemies a severe shock whenever they come in contact with it. The mammary glands of Mammals are modified oil glands. Feathers of birds and fur of Mammals are modified scales of Reptiles. The Eustachian tube of our middle ear is the modified old spiracle of the dogfish put to a new use.

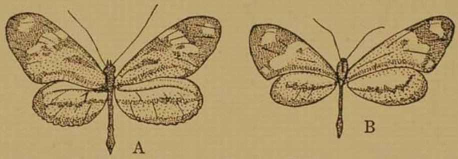


FIG. 380. — Illustrating Mimicry. Fig. A is Heliconius, a butterfly which is the model for B, Mechanitis, which mimics A. A is nauseating to taste and birds avoid it. B is not, but is protected. Both from Honduras.

Parasitic life has brought about extensive modifications resulting in adaptations of dependency. In the case of the tapeworm, organs of locomotion and sense organs, no longer needed for adjustment, disappear. The digestive tract also disappears. Under the special conditions of life the chance of completing the life cycle is reduced. To meet this situation, an enormous number of eggs and sperm and even embryos are produced. In some cases the embryonic form of the parasite is similar to that of related independent species, but degeneration later appears.

Degeneration and modification of organs do not always lead to parasitism, but sometimes to adaptations for a special mode of life. The tadpole of the tunicate is a free-swimming animal, but as it develops, the tail and notochord and most of the central nervous system disappear and it becomes an adult sedentary animal but is not parasitic. Fishes that live in caves have degenerate and, so far as we know, useless eyes.

**Commensalism.** Certain adaptations result in an association between two forms with no harm to either. Such an association is known as commensalism. Fierasfer, a peculiar fish, spends most of its time in the gastric cavity of a sea cucumber, from which it emerges at times for brief periods to capture food. The form of the fish has become fitted to this environment. You may have seen the little crab that lives in the shell of the living oyster. The shark-sucker is a teleost that has a sucker-like pad on the top of its head and although its locomotor apparatus is weak, nevertheless it makes long journeys because it attaches itself to the body of a shark and is thus carried about.

**Symbiosis.** There is another special adaptive association known as symbiosis or living together. In this case the two forms mutually profit. The green color of Hydra viridis is due to the presence of a small Green Alga and both forms benefit. A lichen is a symbiotic association between an Alga and a filamentous Fungus. The Alga makes carbohydrate, some of which is available for the Fungus, and the Fungus absorbs and holds moisture, some of which is available for the Alga. The hermit crab lives in the cast-off shell of a marine snail to which sea anemones may become attached. Some hermit crabs deliberately seek anemones for this purpose. The anemone can ingest floating fragments of the crab's food and the crab possibly gains concealment due to the presence of the anemones. We have already called attention to the association between ants and plant lice.

**Conclusion.** The observation of so many differently adapted forms, which in many cases comprise groups whose members are fundamentally similar from a structural point of view, have forced the philosophical investigator to the conclusion that modifications of an original type pattern have taken place and that the special forms have been *derived* from an original ancestral type, which was generalized in structure. As an illustration of this, the various orders of Mammals have been derived from an ancestral generalized Mammal.

Adaptations due to the effect of environmental conditions on the actively reacting organism are closely concerned with *Organic Evolution.*

## PART II. EVIDENCES FOR ORGANIC EVOLUTION

**Introduction.** The great mass of biological facts, of various kinds, leads to the formulation of the *theory of organic evolution* as a fundamental life principle. It is the business of the scientist to discover the laws according to which phenomena operate, and the biologist finds that the history of living forms and what they are today involves a process of evolution. The principle of evolution is not limited to the science of biology but is also a fundamental conception in astronomy, geology, chemistry and physics. As a matter of fact the principle of evolution is evident to all who read the daily newspaper understandingly. Human history is a story of evolution. We are all familiar with the evolution of mechanical contrivances, evolution in medicine, in politics and in education.

It is not the business of the biologist to discuss the *Original Cause* or *Creator* of Things.

There are great classes of facts that bear witness to the truth of the theory of organic evolution. These are the facts of (*a*) Palaeontology; (*b*) Geographical Distribution; (*c*) Comparative Anatomy; (*d*) Embryology; (*e*) Classification; (*f*) Physiology; (*g*) Experimental Evolution. Let us study each of these.

(*a*) **Palaeontology.** The geologist studies the distribution of, characteristics of and agencies concerned in the formation of sedimentary rocks which form a more or less continuous mass at the surface of the earth. The geologist recognizes certain definite rock strata which he can identify at widely separated points. He tells us that elevated lands, now far above sea level, once formed the bed of an ocean. He describes mountain-forming, great climatic changes, ice ages; and he presents to us the history of such great changes in the past.

He concludes that sedimentary rocks have accumulated in thickness for a depth of about seventy-five miles. He estimates that a long period of time has elapsed during which this sedimentation and rock formation took place. By utilizing certain data, he estimates that this took between five hundred million and one thousand million years. He divides geologic time into *Eras*. We have already studied a brief account of the life during these Eras. We noted that during the long and primary Archezoic Era there were no organic forms since these basic strata have no fossils.

Succeeding these rock formations are those of the Proterozoic Era in which there is a great paucity of fossils. At any rate, very few have been found there as compared with the richness of finds in the next Paleozoic strata. The Paleozoic Era was a time of dominance of marine invertebrates and lower plants. The order of appearance of the index fossils corroborates conclusions as to age and order of appearance arrived at by other methods of reasoning and other kinds of observations. In offering the facts of palaeontology as indicators of the process of organic evolution, the student is referred to the discussion of the *distribution of animals in time*, already presented. We note here, however, some general conclusions from those facts. First: Organisms of the highest (newest) strata are most like living forms and they are also the most specialized. Second: Organisms of the lowest (oldest) strata are most generalized. Third: There is a gradual progression from simple generalized forms to complex specialized forms. Fourth: Many types of plants and animals which appeared in early times, flourished for ages and became extinct. Fifth: Lines of increasing specialization with consequent extinction have been worked out. Sixth: As time went on, *new types* appeared and these were *more specialized* than the older types (Fig. 381). Seventh: More specialized types emerged from what were already comparatively specialized types, as, for example, mammals from reptilian ancestors. Eighth: Most of the Invertebrates had already been well established during the earliest known life strata. Ninth: Since skeletal structures lend themselves best to fossilization and since at the same time they are good indices of organization, it follows that *vertebrate* palaeontology would probably be well developed. Vertebrate palaeontology presents a wealth of evidence for the theory of organic evolution, as evidenced by what we know about such forms as the horse, camel and elephant. Tenth: The fossil history of one part of the earth's surface agrees in general with that of other parts. One general science of palaeontology is possible.

