THE

PEDIGREE OF MAN:

And Other Essays.

BY

ERNST HAECKEL.

Translated with the Author's permission, from the German,

BY

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WITH 80 WOODCUTS.

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TO HIS FRIENDS

HERMANN ALLMERS,

Loyal Fellow-Traveller in Sicily and Naples,

AND TO

ERNST KRAUSE

(CARUS STERNE),

Faithful Comrade in the Fight for Truth,

THESE PAGES ARE CORDIALLY

DEDICATED

BY THE AUTHOR.

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PREFACE.

THE central idea that all the lectures in the following volume have in common is the monistic principle of the unity of development, of mechanical causality throughout Nature. It is that same principle, the most important in modern science, on which rests the law of the Conservation of Energy, the principle that Kant has already pointed out as indispensable to every true explanation of things, the principle to which Goethe has so often given admirable expression, that Lamarck, in 1809, laid down as the foundation of his Transformism, and that Darwin, in 1859, utilised in general Biology by his theory of Natural Selection. How this monistic principle is applied in different branches of knowledge, these lectures are intended to show. They are arranged so as to be easily understood by the cultured who are not especially students of science. As they have been delivered at different times, without any connexion one with another, and have been given under different circumstances, without regard one to the other, repetitions have been inevitable.

Although to remove these repetitions would have been of value to the collection of lectures as a whole, this would have been impossible without completely reconstructing the individual lectures. Further, much of the interest that has given rise to the wish among my friends for the publication of this collection lies actually in the exact form and method of treatment that the study of development, itself developing, has received at different times in my earlier discourses. I have therefore considered it best to publish the lectures unaltered in their original form. In certain places I have struck out palpable errors and added some new annotations. Further, I have naturally chosen for publication the latest, most improved edition of those lectures that have passed through several editions. He who wishes to instruct himself more fully upon the questions treated here, will find further information in Darwin's Works, in "Cosmos" (a publication dealing with the study of the universe in the light of evolution), in Carus Sterne's "Growth and Decay" (a popular history of development in Nature, Berlin, 1876, Eggers), as well as in my own larger popular works, "The Natural History of Creation," 6th edition, and "Anthropogeny," 3rd edition.

The first of the five lectures in this first part is on the Evolution theory of Darwin. It was delivered on the 19th of September, 1863, at the first open sitting of the Thirty-Eighth Congress of German Scientists and Physicians at Stettin, and until the present time has only been printed in the official report of the Congress. As the proof of this report was not sent to me, I was unfortunately not in a position to correct the many gross printer's errors therein. I was very desirous of an opportunity to publish this lecture, the more so as in it the Evolution theory of the present day was brought for the first time, *vivâ voce*, before an assembly of German scientific men. It was an experiment by no means easy or devoid of danger, an experiment also not without its results, as I have pointed out in the preface to the fourth edition of my "Natural History of Creation."

The three following lectures (II., III., IV.) first appeared in the "Series of Popular Scientific Lectures" issued by Virchow and Holtzendorff (Parts 52 and 53 of the Third Series, Part 78 of the Fourth). The two lectures "On the Origin of the Human Race" (II.), and "On the Pedigree of the Human Race" (III.), appeared in the first edition of 1868, in the third of 1873. But they had been already delivered in identical form with that they have at present in October and November, 1865, to a small private circle at Jena, at the request of my lost friend August Schleicher. This renowned philologist, whom premature death reft from science and his friends in 1868, took the keenest interest in the monistic theory of Evolution, and devoted himself with the greatest success to the department of comparative philology. In consequence of our many conversations thereon, and moved by the many attacks that my first lecture in Stettin had brought upon me, he sent me a letter on the Darwinistic theory and the science of language (Weimar, 1863). In that letter the reader of this volume will find an able investigation of Evolution from the linguistic side. Further, Schleicher especially urged me to follow up the anthropological side of the descent-theory. Hence, in 1865, the two lectures on the origin and the pedigree of the human race. These are to be considered as forerunners of my "Anthropogeny."

The fourth lecture "On the Division of Labor in the

Life of Nature and of Man," was given December 17th, 1868, before a mixed audience in the hall of the Berlin Artisans' Union, and appeared in 1869 as the Seventy-Eighth Part of the Virchow and Holtzendorff Series. A second or third edition appeared in 1873 (the title-page does not give the edition). The wood-cuts belonging to this have been improved and increased in number in the present issue.

The fifth lecture on "Cell-Souls and Soul-Cells," was delivered March 22nd, 1878, in the Concordia Gathering at Vienna, and in July of that year appeared in the *German Review* (Part 10 of the Fourth Annual Series), but without the wood-cuts that illustrate this lecture in the work now under consideration. Separated by an interval of ten years from the four preceding lectures, it stands in close internal relationship to these, and repeats, indeed, some of their details and figures. On the one hand, the pregnant principle of the division of labor finds in the souls of the higher animals, and especially of man, its fullest application, clearing up the dark mysteries of spirit. On the other hand, the soul-cells have really been produced by division of labor from cells gifted with a common cell-soul. They explain, therefore, admirably the physiological process of division of labor. Of purpose, therefore, is reference specially made in both lectures to the Siphonophora, that interesting and instructive class of sea-animals. The extraordinary significance of the Siphonophora in the study of soul-life is less clearly recognised, but is not of less moment, than their great use in the thorough understanding of the principle of division of labor.

May these popular lectures, thus gathered together, aid in advancing the knowledge of our Evolution theory of to-day among those who, though not themselves scientific students, are yet firmly convinced as to the necessity of a clear, unifying conception of the universe.

ERNST HAECKEL.

Jena, October 12th, 1878.

I.—THE DARWINIAN THEORY.

THE DARWINIAN THEORY.

ALTHOUGH in the lecture I am about to give I shall try to discuss with you the principles of Darwin's celebrated theory of Evolution, I do not make the attempt without great anxiety, nor without asking your forbearance for what may be lacking in its presentation to you. For to an audience like the present, composed of laymen and men of science, all popular treatment of a theory that is scientific and far-reaching must present much of doubt and difficulty: it can never do more than satisfy a part of the listeners. Of modern studies, that one must be in a very special position, which threatens to shake to its very foundations a vast structure of human thought, that has boasted and yet boasts of almost universal acceptance through many centuries, and also touches the personal, scientific and social views of every individual at the heart's core. That the question is of an idea that modifies the whole conception of the universe those of you not yet acquainted with the tenor of the Darwinian account of that universe will see at once, if you listen to the principles thereof, as embodied in the following words: "All the different animals and plants living to-day, and all the organisms that have ever lived on the earth, have not been created separately, each after its kind, as we have been wont to believe from our youth, but have gradually developed in all their manifold forms and varieties in the course of many millions of years from a few, perhaps from one single primordial form of the very simplest nature."

Therefore, as far as we, as human beings, are individually concerned, we have, as we are the most highly organised Vertebrates, to seek for our ancient ancestors in ape-like mammals, beyond these in kangaroo-like marsupials, still further back in the so-called secondary period among the sauroid Reptilia, and finally, at a still earlier time in the primary ages, amongst the lowly organised Pisces.

In the limited space of time of one short hour it is clearly impossible to lay before you from the storehouse of science even the most weighty and striking arguments for and against this able hypothesis. To estimate these rightly, and to be able to apply them, one essential is a close study, extending over many years, of the structure and functions of organisms, their affinities and histories. If, despite these and many other difficulties, I try to draw you into the strife that has arisen as result of Darwin's theory of Evolution, it is because of the vast dimensions that this strife has already assumed. Already the whole vast army of zoologists and botanists, of palæontologists and geologists, of physiologists and philosophers is divided into two widely separated parties. On the standard of the progressive Darwinists are the words "Evolution and Progress." From the camp of the conservative foes of Darwin sounds the cry : "Creation and Species." Every day the gulf widens, the two orders of thought become more asunder. Every day new weapons of offence and of defence are brought forth on all sides. Every day wider circles are embraced by this powerful movement ; far-off things are drawn into its eddy, and whether he will or not, the man who would fain hold aloof from both parties must give in his allegiance to the one or to the other. Already the Darwinian theory, at first scoffed at as a wild speculation, numbers among its adherents the majority of the most famous men of science. For example, I make mention of but three of its most prominent advocates in England, Huxley the zoologist, Hooker the botanist, Lyell the geologist. The last-named is the more notable an advocate, as he was in earlier times an opponent of Darwin. Under these circumstances it seems to me that it should be the aim of every scientific man not to approve of that which will stifle and choke the whole inquiry, that which is the design of the esoteric priestly system, viz., that these family quarrels should not be produced before the general public, but should be fought out on the special ground, and in the serene solitude of scientific publications. If a movement of this kind has already taken so wide a range, if the fight for truth has already reached such a pitch, it seems much more agreeable to the interests of both sides to lay the matter in dispute openly and clearly before the eyes of all men, and to give to those afar off, who may nevertheless hear of the contest in this direction or in that, a clear idea of the position of the contending parties and of the condition of the strife.

If we compare closely our new theory of Evolution with the histories of creation given in earlier times, we find the fundamental principle of Darwin by no means a new one. It has been formulated already by many philosophers, not only in our own century, but in much earlier times, in one form or another. The proofs and arguments that Darwin has discovered in favor of his views are new. The vigorous carrying out of the hypothesis in the light of the science of to-day—that also is new. If we study all the earlier theories of creation, we can arrange them all into two distinct series—(1) Cosmogonies that hold, with the Mosaic account of creation, that all kinds of living beings have been called into existence independently, separately, at the will of an almighty creator ; (2) Cosmogonies that regard all living things as branches of a single stem, products of one eternal law of Nature, the law of progressive Evolution. With these two fundamental ideas a whole series of antagonistic theories are bound up inseparably, and in most characteristic fashion. Each of the two orders of thought has utilised the extraordinary acquisitions made by science during the last century in entirely different manners. Each has used them for the building up of its own special system. Out of these many acquisitions my purpose will be to glance at those dealt with by geology, the study of the construction and of the origin of the globe.

According to the generally accepted idea, that globe was in very early times a fiery, liquid ball, whose surface, cooling down, hardened into the crust of the earth. When the temperature had sunk to a certain level the hot vapors condensed in the form of water. Then came the first possibility of the existence of living beings on the cooled, hardened crust of the globe. The beings that in those early, far-off ages peopled this earth through many, many millions of years took origin from organised matter of a much lower kind than that of which the majority now in existence consist. Of many important divisions in the vegetable and in the animal kingdom for a long period no representatives appeared: of other divisions only the simplest and most imperfect forms existed. In the course of the measureless ages that have passed since that time series on series of beings have evolved, approaching gradually, step by step, in ever-growing perfection and complexity, the fauna and flora of the world of to-day. Stratified rocks deposited in the water investing the originally naked crust of the cooled globe, teach us that the surface of that globe had to pass through many a change in the course of these long ages, and underwent many a rise and fall. As result of volcanic and meteorologic influences the earth-crust split now here, now there, and ere long one or another region sank beneath the water, and anon rose again from the waves. Dust and stones, the fragments of rock, worn, broken, pulverised by wind and water, aggregated into the form of mud and sand at the bottom of the waters, enclosing within themselves the remains of dead organisms.