The question is often asked: "Why do we not find missing links oftener?" For one thing, it is only where natural forces have so lifted and broken the strata that we have any hope of being able to find fossils, and most of the earth's crust is closed to fossil hunting. Again, all the fossil collections in the world comprise but a very small part of all the fossils entombed in the rocks. In fact no museum in the world contains *all* forms which we *think* exist. New collections are constantly being made and, of course, new fossil forms are being discovered. It is only recently that fossil hunting has been adequately undertaken. Finally, modern biological thought does not demand a completely graded series of forms since origin of species by mutation is a possibility.

(*b*) **Geographical Distribution.** Any plausible explanation of present-day distribution of faunas and floras on the earth's surface

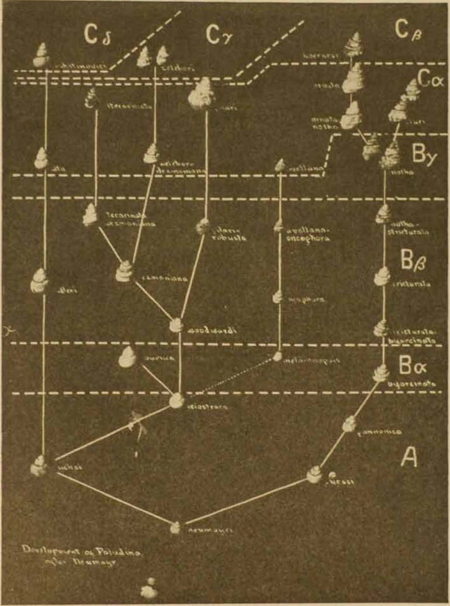


FIG. 381. — Evolution of Paludina, a snail, as shown by fossil shells taken at different geologic levels. After Neumayr. (Courtesy American Museum of Natural History.)

involves the principle of *organic evolution* and of *geologic evolution.* We have already discussed this in the chapter on *geographical distribution.*

(*c*) **Comparative Anatomy.** In our discussion of comparative anatomy and of adaptations, we found that a comparison of the various systems of organs of animals led us to arrange them in groups of increasing complexity and that such studies suggest the idea that more specialized forms could have been derived from organizations like those possessed by simpler types, or in other words, that we could explain the progressive modifications by a process of organic evolution. It seems reasonable to conclude that closely similar animals are closely related. Vertebrates have sufficient similarities in common to warrant the conclusion that all are related. If we tabulate the structural organization of such organs as the skeleton of the limbs, and chambers of the heart; the parts of the brain and cranial nerves; the ear, the intestinal tract of Elasmobranchs, Fishes, Amphibians, Reptiles, Birds and Mammals, we find an exposition of evolution.

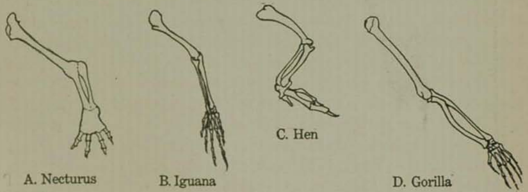


Fig. 382. — Homology shown by structure of fore-limbs of vertebrates.

The case is made still stronger when we set down the embryology in each case. If we extend our study to particular organs in several types of the same class which exhibit special adaptations, we find that the case for evolution appears to be still stronger. For example, let us consider the fore-limb structure of man, dog, bat, horse and deer (Fig. 382). The limb plan of the man and dog seems to be more like that of the generalized vertebrate fore-limb, and those of the other three mammals appear to be specialized limbs. We say that when the use of the limb becomes specialized, then the structure of the limb is accordingly modified from the generalized plan. On the other hand, when we compare the limb and brain of Man with that of the Reptile and Elasmobranch, to name widely different groups, then we find that although the human limb appears to remain more or less generalized, yet his brain is very much specialized. A study of the comparative anatomy of Urodela and Anura leaves the impression that Anura are, so to speak, specialized Urodela and that Urodela are more like fishes than are Anura. A comparison of the anatomy of Arthropods and Annelids reveals many annelid characteristics in the former group. The tabulation of the facts of comparative anatomy alone would enable us to arrange phyla, classes, orders, families, genera and species of animals in a very satisfactory phylogenetic order, *i.e.*, such an arrangement would represent fairly well the order of evolution of those forms. And this can be done with plants as well as animals.

(*d*) **Embryology.** But the facts of embryology go hand in hand or corroborate those of comparative anatomy. The mere fact that all Metazoa begin life as a single cell is in keeping with the notion that all Metazoa are descended from some kind of Protozoan ancestor. Some people find it difficult to think it possible that man has been evolved during long, long ages from a remote protozoan ancestor. However, *it is a known fact that a human being is evolved during the short space of nine months from a microscopic speck of protoplasm, the human fertilized egg.* This known *fact* of ontogeny is no less marvelous than the other *theory* concerning his phylogeny. A comparison of development of different groups shows cleavage stages, gastrula stage, appearance of ectoderm, endoderm and mesoderm, and organ formation proceeding in much the same order if we allow for the special adaptations in each case. The similarity is great enough to be considered significant evidence of phylogenetic relationship. We do not expect that an Arthropod in its development should pass through a specialized echinoderm and molluscan stage, for Echinoderms and Mollusks, as we know them, appear to represent *different lines of evolution* from that of the arthropod. However, we should expect to find something in common between all three in their early development and we find embryological facts which connect these three phyla as well as all the other metazoan phyla. The recapitulation theory, once so widely followed, claimed that ontogeny recapitulated phylogeny, *i.e.*, that an individual in its development revealed stages through which its species passed, or in other words its evolutionary history. In our study of embryology we criticized the too literal interpretation of such a principle. Haeckel insisted upon complete application of this so-called law, but consequent research proved its limitations. However, the facts of comparative embryology (Fig. 383) compel the retention of the general truth of recapitulation. A study of the foetal membranes and placentas of Mammals is greatly amplified by a knowledge of their formation, but they are not understood until we view them from the point of view of the yolk sac, allantois and amnion of Reptiles. Mammalian and avian gill slits become meaningless until we compare their embryology with the phylogeny of gills in Fishes and Amphibians. The comparative anatomy of the heart and its great vessels in Vertebrates is understood when we take into consideration at the same time the embryology of the same structures in representatives of


FIG. 383. — Similarity in early embryos of mammals, *i.e.*, reading from left — Pig; Cat; Monkey; Man. Gill slits are shown in earliest stage. From Haeckel. (Photo courtesy American Museum of Natural History.)

each class of Vertebrates (see page 386). We can understand the kidneys and urino-genital ducts of the Vertebrates series only when we know the embryology of these structures (page 389) in each case. All of these studies indicate a process of evolution.