These valuable fossil remains, as petrified animals and plants, or the imprints of these, afford disclosures of the vastest importance as to the history of the earth, the succession of organisms, and the nature of the living beings that have dwelt upon its surface. The succession of organisms wherein living beings appear one after another, and the demarcation of the many strata placed one upon the other, in which the former are preserved, have been explained in very different ways. Following Cuvier and other naturalists of the foremost rank, men held generally, towards the end of the last century and until the fortieth year of the present one, that a succession of entirely distinct earth-periods had followed one another, each with its own special population of living things. The surface of the globe had from time to time been changed by vast cataclysms of unknown origin, in such fashion that on each occasion the world of living things had perished wholly, or to a great extent. After each revolution of this kind every group of animals and plants that came into view must therefore owe its origin to a special act of creation. With this idea, that the animal and plant world of a given creation-period has been created independently, and without any connexion with those that preceded it, is closely connected a second, very influential opinion, introduced by Linnæus, and specially followed up by Cuvier. It is that all organic individuals that we encounter in Nature can be arranged in groups that bear the title of species. What is a kind or a species? No scientific man has hitherto been able to give a well-grounded and satisfactory definition of the word. According to the opinion of the majority all those individuals, as, *e.g.*, all horses, all apple trees, belong to one kind or species, which either originate from a single pair of ancestors, or (as this generally does not admit of proof) agree in all essential particulars, and only differ in points of secondary importance. Every species, indeed, within defined limits may appear variable, and may vary. Thus, in the species Horse many different races, in the species Apple tree a series of varieties of apple can be distinguished. But all these races and varieties of one species ought never to be separated from one another by essential marks as are all the closely related species of one genus—*e.g.*, horse and ass, or apple and pear tree. On the other hand, if we consider certain resemblances, some close, some more remote, and if we study the marks of agreement among living beings, we are able to group together several species into one genus, many genera into a family, and allied families into a class. But these divisions are generally regarded as arbitrary, whilst much strife reigns as to their limits and extent, and as to whether the idea of a species is a precise one and really founded on Nature. "There are as many species," says Linnæus, "as the spirit of god in the beginning created living beings." Or as Agassiz expresses it: "Every species is an embodied thought of creation." On this conception, on the dogma of the constancy of species, is laid the foundation of the theological cosmogonies. Every species is regarded as an independent unity, unconnected with all other species, and endowed by a creator with qualities and instincts adapted for its particular mode of life.

The followers of the philosophical Evolution theory take a very different view. According to them, the different periods that the older thinkers regarded as sharply-defined sections of the earth's history are not separated one from the other by definite limits. They glide one into the other, after the manner of the periods that we recognise in human history. Even as now, each age bears its individual character. Two successive sections of time are never separated by a violent cataclysm, destructive of the existing living world and necessitating a new creation at the beginning of a new period. Further, a direct connexion is always evident amongst organic things. A larger or smaller proportion of the living beings passes over unchanged from every older period to the next youngest, although their strata seem so sharply defined. But even the new animals and plants that seem to appear on a sudden in the later strata are so closely allied to certain others in the preceding stratum, are in certain respects so like these that the conclusion is well founded, that they have originated directly or indirectly from their predecessors, and only represent the sub-species or varieties of those earlier species modified and adapted to changed conditions of life. This idea attains its full development in the conception that is its necessary result, that all the organisms of any given earth-period have arisen from the organisms of preceding periods, all the living things of the world of to-day from those of the world of yesterday: that the organic life now existing is connected indissolubly by real, genealogical blood-ties with all animals and plants ever existent on this earth in earlier ages. The fact that the history of the evolution of earth shows us a continual, uninterrupted advance in its population, a continual increase of organised species in number, complexity, structure—this in addition to a series of other geological truths, the discussion of which in this place would carry us too far—forces us to the belief that all these different species have evolved from a few, perhaps from one original primordial form by way of natural descent that has been accompanied by continual advance in structure. The whole of the natural system of plants and animals appears from this point of view as a vast genealogical chart, and may, like every family pedigree, be best imaged under the similitude of a wide-spread tree, whose simple root lies hidden in the remotest past. The myriad green leaves that cover the younger, more recent branches, and spring out from the central stem in all varieties of shape, represent the species of plants and animals now living, the more perfect the farther they are distant from the original stem. The dried, withered leaves, on the other hand, on the older, dead branches represent the many lost, dead species that dwelt in earlier times on the earth; and the more they resemble the original simple primordial form the more remote are they. No species, not even the first, has been independently created. They have all originated in the course of immeasurable ages from a few or from one simple spontaneously-arising original form that has obeyed one law of Evolution—a law that works slowly and gradually, but ceaselessly—a law that leads to higher and higher levels of perfection. Thus the idea of a species is as changeable, as arbitrary, as little absolutely conclusive, as the more general and larger conceptions of the genus, the family, the class. New species can only arise from existing species.

At the beginning of this century this idea, that at the first blush seems so strange, had already dawned upon several eminent minds. Even whilst Cuvier was framing his system, a foe had already appeared who threatened to pluck up his whole crop by the roots. This was the celebrated French scientist, Lamarck, who as early as 1809 published, in his remarkable "Zoologie Philosophique," a theory thoroughly thought out, as to the origin of organic species by the gradual variation of a few spontaneous original forms. The school of thinkers whose most important adherents were Geoffroy St. Hilaire in France, and Oken in Germany, joined him. With prophetic insight these deep-thinking men moved in advance of their own time, and, in truth, held the very views on the actual blood-relationships of organisms whose scientific foundation upon facts was reserved for Darwin and his followers to build up during the last four years. At that time experimental facts were on the whole wanting to these men, especially those relating to the embryonic and palæontological development of organisms, that we at the present day know with comparative accuracy. It is no wonder, therefore, that they often went beyond the limits of experimental inquiry, and thus furnished their rigidly-accurate opponents, Cuvier and his disciples, with not a few weak points for attack. The contest between the two opposed orders of thought, carried on with much ability on both sides, reached its height in a violent discussion at an open sitting of the French Academy, on February 22nd, 1830, between Geoffroy St. Hilaire and Cuvier. It ended in a victory for the latter that lasted the next thirty years. This remarkable contest has been described and criticised in the most striking and ingenious way by Goethe, in one of his last essays, written only a few days before his death. Goethe followed the philosophical contests of his time with the keenest interest even in his later years, and in this dispute he sided with Geoffroy, and was opposed to Cuvier.

For thirty years from that time Cuvier's theory, rigidly limited by experimental inquiry, held sway, until, in 1859, it was shaken to its foundations by the epoch-making work of Charles Darwin "On the Origin of Species in the Vegetable and Animal Kingdom by Natural Selection," or by the survival of the fittest races in the struggle for existence. That which is really new and valuable in the Darwinian theory is this: that the correct theory of Evolution of the earlier philosophers, mingled as it was with many errors, was cleared of these erroneous elements, and in addition was supported by arguments based on fact, in part altogether original and peculiar to their enunciator, in part borrowed from the antagonistic works of Cuvier himself. Geoffroy and the other philosophers derived the manifold likenesses and relationships with which the bodily structure of organisms presents us from one common archetype that underlies all organisation. The differences that accompany these resemblances would arise in the course of the reproduction of the species, for whilst certain organs would advance, others would retrograde. This derivation of the resemblances, or homologies, from the principle of a common origin, Darwin uses. But he avoids the limited application of the principle by connecting with it, in a manner most fruitful in results, an idea of Cuvier that is apparently opposed to the principle. The idea is that every animal and every plant, independently of any common archetypal plan, has received, or better, has acquired a special organisation adapted to its conditions of life; not that its size, color, form and internal structure, have been adapted to the manner of life appointed for it by the creator, but rather that the living being has adapted itself to the conditions of existence of its environment.

The great importance of that agreement in ground-plan of organisms that without doubt does exist (the unity of organic composition, as Geoffroy calls it) is, very differently from Cuvier, acknowledged and valued by Darwin. But by him this idea is at the same time explained in simplest and most natural fashion. He traces it back to the fundamental, momentous principle of heredity. Heredity is a property common to all organised bodies, a universal law of organic Nature, the lofty significance of which we generally overlook, because in our every-day life its working is at all times and in all places before our eyes, and in its action we ourselves are included. From our childhood we are so accustomed to it that we wonder at deviations from the principle of heredity more than at heredity itself. It is well known that every pair of human beings transmit to their offspring not only the general properties of the human organism, but also a certain quantity of peculiarities of body and of mind that to some extent distinguish very definitely the various members of a given family from other human beings. For example, in some families six fingers are congenitally present on each hand. So generally is it recognised that the color of the hair and of the eyes, the outline of the face, and further the specially mental qualities of temperament, disposition, force of will, are transmitted within the limits of the family, that any further enumeration of examples in this connexion is unnecessary. On the other hand, it is equally well known that this same heredity is never absolute and unconditioned. It is only relative. However the children of the same pair of human beings resemble each other, however closely their bodily and mental natures agree, they are nevertheless distinguished from each other and from their parents by certain special peculiarities only belonging to the individual, that we therefore call "individual qualities." These specialties are in some degree established even in the egg or germ of the individual. So that all organisms are compelled by the law of heredity, and also by a general law of variation, to transmit to their offspring their peculiar character of disposition or of faculty, unchanged to some extent, but altered in greater or less degree in other particulars. To some extent, also, individual qualities are acquired for the first time during the life of individuals, through adaptation to the conditions of life, and especially through the changing relations in which every organism stands to all others that environ it.

Whilst those qualities, transmitted and inherited from ancestors, heirlooms in a particular family through many generations, are reproduced in the progeny, it frequently happens that special variation, appearing suddenly for the first time in one individual or suddenly acquired by it, is transmitted in like manner to the offspring of that individual, and thus becomes the possession of a series of beings, of a complete division of a family. This happens frequently with certain consumptive diseases and with peculiar mental disturbances. In the first instance the abnormality appears as a deviation from the law of heredity. Next it is itself subjected to this very law. If we wish hereafter to trace out carefully the genealogy of any great human family of which we have, in addition to the name, a brief account of each member, we shall find that the original family marks disappear more and more as we descend from the primal ancestors to the later descendants. The larger the number of these, the more numerous the generations intervening between them and the ancestral forms, the more are they differentiated, the more widely apart are they in many respects, the more completely are the old hereditary family marks eliminated and replaced by new peculiarities, partly inherited from younger ancestors, partly acquired anew. We shall be able to separate on the genealogical tree certain groups and sub-groups that we can connect by radiating and divergent lines of relationship.

It is evident that the same kinship that among men connects the individuals of one family and of one name is widely spread in the vegetable and in the animal kingdom. In these each individual has certain characters inherited from its ancestors, certain others that it has independently acquired, and that it can transmit to its offspring. The principle of heredity in these cases is still dominant, and has been used by many scientists to maintain the idea of a kind or species. According to a view widely held, those individuals, and only those that have originally sprung from one pair of ancestors, should constitute a species. This definition is not only accepted, but is widely extended, by Darwin. He not only believes, in fact, that all the members of a species have had a common ancestor, but he asserts the same truth of all the species of a genus, and, yet further, of all the genera of an order. Finally, all the orders of a class—*e.g.*, the class Aves—must have taken origin from one common ancestor lying far back in the series of periods of creation, and the separate ancestors of all the classes must have sprung from one most simple form. On this same principle of heredity new species can continually arise. It is well known that in many species certain groups of individuals are distinct, often very markedly distinct, from one another. Hence it follows that these groups are distinguished as races, sub-species, varieties. But the difference between the varieties of a species ought never to be so great as that between two nearly allied species. Darwin contradicts this idea; for if once a very strongly aberrant variety, or a single monstrous individual, has presented a certain variation so marked that the difference between it and the parent species is greater than the difference between the latter and the species most nearly allied to it: if, further, the strongly aberrant individual in turn transmits this special variation to its offspring: if, finally, this variation maintains itself unaltered through several generations and becomes permanent—in this way a new independent true species is constructed from the variety or race of the original older species. Thus, by heredity, many species may originate from a single species.

In what circumstances is a new species thus suddenly appearing actually maintained, and under what conditions does it find a footing independently of its parent form? Darwin's special work has been to place this very momentous question in a light wholly new and clear. When we study these conditions we reach the central point of the Darwinian teaching in the investigation of the immensely important successive changes of organisms that he names "Struggle for life" and "Natural Selection."