The evolutionist holds that Cetacea were land Mammals which, during mammalian evolution, turned to the sea. As Mammals they should present indications of hair and hind limbs, which are lacking, and although some cetaceans have teeth, others have none. Yet, the embryos have hair and embryonic hind limbs and the adult toothless forms have embryonic teeth. Modern birds have no teeth and yet the embryos of some types have them and so did Archaeopteryx, the reptile-bird of the Jurassic Period. The lower Mammals have two distinct oviducts, as have the lower classes of Vertebrates. The primate embryo has two distinct oviducts, but there is a progressive fusion from behind forwards, forming the single vagina and uterus (Fig. 271). In adult ruminants such as oxen, sheep and goats, there is no collar bone (clavicle), but this forms in their embryos and is later absorbed. Embryology shows that many adult parasites, without appendages, muscles and other organs, are degenerate descendants of more complicated independent forms. Embryology allies the horseshoe crab with the arachnids and not with crustacea. Embryology links crab-like forms with lobster-like types. Embryology, by way of the trochophore larva, links several phyla of animals (see Fig. 173). Serpents now have no limbs, but embryology indicates that they were derived from an ancestor that possessed limbs, and the python has remnants of the hind limbs in its body. Rudimentary and now useless structures, found in many animals, are explained on the theory that these animals are descendants of ancestral forms which possessed the fully developed form of such structures. The study of comparative histology makes the case for evolution still stronger.

(*e*) **Physiological Evidence.** The fact that all animals and plants have to perform about the same general functions, in order to live, is evidence of their relationship as well as the fact of the fundamental similarity of all protoplasm and the chemical reactions that take place in it. If we narrow the problem down to the general physiology of *animals*, we find further similarities, as, for example, in the nature of necessary food and the known types of products of metabolism. Animals which are considered related on other grounds exhibit more similar physiological processes. Mammals other than man react to bacterial poisons in much the same way as man. This fact makes it worth while to conduct experiments on the lower animals, and the results prove of the greatest value in the treatment of human disease. In the reverse fashion information concerning human pathology is of use in the treatment of disease in animals. Antibodies, antagonistic to the diphtheria germ, are produced in the horse and are injected into the human blood system in an effective treatment of diphtheria in man. Against smallpox in man we use vaccines which have been produced in other mammals. The entire vaccine and serum treatment is based on the proven knowledge that the physiology of the Mammals is to a certain extent similar, and this indicates their relationship.

Of more precise moment are the evidences furnished by the so-called blood tests, *i.e.*, the application of the *precipitin reaction* of various bloods to the questions of phylogeny. The great work in this field was done by Nuttall of England and his collaborators, and results appeared in a book entitled " Blood Immunity and Blood Relationship " in 1904. This volume records results of thousands of experiments which constitute a physiological evidence for evolution.

Before presenting any results it is necessary to understand the methods used. A quantity of fresh human blood is taken and allowed to clot. A clear yellowish serum, freed from corpuscles and coagulating ferments and products, is obtained. Very small quantities of this serum (1 cc. to 2 cc.) are injected at intervals (two days, for example) into the veins (circulation) of a rabbit. The body organization of the rabbit reacts to the introduction of this foreign substance. An anti-body (antagonistic substance) is formed in the blood of the rabbit to counteract the toxic-like human serum. *The injection of a large quantity of human serum all at one time would have killed the rabbit.* The anti-human-serum-body formed in the rabbit is roughly comparable to the antitoxin produced in horse blood when diphtheria toxin is intravenously injected into the horse. This periodic treatment of the rabbit is continued for some days, then is discontinued. A waiting period of a few days follows. Blood is now obtained from the rabbit, and from this a clear *rabbit serum.* If a drop of human serum is *now* added to the above, a white precipitate develops which is an index of the neutralizing effect of the modified rabbit serum on the toxic human serum. The method can be used for other purposes. For example, if a few drops of a clear, saline extract of an old human bloodstain are added to such rabbit serum, a white precipitate is also formed. Although the bloodstain may be many weeks old, a positive result is obtained. If this immunized rabbit serum is tested with blood serum or bloodstain extract from other animals such as chicken, dog, cat or cow, no precipitate is formed.

This is a delicate and certain test for human blood and is, therefore, made use of in criminal cases in the investigation of suspected bloodstains. It is known as the *precipitin test.* The rabbit can be immunized, however, against the blood of any animal. If cat serum is repeatedly injected, the rabbit serum will give a precipitin reaction to cat blood. Nuttall and his co-workers employed this method to investigate blood relationship among animals. They not only immunized rabbits to blood of animals of as many different orders or families as they could secure, but they also secured bloodstains from a great variety of animals all over the world.

Finding that a hunting expedition was starting for Africa, these investigators provided it with material for obtaining and preserving specimens of blood from all the animals captured. If an animal was killed, the hunter soaked a small sheet of filter paper in the blood. The stained paper was pinned up to dry. It was then placed in an oiled-paper envelope and sent to Professor Nuttall. The experiments indicate close relationship between man and the apes, the precipitate with ape blood being more like human blood than monkey blood. All Carnivores have a similar blood. If anti-cat serum is used to develop immunity, then the immune serum shows that the various cats are more closely related to each other than to dogs or wolves. Anti-deer serum gave a good reaction with serum from antelopes, goats, sheep and oxen. Anti-lizard serum gave the best reaction with the blood of lizards but very good with that of snakes and better than with that of Chelonia or Crocodilia, thus supporting other evidence for considering snakes and lizards to be closely related. This test indicated the relation of the horseshoe crab to other Arachnids rather than to Crustacea. We have stated, in the first part of this section, that the blood of the different orders of Mammals is similar. Here it should be emphasized that in more particular respects, each order has specific differences. It is reactions of the present type that indicate the more particular differences. Large quantities of foreign blood injected at one time into an animal will cause death. We could not use sheep's blood in human blood transfusion. In fact we must use only human blood of the particular type as that of the patient and there are a number of types. Notwithstanding this, the fact remains, as stated in the words of the above investigators, " a *common property has persisted* in the bloods of certain groups of animals throughout the ages which have elapsed during their evolution from a common ancestor, and this in spite of differences of food and habits of life." The blood tests indicate a genetic relationship between different species of the same general kind.

(*f*) **Classification.** How foolish it would be to classify stamps as to color or books as to size or animals as to habitat. Such methods of classification mean chaos. Taxonomists have what they call a natural classification in which the data are largely morphological and in which the underlying principle is descent with modifications or organic evolution. This system of classification was "invented" by Linnaeus (Fig. 384) about the middle of the eighteenth century, and published in his "Systema Naturae," which presented an orderly classification of plants and animals. In this scheme of classification Linnaeus devised several kinds of groups, extending from the most general and inclusive to the more circumscribed and specialized. In current terminology, the European wolf belongs to the *species lupus*. But the several *species* of wolf-like animals constitute the *genus Canis*. Linnaeus adopted the scheme of *combining the name of the species with that of its genus to identify it.* The house dog is *Canis familiaris.* Wolves, foxes, hyenas, jackals, all belong to the *family Canidae,* all being wolf-like or dog-like forms. The Canidae, Felidae (cat family), Ursidae (bear family) and the aquatic seals and walruses constitute the *order Carnivora,* or flesh-eating animals. The Carnivora, Cetacea (whales), Rodentia (gnawing form, like rats), etc., form the *class Mammalia,* which are all fur-bearing.

FIG. 384. — Linnaeus, Taxonomist. Linnaeus originated binomial system of naming plants and animals.

The Mammalia, Aves (Birds), Reptilia, etc., have an endoskeleton with a jointed backbone and hence are members of the *sub-phylum Vertebrata* of the *phylum Chordata.* Chordata, Mollusca, Arthropoda, etc., constitute the *kingdom Animalia.*

Not all of the names or subdivisions now in use were devised by Linnaeus nor is the classification necessarily the same. Linnaeus, on the whole, thought that each species was a separate creation and stated as much. He denied the principle of organic evolution. But one who collects great numbers of individuals of any species soon recognizes the great variation among them. If the form has a wide geographical range, then those at the extreme limits may appear to be separate species and would probably be so considered if nothing were known of the intervening forms; but, one notes a gradual transition from one type to the other when the whole series is at hand. At the same time, the differences suggest that the ancestors of all may have migrated from one place of origin or introduction and that the variations present have been due to long residence in different places under different conditions.

The taxonomist finds that if he adopts the principle of organic evolution he has the most satisfactory method of classifying animals and plants. The modern classification is a map of the order of evolution and the genetic relations of organic forms — in short it is a code or formula of the history of organic life. At the same time it is a human device. What we call phyla, classes, orders and families are names of concepts. But such a classification may be pictured as a tree with two large trunks. How shall we describe them? One by the characteristics of all animals, the other by the characteristics of all plants. Both these trunks have a common short trunk near the ground. What is that? We define it in terms of the primitive hypothetical plant-animals, first formed from the inorganic represented by the earth from which this *tree of life* is growing.

Along the line of the animal trunk we see great branches. These are the *phyla*. We describe the chordate phylum by the characteristics of the Chordates. This grows out into two branches, sub-phyla, the Prevertebrates and the Vertebrates. The vertebrate branch subdivides into *order* branches and each of these successively into, possibly, *suborders, families, genera* and *species* and the last, possibly, into *varieties*. The taxonomist holds that all the species of any genus are descended from an ancestor which is described by the characteristics of that genus; that all the genera of a given family are descended from ancestors which had the characteristics of that family and so on, so that all the phyla of the same animal kingdom would have been descendants of an ancestor that had the general characteristics of all animals. Coelenterates are more ancient than the Annelids because they are more generalized and Annelids are more ancient than the Arthropods for a similar reason.

Modern methods of classification support the theory of evolution, because classifications based on this principle are most satisfactory. Sometimes the taxonomist is at a loss to decide upon genetic relationships and it is just these cases that give him trouble in classification and here it is that debate among taxonomists arises.

It is of interest to note that Linnaeus was the founder of this method of classification. He denied the principle of evolution but he *unconsciously applied it.*

(*g*) **Experimental Evolution.** Experiments in plant breeding which have resulted in a new variety may be considered a kind of experimental evolution. As an example of this we have already referred to Professor Biffen's production of a new variety of wheat. Experiments of this sort are constantly being made and as stated (page 485) at present better results are being obtained with plants than with animals. Breeding experiments that have led to the discovery of mutants may be considered as having an evolutionary significance, as, for example, De Vries' evening primrose mutations (page 544) and Morgan's Drosophila mutants (page 545).

In addition to the above we see everywhere evidences of another kind of experimental evolution that has been in progress since human civilization began. The plant and animal breeder has produced many kinds of plants and animals that do not occur in a wild state. Moreover, many of the domestic forms of today are not at all similar to their own ancestors of years ago. Furthermore they are descendants of still more dissimilar wild forms. In other words, we may call the production of domestic varieties a form of experimental evolution. The ancestor of all the many varieties of common fowl was the jungle fowl of India, *Gallus bankiva.* The various sorts of domestic pigeons have been produced from the wild blue rock-pigeon, *Columba livia* of Europe, Asia and China; domestic geese from the native *Anser anser* of England and most of the ducks from the wild mallard, Anas bocas. Domestic pigs of America and Europe have been " evolved " from the wild boar of Europe, *Sus scrofa.* The wild progenitor of our domestic cattle was the aurochs, which was probably hunted by the Goths and even by Julius Caesar's soldiers in ancient Britain. Our domestic horses probably had two wild forms as ancestors and our dogs have probably been derived from two or more wild forms. Gager calls our attention to the fact that over 1600 varieties of pears grown in the United States have been derived from two or three original wild ancestors. And that the 2000 or more varieties of apples have been produced from two ancestral wild forms. Cauliflower, Brussel's sprouts, red cabbage, green cabbage, Savoy cabbage, broccoli and kohlrabi are descendants from a headless cabbage found wild in southern and western Europe.

The objection may be raised that the examples named are not true species. But what is a species? After all it is an artificially created subdivision in taxonomy. Species are the distinctive subdivisions of a genus. Furthermore, members of a species can be interbred and the offspring should possess the characters of the parents. According to this definition, domestic breeds could be considered species. But another criterion of species is that a species is infertile with a different species. This is, in general, true, but not always. The horse bred to an ass produces a mule. Numerous other examples could be given. Let us suppose that an ancestral type has split into two new and more specialized forms. It seems reasonable to expect that if the diversity goes far enough, they would become infertile, for infertility is after all one expression of the specific physiological constitution which has evolved as well as morphological characters. So that, notwithstanding the above criticism, the production of the great variety of domestic plants and animals must be considered as an evolutionary process.