Darwin starts here from the weighty truth that all organisms propagate themselves by offspring, whose number constantly increases in more or less swift progression. All animals and plants, without exception, strive to multiply to such an extent that, left to themselves and protected from all adverse influences, each would completely possess and people the region best fitted for its existence in a very short space of time. The whole surface of the earth would be occupied, *e.g.*, after a few years, by the progeny of a single pair of mice, who multiply very rapidly. Even of the elephant, which reproduces itself most slowly of all animals, the offspring of a single pair would in five hundred years amount to the enormous number of fifteen millions. In this calculation the minimum is taken—viz., that each pair of elephants, during their whole life of ninety years, only bring six young into the world. Among the lower animals, on the other hand, are many even among the class Pisces, of whom each individual produces not merely a hundred or a thousand, but even a hundred thousand or a million eggs. In all cases only a very small proportion of these germs come to maturity, so as to serve for the propagation and the maintenance of their race. By far the largest part perish early. The reason of this fact is very simple. Only a limited number of places exist in the vast household of Nature. Only a limited number of organisms can exist at the same time on the restricted space of our globe. In a field of a certain size only a certain number of seeds of one or of several kinds of plants can be sown, and only a part even of these ripen. Of the buds only a small number will flower, a still smaller number fruit. The majority of the seeds sown are carried off by birds and other animals. A thousand foes lie in wait for the young bud that has struggled upwards out of the earth, the more numerous and the more formidable the younger the delicate bud may be. Many of the young plants therefore perish during their growth, as they are outgrown, supplanted, arrested in their development by others of their own kind. Between all allied individuals a constant strife, a battle goes on for space for their roots, for moisture, light and heat—a battle in which the weaker ones must perish.

The world of Nature, as a whole, shows us the same conditions. More than a certain number of living beings can never reach their full development, whilst by far the greater part perish early. In most cases the struggle for existence is very complicated, and generally a number of different species of animals and plants living in the same place are connected in conflicting ways that are as a rule only very imperfectly known to us. Thus carnivorous animals have great influence upon the existence of certain plants, for the insectivorous animals, that serve for the most part as food to the carnivorous ones, affect especially certain carnivorous beetles. But the latter live chiefly on certain other insects, that in their turn are dependent upon the particular plants under consideration. In this chain each link is dependent upon the next. As a good example of this relationship, that is often very complex, Darwin quotes the effect that in England cats exert on the formation of seed in red clover. The buds of the red clover belong to those flowers that can only be fertilised by aid of certain insects. In this special case the necessary insects are the humble-bees. The chief foes of the humble-bees are the field-mice. Now where cats most do congregate, who kill a large number of mice, the humble-bees will be more numerous, and, therefore, the clover will more frequently attain fructification. In a similar web of manifold relationships is every animal and every plant linked on to all others that live in the same place. In most cases these relationships are wholly unknown to us, but that they exist everywhere may be asserted with certainty. As long as each individual requires a certain amount of food, a certain position or standing-ground, it must necessarily come into collision with many neighbors striving after the same end. In Nature, as in human society, reigns everywhere a battle of all against all, remorseless and unceasing. And as the number of places in the world is limited, as space and food only exist in sufficient quantity for a very small proportion of the germs, the majority must of necessity perish.

Now it is clear that, on the average, in this fight for existence, those individuals of the same species will conquer and outlive others that are in any way better organised, possess more strength to withstand their adversaries, greater readiness to beget offspring, or in some other way have, through any special quality of organisation, an advantage over others. On the whole, it will always be the weaker and worse individuals that succumb and die out, the stronger and better that survive and propagate their kind. As this advance is repeated by the same species through many generations, a continual advance in perfection of organisation must result. Truly, in each individual case the approach towards perfection is but slight, and generally not noticeable. But if this slight improvement is repeated very often, at last, as result of continued increase and of accumulation, the many small improvements produce so much more advanced a condition of the organism that the final term of the long series differs very widely from the first.

This advancing improvement of the species confirms in remarkable fashion the opinion that fits in with the tendency to variation explained above, and with the general habit of all organisms not to transmit the sum-total of their qualities to their offspring, but to alter them within certain defined limits. It has been already shown that these modifications extend so widely in many species that we can mark off in each species a number of different races or sub-species. Now it is clear that these, like the single dissimilar individuals, will be differently situated in the fight for life. One race or variety will be more, another less gifted, as result of its special qualities, and it must follow that, if several races of the same species struggle for existence one with another in the same place, the races that are stronger, better developed, or, as consequence of certain properties, better fitted for existence, will overcome and supplant the other races that are weaker and less favored. In this way, according to Darwin, arises, *e.g.*, the sympathetic coloring so frequently to be seen in animals, *i.e.*, the relationship between the color of their skin and that of their habitat. Beetles, aphides, and other insects living on leaves appear green; bark-eating insects grey or brown; butterflies and other insects that live on parti-colored flowers are colored in variegated fashion. The inhabitants of the vast steppes and deserts, *e.g.*, the gazelles, jerboas, jackals, etc., imitate very closely the yellow or brown-yellow color of the sand. The majority of the polar animals are white, like the snow and ice on which they live. Amongst these animals are many, like the snow-hares, the ptarmigan, the polar fox, that are white in the winter, when the whole land is covered with snow, but in summer, when the snow is partially melted, are colored grey or brown. These remarkable sympathetic colors are easily explicable, on the ground that they are very useful to the animals concerned, and give them a distinct advantage over individuals that are colored in different manner. Evidently, those individuals whose color differs least from that of their habitat will be least easily seen by others that hunt them or use them for food. They can more easily escape their pursuers, more easily approach their prey, than other individuals of the same species that, on account of their color contrasting with that of their surroundings, will be more noticeable and more easily seen. Further, if at first many varieties of a given species are living hard by each other with different color-markings, later those that have an advantage through their particular hues will inevitably take the place of and conquer the others. In like manner many peculiarities apparently accidental are understandable on the view that they give to the beings or to the varieties that possess them an advantage over others of the same kind. These last, not possessing these advantages in the struggle for existence, must go down before their more favored rivals.

Darwin calls this immensely important principle Natural Selection. He compares it to the artificial selection that man is constantly exercising in relation to domestic animals and plants. If we look closely at this latter selection we find that the aim of the breeder is not simply confined to producing and propagating races that are good, useful, profitable to him. It embraces the creation and the bringing up of yet better and more useful varieties than had existed. It includes in fact, to put it shortly, the improvement of the race. This aim the breeder attains to some extent by using for breeding and propagation only the best and fittest individuals, or if he is following up some special plan, only those that show the peculiarity he desires in special degree. Thus the gardener only takes for planting the seeds of the best and strongest plants. The farmer selects carefully for breeding only those animals distinguished from others of the same herd by size, speed, strength, or any other special quality that he desires to bring out. These individual advantages reappear as a rule in the offspring, and generally in unequal degree in the different offspring. If, again, of these latter those are selected for the propagation of the next generation that exhibit the required speciality most clearly marked, and if this method is repeated, the advantage becomes yet more strongly shown in the descendants; and if the same careful selection is carried on through many generations, the later progeny are finally improved to so great an extent that the form most recently evolved does not seem to belong to the same species as the far more imperfect ancestral forms. The differences between the various races have grown so marked that we should certainly regard them as quite different species, or even as different genera, did we not know that they have arisen from one and the same parent species by continuous differentiation, and are joined on to that parent species by intermediate links. The majority of our domestic animals have already in this manner departed so widely from their wild originals, that we are altogether in the dark as to the latter.

It is clear, according to Darwin, that this same succession of changes, that man in these cases arbitrarily causes and directs, occurs continually among animals and plants that exist in a natural state, to the profit and steady improvement of these creatures. New races of a more perfect nature constantly arise and improve themselves in the struggle for existence, whilst the less perfect races (like the old parent forms) retrograde, become extinct, and die out. The selection of the best and fittest individuals for breeding, that results from the artificial selection in accordance with man's will and idea, is attained in Nature in natural breeding as result of the necessity of changed relationships between all organisms, as result of the conditions laid on each by the life-combat. But variations in the species do not, as in artificial selection, ultimate in the advantage of man, but in that of the various animals and plants themselves. The struggle for existence is so general, the effect of all organisms one on the other so complicated, the number of antagonistic individuals so great, that only those individuals that are specially favored can survive the fight, in which by far the larger number of the weaker and unfit perish. It is incontestable, if this advancement is considered as a whole, that from it must of necessity result a constant, gradual alteration of the world of living things, a progressive metamorphosis, an advancing transformation and improvement of all organisms. The lower, imperfect forms will continually disappear: the higher, more perfect ones will endure. These will give origin to an increasing number of yet more advanced forms by means of lasting variations, and divisions into new varieties will result.

Every zoologist and botanist believes that in this way varieties and races are unceasingly arising. The capacity for variation of the species is unlimited. The majority of thinkers only oppose the further extension of this succession of changes asserted by Darwin. He holds that new species and genera arise in exactly the same way. Yet further, he concludes by analogy that in kindred fashion also genera have evolved from orders, and orders from classes. Frankly, we are not in a position to confirm these latter conclusions by actual observation. For, although Natural Selection is at work continually and everywhere, seizing upon every fitting opportunity that the variation of species and the struggle for existence afford for the origination of new, independent forms, yet, on the other hand, it works too slowly, too gradually, and requires generally too long a time for the result of these constant transformations to be visible to us. Natural Selection also seems to require a much longer time for the production of a form so marked that it can be regarded as a good species than artificial selection, in which many circumstances combine to favor the strengthening of the new form. But if many generations are necessary for the evolution of a new species as result of gradual modification, it is beyond doubt that the time needed for the production of a complete genus, order, or class, from one primordial form is wholly beyond our power of comprehension. For such a series of evolutions epochs, not of hundreds and thousands, but of hundreds of thousands and millions of years are necessary. But the earth's history as a whole, from the appearance of the earliest original forms of simplest organisation to the rich and manifold series of the organic world of to-day, our knowledge shows to be made up of a series of such epochs of astounding length. Compared with the eternity of these vast periods of time, that we may estimate approximately whilst we can never really conceive them mentally, their latest moment, the many thousands of years since man, last link of the chain of being, appeared, fades into nothingness. The irrefragable evidence of geology gives us proof of these enormous lapses of time.

Although at the present time complete and actual proof of the origin of the larger groups of species from a single species is not furnished as result of direct observation, yet we are acquainted with a vast series of facts that bear convincing evidence as to the truth of the Darwinian theory. Numbers of the most important natural phænomena, inexplicable without its aid, find in it a simple, harmonious explanation. First amongst these ranks that gradual advancing development through which the organic world passes in the successive organisms of successive periods of time. In the oldest strata in which clearly recognisable fossils are generally found, only very few and very simply organised representatives of the great sub-divisions of the vegetable and animal kingdom have been discovered. He that passes upwards step by step in the series of strata sees that these low, imperfect beings give place to many higher and more perfect ones. Not only is there increase in the number of organisms in the more recent epochs near the present time, the simple forms are replaced by others more complex, more differentiated. Thus, *e.g.* of the Vertebrata, we find in the oldest fossiliferous rocks only rudimentary cartilaginous fishes. A little later their place is taken by higher fishes that approach more and more nearly to the majority of the osseous fishes now living. These are followed by the Amphibia (Labyrinthodonta), later by the Reptilia, especially the gigantic lizards. After these cold-blooded quadrupeds a very slow and very long Evolution leads up to the bird-like forms or flying-lizards, to the Deinosaurians, heavy brutes resembling the Pachydermata. Finally, the higher Vertebrata, the warm-blooded birds and mammals appear in the younger formations. At first, even of this last class only kangaroo-like marsupials occur. These hold the lowest place in the Evolution of this class, and from them are developed very gradually the higher, more perfect Mammalia that reach at length their loftiest height in the Evolution of the anthropoid apes, and at last of man himself.

Considering all that we know of human existence on the earth, we are entitled to hold that man also did not spring, Minerva-like, full-armed from the head of Jupiter, nor come from the hand of a creator as an adult and sinless. He has worked upwards very slowly and gradually from his primitive state of uncivilised brutality to the first dawn of culture. To this, the more recent discoveries in the field of comparative philology, in addition to the various facts brought to light by the geological and antiquarian research of later times, bear strong testimony. Speech did not appear suddenly, immediately, all at once, as the complex function of which man generally boasts as the special advantage possessed by him as compared with lower animals. More probably speech arose gradually from a few, simple, crude, animal sounds that served to designate the nearest objects, the most pressing wants. In a form little more perfect than this, speech still remains amongst a few races of lowest rank. The number of these expressions grew very slowly. At first they were by degrees combined into words, later into simple sentences. But a long period must have elapsed ere from this one, or from these few simple rudiments by advancing development and differentiation, the many stocks and families of languages evolved. For these are arranged by comparative philologists in a system, divided and subdivided according to their relationships near or remote, in the same way as botanists and zoologists arrange the families of plants and animals. As with the relationships of these last, those of speech can only be explained and understood on the principle of a common origin and progressive Evolution. We find the same law of advance at work still more widely in the historic development of the human race. Very naturally. For in the relationships of the state and of society occur again the same principles of the struggle for life and Natural Selection that irresistibly urge forward and raise by degrees to a higher culture the nations of the earth. Retrogressions in the life of states and societies, of morals and of knowledge such as the combined and selfish efforts of priests and despots in all ages of the world's history have produced, seem at times to hinder or apparently stop this universal advance. But the more unnatural, the more of an anachronism these retrograde attempts are, the more swiftly, and with the greater energy follows the reaction, the advance that treads ever on their heels. For progression is a law of nature that no force of man, neither the arms of tyrants, nor the curses of priests, can ever long restrain. Life and Evolution are only possible with advancing movements. Already to stand still is to step back, and every step backwards has within itself the beginning of death. The future belongs to progress alone.