**Conclusion.** The above classes of facts constitute evidence in support of the *theory of organic evolution.* The word *belief* connotes an emotional state of mind in which *trust* and *faith* in an assertion plays an important part. A *hypothesis* is a *guess* or *surmise* that is assumed to explain a series of associated phenomena. A *theory* should consist of a principle or body of principles derived from all the facts available by standard methods of inductive reasoning. The biologist's conception of organic evolution is a *scientific theory.* No other scientific interpretation of all the facts involved has been advanced. The theory of evolution is one of the major conceptions of biology.

It is well to add a word here to the effect that a process of increasing specialization or evolution cannot *necessarily* continue indefinitely. The astronomer has evidence of the building up and breaking down of systems; the geologist describes the formation and disintegration of rocks; the palaeontologists tell us of the evolution and dying out of great groups of animals and plants; the embryologist describes fertilization, development, maturity and death of the individual; physiology describes anabolism and katabolism. We have no assurance that evolution of organsims will continue indefinitely; we do not *know* that living things will endure; we do not *know* that the planet will persist. Any discussion of evolution is incomplete if it neglects to consider disintegration which is also a natural phenomenon.

## PART III. CAUSES OF EVOLUTION

**Introduction.** As stated above, many lines of evidence indicate that the organic world has come to be what it is by a process of evolution. The idea has somehow spread in recent years that biologists no longer believe in evolution and that it is a discarded theory. This is not the case. The reason for this misunderstanding can be explained. Probably the greatest contribution to the establishment of this theory was made by Charles Darwin (Fig. 385). Darwin not only made the masterly presentation of facts which have led scientific men to accept this theory, but in addition, he presented a possible *explanation of the causes of evolution.* His particular explanation of the factors which cause evolution is known as *Darwinism.* It will be defined presently. It is Darwinism that has been attacked by scientists and not evolution.

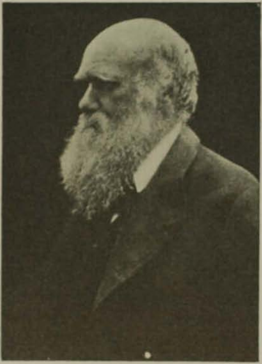

Fig. 385. — Charles Darwin.

It should be particularly noted, however, that the chief reason for everlasting fame for Darwin is that he so marshaled the facts in support of evolution that the theory was accepted by the scientific men of his day and is still accepted by scientific men. He is secondarily noted for Darwinism, his particular explanation of how evolution takes place. And not all scientific men regard this explanation as being as all-inclusive as Darwin maintained.

**Lamarck's Theory.** Although there are indications that the idea of organic evolution was present in the minds of ancient Greek scholars such as Aristotle, the first serious attempt to explain its causes was made by Lamarck in his "Philosophical Zoology," published in 1809. Linnaeus, in the middle of the preceding century, had for the first time invented a good method for classifying animals and plants. He had evolved the idea of species or specialized kinds of organisms. He held that they were invariable and constant, that at the creation of the earth, one pair of each kind was created, that all species today are direct descendants of these, that there are just as many species today as were created at the beginning, and that there are no new species.

Lamarck had studied and classified a host of plants and animals and was an accomplished taxonomist. He could not accept the view of Linnaeus as to the fixity of species, and he suggested in its place the theory of evolution. He maintained, what is often lost sight of, that species do not exist in nature, but that the organic world is a vast assemblage of individuals that differ more or less from each other, and that there are all sorts of gradations present. He held truly that species are mere arbitrary human conceptions set up for convenience of classification, that transformations in animals have taken place, and that some of these are so considerable as to cause scholars to designate them as different or new species. He was one of the first to suggest the picture of a tree to elucidate the relations of various kinds of forms. He believed that favorable conditions such as those of soil, food and temperature accompanying changes in the environment would produce changes in plants directly and in animals indirectly; that new physical needs brought about by changes in the environment would call forth bodily changes. Land birds — to illustrate — compelled to take up an aquatic life would develop structures enabling them to swim or wade. He believed that competition in nature brought about changes, that larger forms would try to destroy smaller, and this would produce changes in each, that in-breeding of a race tended to preserve the peculiarities of that race, but that cross-breeding would obliterate the peculiarities of each race involved, also that isolation tended to keep races distinct.

The two great laws of Lamarck are: (1) *The Law of Use and Disuse.* Frequent and sustained use of an organ strengthens, develops and enlarges it; constant disuse gradually weakens it, decreases its usefulness and finally causes it to disappear. (2) *The Law of Inheritance of Acquired Characters.* Everything that nature has caused individuals to acquire or lose by the long effect of external conditions, or by excessive use of an organ or its lack of use, it *preserves by heredity,* and passes on to new individuals which descend from it, provided that the changes are common to those which have given origin to new individuals.

Lamarck attempted to explain the origin of variations by use and disuse, though he gave little evidence for his conclusions. Modifications are produced by changes in the environment and there is also some evidence that these may produce offspring differing from the parent type. But in all these cases it can as well be said that the modified conditions modify the germ cells directly, and if this is true, then it is not a case of acquired characters. The differences in the offspring are not due to changes in the body or somatoplasm of the parent. Most biologists today do not consider that characters acquired during the lifetime of parents are transmitted to their offspring (see page 333). Bouvier, a botanist, took the shoots of a certain plant and set them out at a high altitude. They grew up remarkably different from the plant from which they had been taken. When such plants or their seeds are grown at lower altitudes, they resume the original form. Tower exposed Colorado potato beetles of both sexes to varying conditions of heat and moisture during the time when the egg cells were maturing. The offspring showed distinct modifications and these were hereditary as long as he continued to investigate the matter, which biologically speaking was but a moment of earth history. Furthermore, Tower explained the results as being due to the action of the external conditions directly on the germ cells. As stated before, there is a great body of evidence showing that organisms can be changed by external modifications. There is no evidence that the resulting somatic changes are transmitted to the offspring.

**Darwin's Theory of Natural Selection.** This was the theory of evolution developed by Charles Darwin in his "Origin of Species" in 1859. "I am fully convinced," he wrote, "that species are not immutable; but that those belonging to what are called the same genera are lineal descendants of some other and generally extinct species." "Furthermore I am convinced that natural selection has been the most important, but not the exclusive means of modification."