While the fact of an advancing Evolution is easily explained on the theory of Darwin, the latter agrees further with the no less important fact that all things living to-day, or that ever have lived, form one vast whole, a single wide-branching tree of life of great antiquity, whose various parts are not isolated or separated by sharp gaps even in the finest branches, but are directly connected everywhere by intermediate links and by transitional forms. In this connexion the study of fossil animals and plants is a necessary complement to the natural history of the living world of to-day. For many living beings that in their external form and internal organisation seem to be widely asunder to-day, are closely connected by a chain of intermediate connecting links that lived in some cases very far back in the history of the earth. If we wish, therefore, to construct a so-called natural system of living beings, the extinct fossils must be considered as well as forms that are now living. If this be done, the whole natural system appears as one large organised body of many members, as a wide-branching tree, all the branches of which, its divisions and sub-divisions, are connected by radiating lines of union gliding one into the other. This fact, at first so surprising, can be explained by no other hypothesis save by Darwin's conception of a common origin for all. The mighty tree, wide-branching, under the similitude of which the natural system is best represented, attains its fullest significance as one huge, universal genealogical tree of all animals and plants. The word "Relationship" no longer remains, as hitherto, a merely figurative expression to indicate the degree of resemblance or dissimilarity between living beings, but acquires its full primitive, real significance when it reveals to us the common origin of these beings from one ancestral form, *i.e.*, their veritable blood relationship. Already the more or less close relationships that exist between groups closely allied and subordinate one to the other, have been denoted by the phrase "natural affinity," without anyone anticipating that this imaginary arrangement expressed the truth as to those relations in the only right manner.

Whilst the hypothesis of Darwin yields us the key to the enigma of affinity, it explains the majority of the rest of the phænomena of organic nature in a fashion as simple as it is effective. As examples, I quote the remarkable facts as to the geographical distribution of animals and plants, the phænomena of the division of labor, alternation of generations, metamorphosis, the meaning of rudimentary organs, which are as important morphologically as they are worthless physiologically; lastly, and most significant of all, the very momentous threefold parallel between the embryological, systematic and palæontological Evolution of organisms. It is not possible, on account of the limited time at our disposal, to go more fully into these three parallels that I, for one, regard as the strongest proof of the truth of the Evolution theory. These and many other deeply interesting phænomena that were described by the earlier naturalists as "curious freaks of Nature," without the aid of the theory of evolution seem as strange, insoluble riddles to us. By its means they are all explained from one and the same point of view.

On the other hand, we ought not to forget that Darwin's theory of Evolution does not by any means give us a system matured and finished. It offers us only the basis of a future system. It gives the first great impulse towards a thorough reform of the present system. Many gaps and weak places in the growing edifice give large opportunity to the attack of foes. On the other hand, many circumstances are still altogether, or almost altogether, unknown to us, that are possibly of no less moment in the origin of species than Natural Selection in the struggle for existence, on which overstress is, perhaps, laid by Darwin. No less important than these must be those external conditions of existence of the inorganic world that are too much neglected by Darwin, climate and habitation, and those geographical and topographical relationships, to which the characters of organisms in many ways become adapted.

Another want, and perhaps the most important in the Darwinian theory, lies in the fact that it yields us no starting-point for the spontaneous appearance, or origin of the one or few oldest forms from which all the rest have evolved. Was it a single cell, like those that even now exist as independent beings on the dubious borderland of the plant and animal kingdoms, or such as the ova of all organisms present at some period of their existence? Or was it at a still more early period, simply a mass of living protoplasm, capable of digestion, reproduction, Evolution—one of the Monera, allied to certain amœbiform organisms that do not seem as yet even to have risen as far in organisation as the cell?

To these and other questions the new aspect of the Evolution theory that is due to Darwin gives no answer. But this is not to be wondered at, if we remember that these inquiries have only been turned into this fruitful path by the epoch-making labors of Darwin during the last four years, whilst most of the earlier naturalists pursued aims of a totally different character. Hence Darwin's new theory of creation has met with many opponents of note among the older naturalists. But if we look back to the greatest discovery made by man—to the discovery of the law of gravitation among the heavenly bodies—if we reflect that the discovery of Newton, universally accepted to-day, was in his day condemned and vilified as an error, harmful, revolutionary, heretical, not only by multitudinous priests and laymen, but even by philosophers and naturalists of note, like von Leibnitz, we shall assuredly cease to wonder that the same impotent anathemas assail the Evolution theory of Darwin, that theory which is the most valuable advance made by science in our time, that theory which gives promise of accomplishing for the organic world results akin to those effected for the inorganic by Newton's law of gravitation.

I therefore, as firmly convinced of the truth of the theory of descent as Darwin himself, bring to a close this imperfect attempt at offering an epitome of that theory by quoting the words with which Bronn, the translator of Darwin—although he acquiesces in the theory only conditionally—recommends the work of Darwin: "The probability of connecting, by aid of the Darwinian hypothesis, all the phænomena of the organised world by a single principle, of regarding it from one point of view, of deriving it from one cause: the probability of intimately connecting many facts that have hitherto been isolated with others, of proving them to be necessary complements of those others: the probability of explaining most problems by it in most remarkable fashion: these stamp it as a pure truth, and gives us the right to expect that the difficulties that still present themselves against this theory will finally be overcome."

II.—THE ORIGIN OF THE HUMAN RACE.

THE ORIGIN OF THE HUMAN RACE.

AMONGST the notable efforts of the human mind that the long history of the Evolution of human knowledge places in strong relief, few have been of wider significance, of deeper influence than the Copernican system of the universe. For nearly 1500 years the spherical astronomy of Ptolemy of Alexandria had held sway over civilised humanity. In entire accord with things as they appeared to the senses, our mother earth was according to the Ptolemaic system the fixed, immovable centre of the whole universe, and around it sun, moon, and stars moved in concentric circles. The movement of these heavenly bodies was from east to west, just as it may be seen of all men day by day. This account of the universe took root in the Christian world the more firmly in that it agreed completely with the words of the Bible. "In the beginning God created the heavens and the earth" are the first words of the first book of Moses. And the 16th verse of the first chapter says : And God made two great lights ; the greater light to rule the day, and the lesser light to rule the night : he made the stars also. And God set them in the firmament of the heaven to give light upon the earth."

What could, in truth, stand more firmly, more securely than the Ptolemaic system ? "Does not the heaven arch over us up there ? Is not the earth lying beneath our feet ? Are not the eternal stars smiling upon us from on high ?" Could not every man of sense see with eye and touch with hand the earth standing still where she was, behold the sun, the moon, the stars palpably moving round this centre of the universe ? And this conception agreed with the place of man in Nature. Man, the veritable image of god, the be-all and the end-all of creation, was as certainly the one lord and head of the universe.

After the long dark night of the mournful Middle Ages comes the dawn of the 16th century with its mighty advances, its heaven-scaling revolutions in all phases of the knowledge and of the belief of man. In this dawn the German Copernicus rises, a star of the first magnitude. His work on "The Revolutions of the Heavenly Bodies" led to the most decisive revolution in the thought of the world of his day. It is true that Copernicus did not himself behold the full result of his magnificent labors. The first printed copy of his work was seen of him only in the hour of his death. But many an earnest scholar and follower helped in the spreading of his views far and wide, and ere long a Kepler, a Galileo won for the Copernican system a complete victory. It is true that Tycho Brahé, distinguished investigator and clear thinker as he was, tried to save the Ptolemaic system, or at least by combining it with that of Copernicus to find a happy mean between the two. The simplicity and clearness of the ideas of Copernicus, Kepler, and Galileo were so plain, their rigid, mathematical proofs so convincing, that ere long the momentous truth was clear to every inquirer who thought and was free from bias, that the earth moves. It turns each day upon its axis from west to east. It is a star among the stars, a planet in the midst of other planets that with the earth move round their common centre, the sun ; and round the earth wanders a single satellite, the moon.

We can hardly picture the effect of these immense strides in the knowledge of Nature on the men of the 16th and 17th centuries, who then were awaking for the first time from the long sleep of the Middle Ages. Not only did the rude, uncultured masses find a huge difficulty in this new teaching that turned the world upside-down, and contradicted absolutely the very evidence of the senses. Able, thinking men were unable to dissever themselves from the old traditions so deeply rooted in their natures. And many of those who were clearest of perception, who were compelled to admit the truth of the Copernican system, feared that the worst consequences would result from the spreading of the truth, and therefore sought to confine it within the narrowest possible limits. Especially did they dread the universal shattering of the Church theories that then lorded it over men, that was inevitably bound up with this new truth : for many necessary points of faith were overthrown by it, and the Bible would lose on many important points its absolute authority. Above all, the ambitious priests offered the Copernican system the most vigorous resistance, and tried to destroy their dangerous foe by the dictatorial utterance of dogmatic points of faith. The whole arrangement of the universe, as perceptible by the senses, and with it all human morality, must perish if the Ptolemaic system went. The pernicious heretics who disseminated such immoral teaching must be extirpated by fire and sword, and the ability shown by the Christian Inquisition in the invention of the most horrible tortures to the glory of god is too well known. Old Galileo, the greatest genius of his time, languished for a year in the dungeons of the Romish Inquisition. He was forced to repeat once a week the seven penitential psalms of David, and kneeling before ignorant monks, his hand on the gospels, to forswear the eternal truth he had made known to man. But his proud speech "E pur si muove" (and yet it moves), spoken at once upon the formula of abjuration as he rose to his feet, has been from that hour the motto of all seekers after truth, who with a noble courage that at times seems almost too daring, have fought a way for the truths of Nature against priests and creeds.

Every attempt to bid the world stand still has been in vain. "And yet it moves." Nevertheless a protracted and obstinate resistance was made to the teaching of Copernicus, of Kepler, and of Galileo, and that from very influential quarters. But it arose in its strength, redoubled its vigor when Newton, the great Englishman, made that greatest of all human discoveries, that of the law of gravitation, and demonstrated in the force of gravity, the attraction of masses, the mechanical cause, simple as momentous of those movements of the planets that were recognised in the Copernican teaching. By this law the new mechanical conception of the universe was so strongly and unanswerably confirmed, an immutable law of Nature so clearly and simply demonstrated as the actual cause of the movement of the planets in their orbits, that it was necessary for the power of the priesthood anew to summon all its forces and set at work all its pens to oppose this heresy, so terrific, so scornful of all revelation. Here also, besides the ignorant and fanatical monks there were men of high culture and deep thought who aimed at the suppression of the free expression of scientific knowledge. The most notable instance is that of the famous philosopher, Leibnitz, who condemned Newton's law of gravitation because it undermined natural, and denied revealed religion.

We are reminded very vividly of these antagonisms and contests at the present day by the theory of Darwin, and the extraordinary stir that it has occasioned. It is in the first place clear that the main point of this theory, the question of the origin of species among plants and animals, has commanded an interest as widespread as the rotation of the earth and the movements of the planets. Every exhaustive and comprehensive investigation of that question soon demonstrates that it has an importance at least as great as these, and that the theory of selection of the Englishman Darwin is worthy to be placed side by side with the gravitation theory of his great countryman, Newton. And this is evident if we reflect upon the different meaning that Darwin's teaching has given to the so-called "history of creation" as a whole, and especially to the history of the creation of man.

Darwin at first only attempted, in his celebrated work the "Origin of Species," to answer the question: "How have the different forms of plants and animals that we generally distinguish as kinds or species originated?" But this question is most intimately connected with two others of the highest significance, which in like manner must be solved along with it, viz., first, the general question: "How did life, the living world of organisms, arise?" and, secondly, the special question: "How did the human race originate?"

The first of these two inquiries, that as to the first appearance of living beings, can only be decided empirically by proof of the so-called Archebiosis, or equivocal generation, or the spontaneous production of organisms of the simplest conceivable kind. Such are the Monera (Protogenes, Protamœba, Protomyxa, Vampyrella), exceedingly simple microscopic masses of protoplasm without structure or organisation which take in nutriment and reproduce themselves by division. Such a Moneron as that primordial organism discovered by the renowned English zoologist Huxley and named Bathybius Haeckelii, appears as a continuous thick protoplasmic covering at the greatest depths of the ocean, between 3,000 and 30,000 feet. It is true that the first appearance of such Monera has not up to the present moment been actually observed; but there is nothing intrinsically improbable in such an Evolution. On general grounds it must be regarded as an essential to the beginning of living beings on the earth, as the point of commencement of both the vegetable and animal kingdoms. This idea is but a necessary sequence, the logical outcome of close reasoning. The second of the two questions that are necessarily connected with Darwin's teaching, that as to the origin of the human race, will alone concern us in this lecture.

The solution of these two problems has hitherto been deemed so difficult by most naturalists that they have not ventured to attack it at all, or they have had recourse to some fundamental force of Nature of a special kind and wholly hidden from us. Not a few declared the solution of these queries to be quite impossible, and held that the origin of living things was not dependent on natural causes and could not be ascertained by science. Many more held that it could only be explained by the conception of a creative force above and external to Nature, that governs and has under its control the ordinary natural forces of matter, the physical and chemical forces. Some looked upon this unknown, enigmatical, ultimate supernatural creative force as the possession of a personal, more or

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less anthropoid, Creator. Others called it vital force, the organic principle of design, final cause, and so forth.

It is only necessary to hint at the fact that the accounts of creation of the religious teachers among different nations are always in conformity with the supernatural, mystical explanation just given. However these may differ in particulars they all agree in this that they regard the first appearance of life on the earth, the origin of plant and animal species, and most of all the origin of the human race as a supernatural phænomenon that could not result from simple mechanical causes, from physical and chemical forces, but requires the direct intervention of a creative personality, working and constructing on a definite and designed plan.

Now the central point of Darwin's teaching—whether it has been already declared by the illustrious naturalist himself or not—lies in this, that it demonstrates the simplest mechanical causes, purely physico-chemical phænomena of nature, as wholly sufficient to explain the highest and most difficult problems. Darwin puts in the place of a conscious creative force, building and arranging the organic bodies of animals and plants on a designed plan, a series of natural forces working blindly (as we say) without aim, without design. In place of an arbitrary act of creation, we have a necessary law of Evolution. By this the widespread incarnation of the divine creative power, or anthropomorphism, is done away with, the false idea that the creative force shows any likeness to human method of action.

Clearly if these deductions are true the epoch-making work of Darwin must give the greatest offence and excite the most violent opposition on the part of all who are of opinion that without that unscientific idea of a supernatural act of creation the whole so-called order of the universe, as perceived by our senses, comes to an end. In the first place there is a revolt of all the scientific men who postulate an absolute distinction between the inanimate and animate, between inorganic and organic Nature, and who consider that for the phænomena of the inanimate or inorganic world (*e.g.*, for the movements of the planets and for the formation of this globe) exclusively mechanical causes or blind unconscious natural forces (*causæ efficientes*) suffice; but for the phænomena of the animate or organic world on the other hand (the plant and animal kingdoms), causes that have a definite aim in view or conscious creative forces are required. In the second place these naturalists have as allies those priests who thought that the very essence of their power over the people was in danger from the Darwinian theory. Still some years passed after the appearance of Darwin's reforming book ere this rebellion was general. For Darwin very wisely did not, in his first book, deal with the most important consequence of his teaching, the Evolution of man from the lower animals. Further he had put on one side the question as to the first appearance of life. But very soon that consequence, so full of meaning, so wide-reaching, was openly discussed by able and brave scientific men, such as Huxley, Carl Vogt, Ludwig Büchner. A mechanical origin of the earliest living form was held as the necessary sequence to Darwin's teaching. Then the storm rose in its full strength—a storm whose fury will for some time to come throw into commotion the world of thought—a storm that will end in the victory of the truth of Evolution.

The same threats, the same fears as in the time of Copernicus and of Galileo, are again aroused by the imperturbable advance of scientific knowledge. With those articles of faith denied by science, not only religion but morality will perish. Whilst science is freeing humanity, pining for liberty from the tyrannical chains of superstition and authoritative rule, it must throw into anarchy and ruin the whole order of the state and of society. But just as in the former time, in the sixteenth century, the new teaching as to the motion of the planets round the sun was the mighty lever that caused a great advance in the true knowledge of Nature and thereby in civilisation as a whole, so we hail Darwin's teaching as the morning star of a new period in the history of human culture, a period that will as far surpass the to-day as this has the darkest time of the Middle Ages.

During the six years that have elapsed since the issue of Darwin's work so many writings, large and small, have been published dealing with it that we may regard the principles of his teaching as generally known. We can here omit a full account of them the more readily as they have been already very thoroughly discussed in most of their bearings, and as we are at present only concerned with a single consequence of the theory, the natural origin of the human race through almighty Evolution. Still we are obliged, before entering upon this special inquiry, to say something on the groundwork of the Darwinian teaching itself and its essential connexion with the subject more immediately before us.

It has been already stated by a number of notable writers, both adherents and opponents to the Darwinian theory, that the latter is so essentially connected with the notion of a progressive development of man from lower Vertebrates, that the one idea cannot be thought of without the other. This is a reflexion of the greatest moment. It may be that related groups of animals and of plants, as all the species of a genus, all birds or Cruciferæ are descendants of one and the same original form, and have arisen from one common ancestral bird or Crucifer-form through transformations extending over a very long time. In that case man also has, beyond a doubt, arisen from lower Mammalia, apes, the earlier simian creatures, the still earlier Marsupialia, Amphibia, Pisces, by progressive transformations. Or this is not the case, and the separate species of animals and plants have been independently created. Then man also has been created independently of other Mammalia. But if we believe in such a supernatural creation, we must take refuge in an incomprehensible marvel, and simultaneously give up all hope of a real understanding, a scientific explanation of the most important processes of Nature. If we can only prove the general truth of the Darwinian theory, our idea of the origin of man from lower Vertebrata follows of necessity, and we are not obliged to give a special proof as to this latter view if the general proposition is well established.

Darwin's theory asserts, as is well known, that every resemblance that we observe in the general organisation of the animals or plants of any natural group, *e.g.*, of a family or a class, is a family relationship, depending on ties of blood, and that the word "affinity," by which we generally denote, figuratively, this similarity of structure, has in fact not merely a figurative, but an actual significance. The species related in form are, according to Darwin, related by blood. If this is true, the so-called "Natural System," in which the scientific man ranks the various species according to the greater or less amount of their resemblance one to another, must be the veritable genealogical tree of organisms.

On account of the extraordinary importance of this conception from the point of view of our lecture, we must illustrate it by an example. Let us take it from one of the familiar domestic animals, the cat. All the different kinds of cat are regarded by naturalists as offshoots of a single primordial ancestor, and are therefore placed in one species (*Felis domestica*). But the genus Felis includes, besides the domestic cat, many other kinds, as the lion, the tiger, etc. All these different kinds of the genus Felis, or cat, agree in their bodily form, in the structure of their teeth and feet so completely, that we regard them in consequence as kinds or species of a single genus. In turn we find a common origin of all the different species of cats from one ancient, common ancestor. The lion (*Felis leo*), tiger (*Felis tigris*), Puma (*Felis concolor*), leopard (*Felis leopardus*), wild cat (*Felis catus*), domestic cat (*Felis domestica*), are later offshoots in different directions of that ancient, long-dead ancestral form. In like manner we consider the genera cat and hyæna, that are included in the family of cat-like beasts of prey (Felidæ) as descendants of a single cat-like carnivorous form, that lived at a stage of the Earth's history far earlier than that of the primordial Felis. In like manner the genera and species in the family of canine beasts of prey (*Canidæ*), had originated from one dog-like ancestor, all the Ursidæ from one bear-like, all the Mustelidæ from one ancestor of a structure akin to that of the marten.

If we now rise still higher in our study of the natural system of animals and compare all the last-named families, we see in all beasts of prey, in all feline, canine, ursine, marten-like animals such an agreement in the most important zoological marks, as in the form of the teeth and the feet, and so evident a difference between them and other animals, that we combine all these families into one great natural group, the order Carnivora. If we are followers of Darwin we are by this combination expressing the genealogical idea that all these carnivorous animals take origin from a single primordial form. It is obvious that this ancestor of the whole order must be of far greater antiquity than his more recent descendants the individual parents of the families discussed above.

As we can assume a common ancestor for all Carnivora, the like principle holds for other orders of Mammalia, the Ungulata, the Quadrumana, Cetacea, the Marsupialia. All these different orders of the class Mammalia agree in the peculiarity of nourishing the newborn offspring by the milk of the mother, whence, indeed, this class takes its name. Further, all Mammalia agree one with another, and differ from all birds and other lower Vertebrata (Reptilia, Amphibia, Pisces) in many important characters of internal structure. For example, the lower jaw of Mammalia is much simpler in its construction than the lower jaw, composed of several distinct bones, of Aves and Reptilia. In addition, the lower jaw in the latter classes is connected with the skull by a special bone, the quadrate, wanting in Mammalia. [The quadrate bone of Aves is now known to be the homologue of the malleus, or first bone of the chain in the middle ear of Mammalia.—*Trans.*] Moreover, the Aves and Reptilia have a nucleus in their red blood-corpuscles, and this structure is wanting in the Mammalia. In the latter class the skull is articulated with the first cervical vertebra by two condyles, in the former classes by one only. In these points, and in several others, all mammals, however different they may be one from another, on other points agree. They are more nearly related one to another than any mammal is to a bird or to a reptile. In like fashion all birds and all reptiles show many greater points of intrinsic agreement than any bird shows to any reptile. The zoologist, therefore, notes all these points of resemblance and of difference, and unites all mammalian orders in the one class of Mammalia, all bird orders in the class Aves, all reptilian orders in the class Reptilia. But behind this systematic statement we, with Darwin, behold the momentous truth that all Mammalia take origin from one common ancestral mammalian form, all Aves from an ancestral bird-form, all Reptilia from a common reptilian progenitor.

As we pass upwards in this wise in the natural system of animals (and the same principle holds also among plants), we rise by degrees from the smaller, lower, younger groups, to larger, higher, older ones, *i.e.*, the originals of the former. We pass thus from species to genera, from genera to families, from these to orders, and from orders to classes. Every higher group is made up of several lower and subordinate groups. Every higher group is on our genealogical idea of the natural system an elder branch of the ancestral tree, and the lower groups comprised in it are the younger boughs and twigs of that branch. If the teaching of Lamarck and Darwin as to the origin of living beings is rightly understood, all the plants or animals that we place in one class are without a doubt the offspring or descendants of one single common ancestral form. But we may go at least one step further, and finally with tolerable certainty affirm a common origin for all those classes of animals and of plants that are so alike in all essential marks of their organisation that naturalists have, since the beginning of our century, after the researches of Bär and Cuvier, grouped them around a so-called central type.

Such a type, more accurately called a stem or phylum, is that of the Vertebrata, to which the classes Mammalia, Aves, Reptilia, Amphibia, Pisces belong. The Mollusca constitute a second type, with the classes

Cephalopoda, Gastropoda, Lamellibranchiata and Brachiopoda. A third phylum consists of the classes Insecta, Arachnida, Myriapoda, Crustacea : it is that of the Arthropoda. In each of these three types the general structure and the individual plan of development are so typical and characteristic that upon these grounds we can assert with certainty the blood-relationship of all the members of the type. All the different Vertebrata must have originated from one common ancestor, a single primordial vertebrate animal; all the Mollusca from a primordial soft-bodied animal; all the Arthropoda from a primordial articulate animal.