To gain an idea of what is meant by evolution by *natural selection,* let us analyze it as follows: (1) *Variation:* The general occurrence of variation is well known. It has already been discussed in the chapter dealing with genetics. (2) *There is a natural tendency toward the over-production of plants and animals.* At times the great wealth of living forms is brought to our notice. Sometimes when the usual unfavorable conditions are not present, species increase in a riotous fashion, as has been shown by the introduction of the English sparrow and the gypsy moth into America and the rabbit into Australia. Darwin pointed out that elephants begin to breed at thirty years of age and a pair may have six offspring in a century. If all the descendants lived and reproduced this original pair would, in 750 years, have nineteen million descendants. For five years Woodruff ran an experiment on continuous reproduction by fission in a certain species of Paramoecium. It can be understood why he did not keep all the offspring, as he computed that the total mass of protoplasm produced would have been 10,000 times the volume of the earth.

Over-production leads to (3) a *struggle for existence.* This may be between individuals of the same kind, — thus newly-hatched lobsters are great cannibals. Young trees growing close together in the forest are rivals. Bachelor fur seals battle for supremacy, the nations of mankind wage war. There is also a struggle between members of different species. Illustrations are the destruction of animals by man, destruction of men by animals. In India, in 1910, 22,478 persons were killed by poisonous snakes, and over 91,000 snakes were killed by human beings. Tigers in India killed 1033 persons and 1068 tigers were killed by men in 1927. (From the *World Almanac* 1929.) The destruction of insects and worms by birds, the destruction of caterpillars by wasps, the destruction of plants and animals by insects, the destruction of animals by bacteria, are other familiar illustrations.

Animals and plants are also, at times, in fierce encounter with the environment. Death is often the result. The destruction of Pompeii and the earthquake and fire in San Francisco are recalled. Drouth not only kills plants but also animals which die from thirst. Unexpected cold has its victims. These are extreme cases, but a greater amount of less conspicuous competition goes on unseen. As a result of this struggle, out of all that begin life, only (4) *the fittest survive.* Those variations which are best adapted survive, those not adapted perish. These three processes: (*a*) tendency toward over-production, (*b*) struggle for existence, and (*c*) survival of the fittest, — constitute what is known as *Natural*

*Selection.* Natural selection is necessarily related to adaptations, and those that are best adapted crowd out the unadapted.

(5) Finally only those animals possessing variations with survival value, *i.e.*, the fittest, remain and reproduce such variations. Therefore by *heredity* those advantages secured by natural selection are maintained. A constant succession of selections and further adaptations, generation after generation, results in the origin of new species. Variations of no survival value would not be selected. Natural selection does not originate variations, it merely preserves those that are of benefit under the peculiar conditions of life. It is in no sense a conscious process, but merely mechanical, as automatic as gravity and chemical affinity. Changes in the conditions of life tend to increase variability. Natural selection operates on internal as well as external organs. It is active at every stage in development from birth to death. Some characters are of apparent survival value, as, for example, the teeth of a carnivore. Other characters may be of important survival value although there may be no evident index of it at the time. Those chosen by natural selection have no insurance against accidental destruction.

Darwin was aided in the development of the natural selection theory by a study of *artificial selection* (see below), the process by which various kinds of domestic animals and plants have been produced (Fig. 386). In a sense it may be considered a sort of experimental test of just what selection can bring about. Domestic selection extends far back into human antiquity. Man produces races which are useful to him in one respect or another. Some of these characters would be detrimental in a state of nature. When artificial breeds become feral, they soon revert to a simpler state.[1] In some cases, as in plants, man is able to continue the kind only by successive grafting. The navel orange is an example of this. In the case of many special animal breeds, close in-breeding of pure stock must be practiced to maintain the breed.

**Artificial Selection.** Artificial selection resembles natural selection. The breeder begins with variations, there is a selection by him of these, and he breeds those selected. Sometimes the selection is general, that is, the breeder simply eliminates the unfit. The result is a general improvement, but does not lead to production of any particular kinds. The breeder may work to secure an all-round, good animal, of large size, tame, fat and

[1] Even natural forms may not persist. See Chapter XXV.

FIG. 386. — Varieties of Domestic Fowls. In the center is the Jungle Fowl of India, the ancestral form. Photograph of exhibit in American Museum of Natural History. (Courtesy Amer. Mus. Nat. Hist.)

fertile. New features may come to his notice and he selects, for mating, pairs that possess this new feature. He may specialize on one character alone, as greater milk production, more meat, more wool or no horns. He also hybridizes, or crosses, two related forms, as was the case of the domestic dog, which is supposed to have been the result of the crossing of the wolf and the jackal. The progeny will tend to vary. And this gives opportunity for further selection. The work of Luther Burbank in this field is unsurpassed. In cross-breeding, wider crosses can be made with plants than with animals. In animals, crosses of varieties are more successful though the offspring may be sterile. Progeny of the male ass with the female horse are mules which are usually sterile. The small hoofs, scanty mane, tail and voice appear to be paternal in origin. The greater size, strength and form come from the mother. The mule is said to be more intelligent than the ass or horse. Cross a male horse with a female ass and the result is a hinny, smaller than a mule but more horse-like. The cross of the male California walnut with a female wild black walnut is a rapid-growing tree with no nuts. Reverse the cross and the result is a tree with larger and better nuts. Speedy race horses have been produced by artificial selection. A speedy horse must have light, slender legs. But there must go with this a certain size and muscular bulk. All increases in speed increase the strains to which the slender legs are subjected, in order to support a great weight in motion.

**Heredity in Pure Lines.** Professor Johannsen, a Danish botanist, was interested in seeing how far Galton's law of filial regression would work. He thought it might serve as an instrument of continued racial betterment. He planned to select consciously the most exceptional offspring for parents in each generation with the hope of producing a permanent, non-regressive, exceptional stock. He worked with the self-fertilizing bean, *Phaseolus*. He chose nineteen beans of differing size and planted them. He thought that the progeny of the largest would be all large and those of the small bean, small, and so on for all nineteen. As a matter of fact, he found different sizes among the progeny of each. He finally discovered in this variety of bean a number of *pure lines* or races and each pure line had a mode of its own and its own variation about the mode. If he planted a seed from any pure line, the variation in size of its progeny was the variation of that pure line. If one selected beans of the largest pure line in the hope of securing still larger beans, his hope would be in vain (Fig. 387). However, one could secure *large* beans, if only the largest pure line were kept pure. The indication is that selection within a pure line has no effect in modifying the size of beans. The germ cells of plants of any one pure line have the same genes and selection alone cannot modify these. Johannsen, in separating beans into different size groups in the beginning, was dealing with somatic characters. Phenotypes are merely those that have similar somatic characters. Genotypes are those with the same germinal composition. One might select seed of the same size that would be somatically or phenotypically similar, but might be genotypically different and this would be revealed in the variations in the progeny.

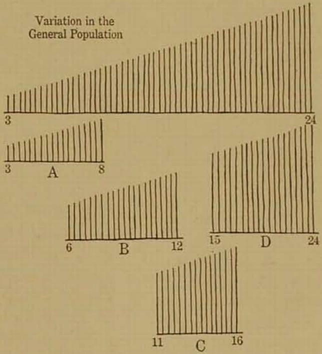


Fig. 387. — Illustrating Heredity in Pure Lines. The main figure above represents variation in the general population. Each vertical line typifies the measure of a certain class and the range is from 3 to 24. Promiscuous interbreeding will show similar results. Selective breeding demonstrates that the whole population consists of several pure lines represented by A; B; C; D. In breeding, any members of Pure Line A will give same range of variation as A, *i.e.*, 3 to 8, etc. The members of any one pure line are similar genotypes. Overlapping members of A and B, for example, are phenotypes. Variation in each pure line is due to the environment, *i.e.*, the individuals do not grow up under same conditions. The mean of each pure line or of the general population is not shown.

Jennings found similar results after he had ascertained pure lines in Paramoecium. Tower, after twelve generations of selection in potato beetles, attempted to establish a dark variety, but without success.

Without giving any further criticisms of the theory of natural selection at this time, it is evident that the study of pure lines shows how inadequately natural selection serves as a complete explanation of the origin of new species.

**Theory of Isolation.** One of the difficult things to understand concerning natural selection is why new advantages secured by natural selection are not lost in breeding with individuals of an older, simpler sort. It has been argued by a number of workers that *isolation* prevents this. Isolation is a sort of selection which possibly segregates pure lines and permits inbreeding only among them. Gulick and Crampton have shown that valleys, running back from the shore in certain South Sea Islands, are populated by their own special types of snails, which are *fundamentally related.* Isolation preserves types once they are formed. Soil peculiarities, heat, moisture are also examples of possible agents of isolation.

The Marsupials of Australia and the wingless birds of New Zealand illustrate the part played by isolation in evolution (see page 507).

**Theory of Orthogenesis.** Some biologists do not believe that variations are fortuitous. These investigators believe that variations occur in determined directions, leading to evolution along particular lines. This is due, they say, to the internal organization of that kind of animal or plant, which begins and continues to evolve toward a fixed end. During the process, the external forces are secondary. It is the internal organization that is primary. External influences, climate and food, however, may determine to some extent this internal organization. If this line of evolution produces something of advantage or disadvantage to the species, then natural selection steps in.

One of the reasons advanced against the acceptance of the theory of natural selection is that the small first stages in the development of vitally important adaptive structures would have no selective value. The orthogeneticist claims that structures *appear* that may be adaptive from the beginning. Osborn is convinced that mammalian teeth indicate this. In many orders of Mammals, the teeth develop with a few similar cusps. These cusps arise independently, gradually, along definite lines, until they are adapted for their work. He believes that selection had little to do with this, but that it was due to a predetermined, underlying, germinal constitution. The material obtained for the study of the history of the horse indicates evolution in a straight line, that is, a case of orthogenesis. Conversely, there are examples of evolution in a straight line continuing to a point where the structures are overdeveloped and are a positive menace to the animal in the struggle for existence. Illustrations are those of the great tusks of the wild boar; the antlers of the so-called "Irish Elk," which, at the time of its extinction, bore antlers thought to have been heavier than the rest of the body; the enormous bulk of some of the reptiles of the Mesozoic Era; the great horns and skull frills of the rhinoceros-like Dinosaurs; and the terrible canine teeth of the saber-toothed tiger, Smilodon. Such over-developments might have been "fitted" for the conditions then prevailing. When conditions of life changed, such highly specialized structures caused the extinction of these creatures. Natural selection may thus be the deciding factor in determining the permanency of orthogenetic variations.

FIG. 388. — Hugo de Vries.

**Theory of Mutation.** Darwin did not emphasize the origin of variations, nor did Lamarck explain their origin at all satisfactorily. The mutationists, founded by Hugo de Vries of Holland (Fig. 388), believe that new species arise suddenly and that offspring appear with well-differentiated variations, not possessed by the parents or the parental line. The mutationist does not believe that natural selection really starts species. Natural selection controls the persistence of this and that mutation. The variations emphasized by Darwin were small and fluctuating. He believed in a gradual quantitative increase in these, generation after generation, by natural selection. But the mutationist claims that such variations are of no evolutionary significance, they get nowhere, they are like the endless rise and fall of the tide. Darwin described sudden distinct, discontinuous variations, but assigned no importance to them. He even described what is now thought to have been a mutation.

In 1791, in Massachusetts there appeared in a flock of a certain breed of sheep, a short-legged ram which was of a distinctively different type. This ram bred to females of the breed, from which he so suddenly appeared, produced offspring that were like him. Thus a new breed, the Ancon breed of sheep, was begun. Due to the short legs, these sheep could not jump fences. The breed was discontinued when the Merino with a better grade of wool was introduced. Bateson in England, in 1894, in "Materials for the Study of Variation," called attention to 886 cases of discontinuous variations. Discontinuous variations were called "sports" by Darwin, such distinctly different characters as a four-horned sheep or an eight-fingered man or a one-toe pig. But all discontinuous variations are not alone differences in numbers of parts. They may be differences along any line, as color, form and size.

The classic case of mutations is that described by Hugo de Vries of Amsterdam, in his book "Species and Varieties," published in 1904. This book gives an account of years of hard work. The rediscovery of Mendel's principles by De Vries, about 1900, during the period of his investigations, influenced him in his conclusion that evolution did not take place by the gradual accumulation of slight, fluctuating variations by natural selection, as Darwin had maintained, but by the sudden appearance of a *full-fledged elementary species.* His studies were made on a primrose of the generic name Oenothera. A certain species, *Oenothera lamarckiana,* was indigenous to America. It was taken to London about 1860 as a garden plant and was introduced in other places in Europe. It spread outside of gardens and De Vries found it growing wild in a potato patch a few miles from Amsterdam in 1886. He observed that it presented considerable variability. *Oenothera lamarckiana* is a large, bushy plant over four feet high with large, bright yellow flowers which open toward evening, hence the name evening primrose. Among them he observed different and distinct types. Wishing to study the matter he experimented further with them in the Botanical Gardens at Amsterdam. He transplanted some of the wild plants or gathered the seed for planting in his garden, and sowed the seeds which developed on the transplanted plants. In seven years he had grown and studied 54,343 plants; 837 of these belonged to new types, or *mutants.* He writes, "These various methods have led to the discovery of over a dozen new types never previously observed or described."