The facts of comparative anatomy and development that prove, beyond a doubt, these blood-relationships of all the animals of one stem or phylum or type, are so convincing to the student of these matters that he can cite no stronger proofs than they of the truth of the teaching as to the origin of living things. Turning specially to the Vertebrata that are at present the most interesting of all to us, we find that they present an agreement throughout all the special structure and arrangement of their skeleton and nervous system that is evident in no other group of animals. The internal skeleton of Vertebrata consists in all cases at first of a central axis, a cartilaginous rod, generally replaced later on by bone, named the notochord or chorda dorsalis. From this the vertebral column is developed. From the dorsal surface of this chorda dorsalis two arched processes grow upwards towards what is to be the back of the animal. These unite to form a closed tube, and within this tube the most essential part of the nervous system is enclosed, the spinal cord, that all Vertebrata, without any exception, possess, and that is wanting in all other animals. Below the notochord lies the body cavity, enclosing the alimentary canal and its appendages, the lungs, the liver, and other organs. From these anatomical details, quite apart from the similar facts that could be given in confirmation of them from the history of development, a common origin of all vertebrata can be predicated with the greatest certainty if the teaching of Darwin is correct in its general principle.

The classes of the animal kingdom that are still left for consideration after the three types of Vertebrata, Mollusca, and Arthropoda, were united by Bär and Cuvier into a fourth and last type, the Radiata. This phylum is not like the three previous ones, natural. It is an artificial collection of several very different stems or phyla. In the present condition of our zoological knowledge this group of Radiata must be replaced by at least four different phyla named as follows: (1), Echinodermata: the four groups Asteridæ, Crinoideæ, Echinidæ, Holothuridæ. (2), Vermes, or worms: the many forms of true Vermes in the most recent zoological sense, *e.g.*, Tæniada, Nematoidea, Trematoda, Tunicata, Annelida. (3), Cœlenterata: zoophytes, plant-like animals, the three classes of Spongida, Actinozoa, Hydrozoa; and lastly (4), Protozoa: the Rhizopoda, Myxomycetes, Flagellata, Protoplasta, and many other organisms of the lowest rank, down to the lowest of all, the Monera.

Amongst these four lower animal types the two phyla of the Echinodermata and the Cœlenterata are groups of species related by blood, as natural as the three higher phyla. This can be said with little certainty of the Vermes, and with still less of the Protozoa. The group Vermes includes very different forms, and amongst these are the primordial forms of the higher animal types. The Vertebrata are placed in genealogical connexion with the Vermes through the Tunicata, the Mollusca through the Polyzoa, the Arthropoda and Echinodermata through the Annelida and the radiate worms. On the other hand, the Cœlenterata are also connected with the Vermes. Lastly, the division Protozoa, whose position is still very uncertain, includes, first, the original progenitors of the Vermes and Cœlenterata, and, second, a great number of organisms lowly and imperfect, that are neither genuine animals nor genuine plants. We shall do most wisely in placing these last in a special neutral group, midway between the vegetable and the animal kingdoms—the Protista. The systematic relationships of all these groups of organisms can only be explained and comprehended by the teaching of Evolution.

The natural system of plants and animals, as it has been taught this long while by zoologists and botanists, does not merely therefore serve the purpose of arranging the different forms in many groups placed side by side, or in series according to the greater or less extent of their resemblance, and thus of facilitating the study of their endless variety of forms. The sole aim of the natural system of organisms is not simply a grouping of our anatomical knowledge as to the structures of living things. The natural system has a meaning far higher, far more widely-reaching than this. It reveals to us the facts as to blood relationships in organisms. It reveals their veritable and actual genealogy.

At present the theory of descent that explains in this manner the natural system of organisms as their genealogical tree is generally associated exclusively with the name of Darwin. Yet historical truth requires the confession that before Darwin many naturalists had arrived at the same fundamental conception, and had in part worked it out. Notably at the beginning of our century the philosophers, with our great poet Wolfgang Goethe and the immortal Lorenz Oken at their head in Germany, with Jean Lamarck and Geoffroy St. Hilaire as leaders in France, guided by their investigations in comparative anatomy, asserted a common origin for related forms of animals. Goethe, as early as 1796, gave forth the remarkable utterance: "This also we had gained. We were able unreservedly to affirm that the more perfect organic natures, under which we include Pisces, Amphibia, Aves, Mammalia, and at the head of these last, Man, have all been formed on one original plan that is only slightly modified in its very constant details here and there, and is still improving and altering generation after generation." And in another place Goethe says (1824): "An internal and original connexion runs through all organisms. Their different forms arise from their necessary relations to the external world, and we ought, therefore, to accept as facts original and simultaneous distinctions, and a continually advancing transformation, that we may understand the phænomena of the organic world, both those that are constant and those that vary." In these and in other words of Goethe the foundations of the theory of descent—named by others, the theory of modifications or of transmutations—are recognisable. Nevertheless, the honor of having published these exceedingly important ideas for the first time as a scientific theory, at once well-founded and thoroughly thought out, belongs to Lamarck, whose "Philosophie Zoologique," issued in 1809, we may place side by side with that revolutionary teaching of Copernicus in its power of opening out a new path for human thought.

One would think that the theory of descent, which threw at once full, clear light on the Evolution of organic species that had been until that time involved in ignorance and obscurity, would have wrought immediately upon its recognition a revolution similar to that of Copernicus in the whole of scientific inquiry. But this was not the case. On the contrary, the theory of descent that lays an indispensable and luminous foundation for all scientific Zoology and Botany was so little noticed in the first half of our century that even in the fourth and fifth decade it seemed almost forgotten. This is the result chiefly of the want of a unified comparative study of the whole of organic Nature, and of the exclusive absorption in the close study of details that distinguished the naturalist of that age. On the other hand, the opposition of weighty authority placed great difficulties in the way of the extension of the new idea, and the two distinct sets of thinkers, the zoologists and botanists, isolated and working separately, failed to see clearly the necessity of allying their forces under the banner of the harmonising principle of the theory of descent.

The inestimable service of Charles Darwin, whose work on the "Origin of Species," appearing in 1859, awoke on a sudden the moribund theory of descent to a new forceful life, lies not simply in his presenting that theory in a far more comprehensive and perfect form than all his predecessors, nor in his having strengthened it by all the proofs gathered together under the various branches of biological science. Another, a greater service of the renowned English naturalist, consists in this : that he enunciated for the first time a theory that explained mechanically the fact of the origin of species. He traced that origin back to physical and chemical causes, to a force of Nature working blindly, unconsciously, without design. This theory, crowning and completing the whole edifice of a mechanical comprehension of Nature is the theory of Natural Selection. It may be spoken of, in brief, as the theory of selection. This is the veritable Darwinism. It is not accurate to comprehend under this name the general teaching of Evolution or the theory of descent. If we would mark the latter by the name of its most prominent founder, we must call it Lamarckism.

The blind, unconscious forces of Nature, working without end or aim, that Darwin showed to be the effective natural causes of all those complex forms of animal and plant life that are apparently built in conformity with a definite purpose, are the two properties of living things known as heredity and variability. All organisms, all plants and animals, without exception, have these two momentous properties. They are only special modifications of two other more general functions of living matter, reproduction and nutrition. Variation is most intimately connected with the nutrition of the individual, heredity with the propagation of the organism. But as now all the phænomena of nutrition and of reproduction are purely natural processes, and are only the result of physical and chemical causes, so these latter are sufficient for those special phænomena that we call the functions of variability and heredity, important and mysterious in their working though they be. The reciprocal working of these two functions, and the special external circumstances under which they act and re-act one on the other, are the sole causes of organic structures and their modifications. Amongst these external circumstances, by far the most important are the varying relations in which every organism stands to its organic environment, to the plants and animals that live in the same place with it. The totality of the varying conditions Darwin sums up under the name of the struggle for life. It has also been called "the fight for existence," "the competition for life," and best, perhaps, "the combat for the necessities of being." In a manner at once full of ingenuity, clear and convincing, Darwin shows that we can explain in simple fashion all organic structures, all the relations of form and of construction in organisms as the necessary consequences of the reciprocal working of variation and heredity in the struggle for life.

As we cannot here enter more fully into the theory of Darwin, as a whole, we will only deal at length with these two principles that are so frequently wholly misunderstood. At the same time we may lead to a better understanding of the exceedingly important resemblances and differences that are evident upon a comparison of natural and artificial selection. By means of artificial selection the farmer and gardener can produce new organisms, even as Nature evolves them under natural selection. The new varieties of plants that the gardener, and even the new races of domestic animals that the farmer produces by artificial selection, are little different from the so-called kinds or species that the various animals and plants present to us in the wild condition. The commencement, and the method of their production, are the same in both cases, viz., the processes of selection or choice. Man makes use, by artificial systematic selection, of the two phænomena of heredity and variation.

Whilst the construction and transformation of living forms takes place in like manner in artificial and in natural selection, and depends upon like causes, on the other hand real differences obtain between the two methods of selection. The reciprocal action between variability and heredity is conditioned and directed, in artificial selection, by the systematic working of man's will ; in natural selection, by the struggle for existence, working without end or aim. The changes, the new structures in plants and animals to which selection gives rise, serve in the artificial form for the use of the breeder, in the natural form for the use of the organism that is bred. Moreover artificial selection produces, in a comparatively short time, new forms that differ from the original parent form in a very striking and remarkable way. Natural selection, on the other hand, works its transformations far more slowly, far more gradually. As a consequence, the changes in organic form that have been produced by artificial selection are much more transient, and easily disappear in succeeding generations, whilst the products of natural selection are far more stable, and maintain their individuality through long series of generations.

Had Darwin not proved, in the perfect way in which he has, the origin of living things by his causative selection, had he not shown the variation of species to be the necessary consequence of Natural Selection, we should none the less be compelled to accept the teaching of Goethe and Lamarck on the subject, since theirs is the only theory that explains the totality of phænomena in organic nature. Those phænomena that present themselves in the structural relationship between different species of animals and plants, or in their so-called plan of structure, come specially within its ken; and in addition, the facts of their geographical and topographical distribution, of their individual, and of their historic development, as they are revealed to us through the study of fossils or palæontology. But most prominent of all is the notable, the very important resemblance between the individual and the palæontological development of organisms. All these and many other weighty truths are easily explicable on the principle of the theory of origins of Lamarck, on the conception that all the various species of plants and animals are the offspring of one or of a few very simple primordial forms that have undergone infinite modification, primordial forms that have arisen, not at the will or by the determinate action of a personal creator, but by archebiosis or spontaneous generation. All the common phænomena that are known to us in the life of organic beings agree perfectly with this idea; not a single fact contradicts it. Hence we are perfectly justified in placing the theory of descent as a broad and general inductive law at the head of organic science, at the head of Zoology and Botany.

If, then, the theory of descent is in truth a necessary general inductive law, the application of it to man is a necessary special deductive law, a theory that follows unavoidably from the former. As the philosophical expressions, induction and deduction, on the right understanding of which everything in this connexion hinges, have been exceedingly misunderstood, an example may serve to explain them. At the time when Goethe was pursuing his studies in comparative anatomy, the want of an intermaxillary bone in man was regarded as the most important distinction between man and the rest of the Mammalia. The intermaxillary bone is placed in the median line of the mouth, between the two halves of the upper jaw, and carries the upper incisors. As in all other mammals that had been examined as to this point, an intermaxillary had been found, Goethe drew thence the induction that this bone was common to all the class. Now as man does not differ essentially, in all structural particulars from Mammalia, Goethe arrived at the conclusion by deductive reasoning that man also must have an intermaxillary. And, in fact, it fell to his lot to find that bone in the skull of man after careful investigation, and thus to furnish the actual proof of his deductive conclusion. In brief, a deduction is a conclusion, drawn from the general to the particular, an induction a conclusion drawn from the particular to the general.