Among the wild Oenotheras he found two different types which he called *O. brevistylis,* because the style of the pistil was short, and *O. laevifolia,* because it had smooth leaves. He regarded these as *mutants.* In his gardens in those years of cultivation, he claims to have found seven other new elementary species all originating from self-fertilized seeds of *O. lamarckiana.* A systematist would regard them as distinct species. It has been suggested that possibly the results of natural hybridization of two or more wild species produced so-called new species which are merely different types of hybrids. Davis has crossed two wild American species and has produced a hybrid resembling *O. lamarckiana,* and this produces forms resembling the mutants of De Vries.

De Vries' work has been repeated and his conclusions confirmed. In 1899, a hornless Hereford appeared in Kansas. From this animal has arisen the hornless breed of Hereford cattle. Tailless cats, dogs and poultry are probably mutants, so also are hairless dogs, horses, cattle and mice.

T. H. Morgan and his co-workers, in their most careful investigation with the rapid-breeding fruit fly, Drosophila, have found hundreds of suddenly appearing new characters which they call *mutations.* Most of the mutants have a " lethal " characteristic and the animals showing these particular mutations die. Most of the experimentally produced mutations in fruit flies differ from each other in only one or two features, while ordinary wild species differ in many individual characters. And yet this is no real criticism, for if one new character could arise as a mutation, there is no reason why many should not do so. Morgan has pointed out features wherein the mutation theory escapes the criticism of the Darwinian theory of natural selection.

As mutants appear fully formed, there are no initial stages to account for. Useless structures appearing as mutations may persist if they are not detrimental to the continuance of the species. Also mutants may be better fitted to live in a new environment than the parental forms. This might lead to isolation which would prevent hybridization (and hence loss of the newly gained advantage) with the parental form. The mutant may differ "from the parent form in only a slight degree for each point, although all the points may be different" (De Vries). Moreover the characteristics acquired by mutation are inherited. This is the most important point necessary to explain evolution.

A certain amount of experimental work has thrown light on the origin of mutations. After obtaining a pure race of potato beetles (*Leptinotarsa decemlineata*), Tower subjected them to different conditions of temperature and humidity. The few offspring showed decidedly different characters and they bred true to these new characters, and Tower claimed them to be mutants. Gager exposed ovules of plants to radium rays which apparently changed the germ cells, for the plants were stunted and abnormal. Some of these continued for several generations. MacDougal injected cane sugar and zinc salts into the ovules of different plants and forms varying distinctly from the parental type developed. These also bred true for the few years that he continued the experiments. An attempt has been made to correlate the origin of mutations with the number and size of chromosomes. The typical number of chromosomes in *O. lamarckiana* is 14, but Gates has found 15, 20, 21, 22, 23, 27, 28, 29, 30, in some. In the fruit fly, Drosophila, Metz has found variations in the number of chromosomes even to a doubling of the number, but the quantity of chromatin remains the same.

**Summary.** Discovery of *pure lines* indicates that the best that selection can do is to isolate pure lines. Selection cannot change genes. Genes or determiners of heredity (*i.e.*, chromatin) have been shown to be possessed of great stability. Morgan cites evidence indicating that factors or genes are not variable. It is true that the production of the extremely valuable domestic plants and animals has involved selection. But it is now believed that other factors have been involved, which were unknown to the producers of these useful breeds. In many cases, the breeder has unconsciously been selecting a " pure line," a " genotype." Or again mutations have probably been chosen. Ears of corn are now grown which are larger and better than any that appear in a state of nature. Often mutations, that can be artificially preserved, would disappear in a state of nature. Luther Burbank made many new combinations by hybridization. He destroyed all progeny but the one that suited, even though the others ran into the thousands, and, as a rule, continued the new form by such methods as grafting. According to Morgan it is possible to form apparently new characters by combinations in hybridization. These can be preserved by following out the procedure indicated by Mendelian heredity as at present understood. If indifferent mutations arise, their future continuance is a matter of chance. If injurious mutations arise, they will disappear by natural selection. If beneficial mutations arise, they will tend to be preserved by natural selection. There is no evidence that natural selection determines the formation of favorable variations.

Professor Morgan says that "Evolution has taken place by the incorporation into the race of those mutations that are beneficial to the life and reproduction of the organism." Genetics is the science of origins. While it works specifically with individuals, at the same time its results throw light on the origin of species. Living things exhibit two great tendencies: first, to produce offspring like their parents in some respects but at the same time different in other respects. It is the preservation, accumulation and continued modification of the unlikenesses in racial lines which make for organic evolution. New combinations of genes as afforded by sexual reproduction would play a part in this. Any qualitative change in a chromosome would be a factor. Qualitative changes have been produced, as, for example, recent experiments in radiation. Müller appears to have produced mutations in Drosophila by means of extreme temperatures and X-rays. Cases have been found in which changes appear to have occurred and these are at present not understood. We have called attention to changes in chromosome numbers possessed by forms unlike their parents. Sometimes there is a multiplication of one of the chromosomes. We have already called attention to the effect of changes in the environment. Sexual reproduction, involving new combinations when paternal and maternal chromosomes fuse, will produce offspring different from either. This is the amphimixis of biparental marriage. We have already noted (page 336) how great a variety of combinations are possible in sexual reproduction.

Is it possible that mutations or the appearance of distinctly new variations have arisen by amphimixis? If this were the case, it would imply that the lowest protozoa and protophyta contained chromatin which was ancestral to all the present chromosomes of all organic forms and possessed all the factors out of which, by a process of sorting out, the present world of plants and animals has been evolved.

Bateson suggested such a fanciful proposition. Somehow one cannot sidetrack the ever-intrusive thought that the constant effect of new environmental conditions has had a great deal to do with evolution; but not in the direct way suggested by Lamarck. In a sense, water at one time was a mutation, so was carbon dioxide and urea and ammonia and other compounds. These combinations are so relatively simple that the physical scientist can experimentally reproduce the mutation. When more is known about the physics and chemistry of somatoplasm and germ plasm, so that we can produce mutations experimentally, then something will be really known about the origin of natural mutations or variations and the causes of organic evolution. This may not be so far distant. Morgan says: "The causes of mutations, that give rise to new characters, we do not know, although we have no reason for supposing that they are due to other than natural causes." Bateson, however, in speaking of the larger question of the causes of evolution pessimistically said: "The many converging lines of evidence point so clearly to the central fact of the origin of forms of life by an evolutionary process that we are compelled to accept this deduction, but as to almost all the essential features, whether of cause or mode, by which specific diversity has become what we perceive it to be, we have to confess an ignorance nearly total."

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