When from the agreement between all Vertebrata in form, structure, development, we draw the conclusion that all Vertebrata have arisen from a single common primordial form, our conclusion is an inductive one. But when we affirm a like origin for man, who resembles in every other particular of an essential nature, the Vertebrata, our conclusion is a deductive one. This reasoning from generals to particulars is the more sound and reliable, the greater the soundness and reliability of the inductive reasoning from particulars to generals on which it is founded. But if the latter rests upon the broadest inductive basis, we may regard the former as equally well founded. The greatest stress must be laid on this philosophical proof as to the human genealogical tree.

Many special facts have been brought to light that support the above deduction as to man by the extraordinary strides made during later years in the inquiry as to the early history and the age of the human race, and in the celebrated investigations into the stone, bronze, and iron ages. Similar facts have been the result of the modern science of Comparative Philology. Zoologists and geologists, antiquarians and historians, philologists and ethnographers join hands in strengthening this theory of vast significance, in building it up in detailed particulars. Important and worthy of consideration as are all these contributions to the history of man, we can only see in them corroboration or verification of that deductive conclusion, that we have drawn with absolute certainty from the general inductive law of descent with modification.

What means are in our possession for building up the zoological genealogy of the human race, in conformity with the theory of descent? The same means that we use for a like end in regard to other animals: above all the comparison of their external form, their internal structure, the history of their development. In the first place, we need only inquire into the place of man in the zoological system. For this system is nothing more than the simplest expression of the facts of blood-relationship as presented to us by the study of Comparative Anatomy, by the thoughtful comparison of external form and internal structure. On this point there is no doubt that man must be placed in the class of Mammalia, and that he belongs to that smaller group in this class that zoologists name Discoplacentalia or Mammalia with a placenta discoid in shape. This group contains five different main divisions of the rank of orders, namely the Rodentia, Insectivora, Cheiroptera, Prosimiæ, and Apes. It is evident that of these five orders man stands much nearer that of the apes than the other four. Therefore, now the question narrows itself down to this: whether man is to be placed in the ape order itself, or if he has the right to demand a special order to himself near the latter.

However this subordinate question may be decided, this fact is certain, that amongst all animals the true apes, and especially the narrow-nosed apes of the old world, the so-called Catarrhini, approach more nearly to man than all other animals. Huxley, supported by the most evident discoveries in Comparative Anatomy, could utter the momentous sentence that the anatomical differences between man and the highest apes are less than those between the latter and the lowest apes. In relation to our genealogical tree of man, the necessary conclusion follows that the human race has evolved gradually from the true apes.

Whilst this very important fact was decided with enough of certainty by Comparative Anatomy, it received the most valuable confirmation from the study of Comparative Development. If we trace the evolution of each human being or individual from the beginning of his life, we are not able, at first and for a long time, to demonstrate the least difference between man and the rest of the Mammalia. Like all the rest, every man at the commencement of his life arises from a simple egg, a globular albuminous body only one-tenth of a line in diameter, surrounded by a delicate envelope, and containing a smaller globular mass, also of an albuminous nature, the germinal vesicle or nucleus of the egg. The human ovum, like that of every mammal and every animal, is a simple cell. This cell divides into two halves, and these again divide. By continuous division a mass of cells arises, from which the germ or embryo is formed. The latter has at first the form of a simple, circular disc that assumes later on a fiddle-shape, and consists of two concentric layers of cells. Very gradually all the different parts and organs that make up the body of the growing mammal arise from this simple germ by a long series of changes, transformations and improvements; up to a certain time the germs or embryos of all mammals, including man, are alike, and can only be distinguished by their size. Then by degrees differences, at first slight, soon more marked, appear that correspond with the systematic division of classes into orders, families, genera. In this connexion it is most noteworthy that the human embryo is not at all different from that of the ape until a very late period in its life, long after the difference between the embryo of the ape and that of other mammals has been evident. Only at a late period, towards the end of embryonic life, just before birth, are those differences recognisable that separate the true human embryo from that of the allied tailless apes. After birth, these points of difference are only trifling, and by degrees acquire significance as man on the one hand, the ape on the other, is modified into his own definite individual form.

The life-history of the human being is, as the physiological laws of heredity and variation clearly show, in its individual nature but a short, condensed repetition, a recapitulation, as it were, of the history of development of the animal type connected with man by blood, the vertebrate type. This history of types, or the so-called history of Evolution, is at present very little known to us ; for the actual witnesses on this point, the fossil remains of animals, have been found by man very sparingly on the whole. If we had to learn the history of man's ancestry from the fossils alone, we should be badly off. Yet these fragmentary proofs from ancient times are very valuable. From them we derive the foundations of the human pedigree in the different geological periods before man appeared on the earth. In the oldest system that has yielded vertebrate fossils, the Silurian, we find only remains of the lowest class, that of fishes. This is the predominant class throughout primary times. In the later periods only of the primary times, Amphibia accompany the fishes. These are the Vertebrata that evolved in closest relationship to the fishes. Later on, in far more recent strata, laid down during the secondary period, we meet the fossil remains of the three higher vertebrate classes, Reptilia, Aves, Mammalia. Of this last class we only find throughout the secondary age the lower division of Marsupialia or Didelphia (kangaroo), but not a single trace of the higher division of placental mammals or Monodelphia. These latter, to which man belongs, make their first appearance at the beginning of the third great division of the earth's history, during the tertiary age. Further, we have in the successive series of vertebrate fossil remains during these three geological periods important evidence as to the original evolution of the human race, and the advancing development of the Vertebrata from the fishes upwards. Naturally this evolution required an enormous length of time. This lapse of time is proved by the thickness of the strata deposited from the water. We estimate the duration of these periods not by hundreds but by millions of years.

Great as is the importance of the vertebrate fossils as the oldest records of man's ancestry, yet we should not be in a position to restore, by their aid alone, man's genealogical tree, as will be done in the next essay. Of the many thousand dead species of Vertebrata amongst which our ancestors existed, only a very few have been preserved, under fortunate circumstances, as fossils, and of these few only certain hard parts, specially adapted for preservation, as teeth and bones. But embryology, or the history of development of the individual, comes to our aid as the most reliable of allies. This stands in most intimate relation to palæontology, or the history of development of the type, as I have already shown. The succession of different forms through which every individual of any species passes from the beginning of its existence, from the ovum to the grave, is a condensed repetition of that series of different specific forms through which the ancestors and progenitors of this animal species have passed during enormously long periods of geological history. On the ground of this uncontradicted and plain evidence of embryology and palæontology, on the ground of the complete parallelism of these two series in Evolution, on the ground, finally, of the whole testimony of Comparative Anatomy that is in accord with these, and of study of the geographical distribution of animals, we are in the position to assert, with full confidence, the evolution of the human race from the lower Vertebrata, immediately from the apes, more remotely from the Marsupialia, Amphibia, Fishes, etc., and to sketch the genealogical tree of man with approximate certainty, as we shall try to sketch it in the following lecture.

Science follows truth as her single aim. She can approach her goal only by the sure path of actual experiment and careful reasoning on that experiment, never by the false route of pretended revelation. It is to her all the same whether such conclusions, founded on the experience of the senses, be agreeable or antagonistic, welcome or repellant to the inclinations, wishes, and feelings of men. She treats, therefore, with indifference, the storm of anger and horror that has arisen against the discovery of the descent of man. Yet we cannot conceal our personal conviction that the fear that has been expressed as to this vast advance in knowledge by well-intentioned men is unfounded. The knowledge of man's origin, far from leading to deterioration, to degradation, leads to the improvement, the ennobling of the race. It hastens on the progress of man's mental development, of freedom in no measured fashion.

We return at this point to the idea with which our lecture began, to the comparison of the theories of Copernicus and Newton with those of Lamarck and Darwin. By the system of Copernicus, the mechanical basis of which Newton founded, by the laws of gravity and of gravitation, the geocentric idea of the universe was overthrown, *i.e.*, the false conception that the earth was the centre of the universe, and that the other bodies, sun, moon, stars, existed only for the purpose of sweeping round and round this world of ours. By the Evolution theory of Lamarck, the mechanical basis of which Darwin founded by the laws of heredity and variation, the anthropocentric idea of the universe was overthrown, *i.e.*, the false conception that man was the centre of the life of earth, and that the rest of Nature, animals, plants, minerals, existed only for the purpose of serving him.

The fears and accusations that were directed by the world in general against the system of Copernicus, and against the theory of gravitation of Newton, have been shown to be groundless and unjust. Instead of destroying the moral order of the world, instead of overwhelming humanity in moral and intellectual ruin, these truths have raised morality and man to a higher standpoint as to the knowledge of what is; they have purified and ennobled the world. They have rescued the peoples from the dark night of the sorrowful mediæval times, and have lifted them into the morning light of a new age. They have broken in fragments the bonds of ignorance, the fetters of superstition, by which ambitious priests and princes strove to degrade their fellow-men to the level of blind tools of their arbitrary will. The tortures of the rack, of the Inquisition, by which a prejudiced priesthood sought to hinder and keep down the followers of the new truth, have but served to hasten their diffusion, to spread abroad the knowledge of them.

The fate and the effect of Lamarck's theory of descent, and of Darwin's theory of selection, will, in many respects, be the same. But the views of these two men, and their application to man, aided by the mighty advances made of late in all branches of science, will gain a more rapid, a more universal victory, than the views of Copernicus and Newton, and their application to earth. Many favorable circumstances are combining to clear the way for the theory of Evolution. Our whole conception of the universe has been altered by the colossal strides that have been taken in chemistry, physics, botany, zoology. By railroads and telegraph, our ideas of space and time have been revolutionised. By spectrum analysis and improved microscopes endless paths of knowledge, once on a time undreamed of, have been opened. By all these giant strides in our advancing mental growth, we are prepared to grasp the greatest, the most pregnant discovery of all, the discovery of the natural origin, the animal descent of the human race. Potent in explanation, and, therefore, powerful to ennoble man, it is at work everywhere, and mankind moves more and more swiftly onwards towards its eternal goal, through the light of truth to the joy of liberty.

III.—THE PEDIGREE OF MAN.

THE PEDIGREE OF MAN.

IN the former lecture we arrived at the general conclusion that the theory of descent must have its application in regard to man as well as to other organisms. In this lecture we will try to solve the special problem as to what position in the genealogical tree of animals must be assigned to man. For the solving of this problem we use the same means as those by which we attained the general propositions of organic pedigrees, viz., on the one hand the individual and palæontological evolution, on the other Comparative Anatomy. The more completely two allied organisms agree in their embryological and palæontological development and in their anatomical structure, the closer is the affinity between them, the more nearly are they together in the genealogical tree.

It has already been mentioned that we may regard all animals as descendants from six or seven types that correspond, on the whole, to the types of the animal kingdom originally distinguished by Bär and Cuvier. These were the types or phyla of the Vertebrata, Mollusca, Arthropoda, Echinoderma, Vermes, Zoophyta. The root common to and giving rise to these six animal types is to be sought for in the group of Protozoa or Protista. It is clear that we can only picture this most ancient root of the higher animals as an organism of the simplest kind imaginable, as a structureless, formless, minute particle of protoplasm, in a word, as a Moneron. The oldest Monera of this kind, simple living albuminous masses, without even the structure of a mere cell, can only have arisen through archebiosis or spontaneous generation.

Of the six or seven phyla of the animal kingdom the phylum of the Vertebrata alone is at present of interest to us, as the human race is a branch of this stem. Until the present time four classes, Pisces, Amphibia, Aves, Mammalia, have been as a rule distinguished under the type of the Vertebrata. To the last of these man belongs. But if we now compare the different vertebrate groups genealogically, and try to construct, step by step, their pedigree on the basis of the history of their development and of their Comparative Anatomy, we must distinguish the following eight classes: (1) Acrania; (2) Monorrhini; (3) Pisces; (4) Dipneusta; (5) Amphibia; (6) Reptilia; (7) Aves; (8) Mammalia.

The first class of the Vertebrata, the animals destitute of skull, or Acrania, is only represented by a single small animal so far below all other animals of this type that Pallas, its discoverer, regarded it as an imperfect snail, minus a shell. This very remarkable animal lives in the sands of various seas, *e.g.*, the Indian Ocean, the North Sea, the Mediterranean near Naples. It bears the name of Lancelet (*Amphioxus lanceolatus*). It has no head at all, no skull, no brain. All the rest of the Vertebrata have these and are named Craniata. A true heart, such as exists in others, is not present in this animal. The blood is circulated through the body by regular contractions of the blood-vessels. Hence the special class that Amphioxus constitutes may also be named Leptocardia, and in contrast with it all other Vertebrata that have a centralised heart may be called Pachycardia. The lancelet is very like a leaf, colorless or with a glimmer of red, half transparent, very small, lancet-shaped, about two inches long. But that this Amphioxus, despite the want of head, skull, brain, heart, is nevertheless a Vertebrate, is proved by its spinal cord and by the cartilaginous rod or chorda dorsalis that underlies the spinal marrow. These two highly important organs, spinal cord and chorda dorsalis, belong exclusively to the Vertebrata, and are wanting in all other animals with the sole exception of the Ascidians. The Ascidioida, the class to which the latter belong, are the nearest allies in blood of the Vertebrata. In man, as in the rest of the vertebrate sub-kingdom, the internal skeleton consists in the earliest period of embryonic life of this notochord alone, and the central nerve axis consists only of the spinal cord that lies above it. The brain and the skull that encloses it are developed later on by the differentiation of the anterior part of the notochord and its surroundings. Amphioxus exhibits throughout life in the structure of its most important organs the same lowest conditions of structure that all other Vertebrata run rapidly through in the earliest part of their embryonic life. It is clear that we have in this strange little animal the last surviving remnant of a low Vertebrate class that was well-marked at a very early period before the Silurian age, a class of which no fossil remains have come down to us on account of its want of enduring structures. Amongst these Acrania, the ancestors of the rest of the Vertebrata, the Craniata that later branched off from the former must have had their place. We must look upon Amphioxus with special reverence as the being that alone, among all the animals still living, is in a position to give us an approximate idea of our oldest Silurian vertebrate ancestors.

The second class of Vertebrata is far in advance of the Acrania, but is still so far below the Pisces that we cannot include it among these, as is generally done. To it belong the well-known lampreys (Petromyzon) that are so prized as a dainty, and the hag (Myxine), closely allied to these. Whilst in all other Vertebrata the nose consists of two similar lateral moieties, the nasal cavities, it consists in the Petromyzontes and Myxinoids of a single unpaired median part, and the whole class can be named Monorrhini, in contrast to the rest of the Craniata or Amphirrhini. Whilst the latter have three semi-circular canals in the labyrinth of the ear, only one or two are present in the Monorrhini. The lower jaw and the peculiar sympathetic system that occur in all Amphirrhini are wanting in the lower class. By these and other peculiarities they rank far below the former, and in all probability we have to regard them as a solitary survival of an ancient vertebrate class once on a time very numerous, that constituted the bridge from the Acrania to the Amphirrhini. The Acrania are the grandfathers, the Monorrhini are the fathers of the Amphirrhini.

The third class of Vertebrata that commences the series of the Amphirrhini contains the true fishes, cold-blooded Vertebrata that breathe air dissolved in water by aid of gills. This class is divided into three sub-classes, the Selachii, the Ganoidei, the Teleostei. The first sub-class, that of the Selachii, or ancient fishes, comprises the sharks (Squali), rays (Rajæ), and the Chimæræ that live in large numbers in certain seas. The second sub-class, that of the Ganoidei, or enamel-fishes, was very prevalent in the earlier ages of the earth's history, especially from the Devonian to the Jurassic, and constituted the chief part of the population of the seas of that time. Then it died out in great part, and was replaced in the Cretaceous time by its successors, the Teleostei. At the present time only a few survivors are in existence, such as the Polypterus of the African rivers, Lepidosteus and Amia in those of North America. But the most familiar Ganoids still living are the different species of the genus Accipenser, the Sturgeon and the Sterlet, whose eggs we eat as caviare, and whose swim-bladder yields us isinglass. Finally, the third sub-class of Pisces is the Teleostei, or osseous fishes, that have now far surpassed in numerical development both the other sub-classes, but were first evolved from the Ganoidei in the Cretaceous or earliest of all in the Jurassic age. To this belong the majority of marine fish now in existence, and all fresh-water fish except the so-called enamel-fishes.

The Comparative Anatomy and the history of the development of the three groups of Pisces enable us to determine their genealogy with the greatest certainty. The oldest division is clearly the Selachii, that were the first offshoot of the Monorrhini: and the most ancient fish in turn seem to be the sharks (Squali) that we on this account, and on account of their whole structure, must regard as the progenitors of the rest. Further, the ancestors of man in the Silurian age must have been true sharks, or at least very closely allied to these. The sharks still in existence at the present time have altered very little since that period, far less than all other fishes, and especially than other Amphirrhini. In addition to this direct line of descent, with but slight modification, the ancient sharks of the Silurian age have left behind them descendants that have undergone much modification. These are, on the one hand, the Ganoidei, from whom, later on, the osseous fish went off ; on the other, the Dipnoi, from whom, in all probability, the Amphibia arose at a later time. The Ganoidei, at all events, take origin from the Selachii, as the Teleostei, or osseous fishes, do from the Ganoidei. The Selachian branch may be named the grandfather, the Ganoid the father of the Teleostean. The oldest osseous fish, the Thrissopidæ of the Jurassic age, from which all other bony fish have evolved, are most nearly allied to our sharks. Neither Ganoidei nor Teleostei can be regarded as direct ancestors of the higher Vertebrata : the Selachii alone can be thus regarded.

As a fourth class of Vertebrata, we turn to the consideration of the Dipnoi, or mud-fish. These very important animals are so exactly midway between the true fish and the Amphibia that the most famous zoologists are still at strife as to whether they ought to be placed among the former or the latter. This contest is best ended by placing these animals as a special class between Amphibia and Pisces. Of this intermediate group only very few remnants exist to-day. Some of these are in Australia (Ceratodus), some in the waters of the Amazon in South America (Lepidosiren), some in the African rivers (Protopterus). In winter, during the rainy season, the mud-fish live in the water and breathe by their gills air dissolved in water. In summer, during the dry season, they build themselves a nest of leaves in the dried-up mud, and breathe air by their lungs. Their heart is conditioned as that of the Amphibia. Externally, on the other hand, they more resemble ordinary fishes. They are covered with scales like osseous fish. As the Dipnoi stand thus midway between Pisces and Amphibia, it is very probable that they connect these two classes in genealogical wise ; that they are descendants but slightly altered of those ancient Vertebrata that constitute the transition from the early piscine type to the Amphibia.

The fifth class of Vertebrata consists of the true Amphibia or Batrachia, in the limited sense in which this name is at present employed. From this class are excluded the Dipnoi, just considered, and the Reptilia that were once regarded as akin to the Amphibia.

To this class only the mail-clad Batrachia and the naked Batrachia belong. Of the former, the only living members are the small Cæciliæ, for the gigantic Labyrinthodonta of the Triassic age have long died out. To the latter belong the three orders of the gilled Batrachia or Perennibranchiata (*e.g.*, the well-known Proteus of the Adelsburger Cave); the tailed Batrachia, or Urodela (salamander and water-salamander); and the Batrachians (frogs and toads). Of these three orders the Batrachia are the descendants of the Urodela, as these are of the Perennibranchiata. Every individual frog, every individual toad even now in its early metamorphoses runs through these three stages, assuming at first the form of the perennibranchiate, then that of the tailed Amphibian, finally that of the adult frog without gills or tail. The Perennibranchiata, at all events, take origin from the earlier type of Pisces, either directly or through the mediation of the Dipnoi.

The three remaining classes of Vertebrata, Reptilia, Aves, Mammalia, show a much closer relationship among themselves than to the preceding classes. At no time of their life do they breathe by gills, whilst in the preceding classes this is always the case, though it may only occur in the earlier stages of the animal's life. All Reptilia, Aves and Mammalia are, during embryonic life (so long as they are within the egg), surrounded by a special membranous, investment, the amnion, that is wholly wanting in the four classes already discussed. These and other facts show that the three classes of Reptilia, Aves, Mammalia, have evolved from a common ancestor, and that this latter has originated from an offshoot of the Amphibian group. Probably this common ancestor of the three highest vertebrate classes divided early into two different lines. Along the one line Reptiles and Birds, along the other Mammals have developed.

The Reptiles will now be considered as the sixth vertebrate class, and the one that ranks next in succession to the Amphibia. To this class belong lizards, snakes, crocodiles, turtles, and the great number of extraordinary, dragon-like monsters (Sauria) that were so largely developed in the secondary period of the earth's history, in the Triassic, Jurassic and Cretaceous ages, but died out completely at the end of that period. All these reptiles resemble externally the true Amphibia (Frogs, Salamanders, Perennibranchiata) and resemble them also in their cold blood. But they are altogether different from the Amphibia in the most important particulars of their structure and in their development. They show rather a very striking kinship to Birds, with whom, as far as their external form and habits of life are concerned, they have but little affinity.

The Birds (Aves) that rank next to the Reptilia as the seventh Vertebrate class have without doubt evolved from the latter class, and very probably from reptiles very nearly allied to the Dinosauria. This close affinity between Reptilia and Aves, which at first sight seems very unlikely, is established beyond dispute by the resemblance as to the most important characters of the organisation already mentioned, and by the whole development of the young in the egg. The class Aves is no other than a single branch of the reptilian group, that has acquired by adaptation to special life-conditions a number of special peculiarities of structure.

The class Mammalia, eighth and last of the Vertebrate classes as distinguished by us, is the most important and the most highly-developed of all. At first sight it appears related most nearly to the Birds, with whom it shares, among other things, warm blood, complete separation of the right and left halves of the heart, the higher development of the brain and of the mental functions. But we are shown, by a series of important facts in the anatomical developmental history of the Mammalia, that this class has not evolved from the Birds nor from the Reptiles, but more probably directly from the Amphibia. It has already been said that we may certainly assume one common ancestral form for the three classes of Reptilia, Aves, Mammalia, a form that arose immediately from an offshoot of the class Amphibia. But the descendants of this ancestor, that lost altogether branchial respiration and developed an amnion, separated very soon, perhaps during or soon after the Carboniferous age, into two lines; on the one hand the Reptilia, from whom the Birds sprang later; on the other hand, the form intermediate between Amphibia and Mammalia, whence finally the true Mammals took origin.

Of all the classes of the animal kingdom that of the Mammalia is by far the most important and most interesting, if only on the ground that without doubt man —regarded by the unbiassed mind of the scientific thinker—must be placed in this class. Man has all the peculiarities and distinctive marks by which the Mammals are marked off from all other animals, and if the theory of descent is a general truth there cannot be the least doubt that the human race has arisen from this class by gradual evolution and differentiation. We must, therefore, of necessity, now give especial attention to the genealogy of this class, and to the systematic classification which is the expression of that genealogy.

The older naturalists simply divided the class Mammalia into a series of some ten to fifteen different orders. This series began with the order Cetacea, which seemed to claim the lowest rank by the fish-like shape of its body. It ended with the order of the apes, the Quadrumana that approached most nearly to the human form. From these, as a rule, the human race was separated, as the order Bimana. More recent zoology, that lays less stress upon external resemblances than upon the far more significant differences in internal structure and development, has given, on the other hand, a very different classification of the Mammalian class. It marks off first three chief groups or sub-classes that are, despite their different extent, separated from one another so widely by their structure and by the history of their development that they might even be regarded as distinct classes. These three sub-classes are the Monotremata, the Marsupialia, and the Placentalia. Probably these three groups are related one to the other as the Perennibranchiata, Urodela, and Batrachia among the Amphibia; that is, the Monotremata group is the grandmother and the Marsupialian the mother of the Placentalia.

The first class of the Mammalia, that of the Ornithodelphia or Monotremata, is to-day represented by only two living genera—the one a water animal, the duck-billed Platypus (*Ornithorhyncus paradoxus*); the other a land animal Echidna hystrix. Both genera are confined to New Holland, that part of the earth that is the habitat of so many other classes of animals and of plants of simplest and most rudimentary organisation. These low forms are of deepest interest, for they tell us of that long-vanished time in which the higher and more perfect forms of the same class had not yet arisen from these lower organisms. We ought therefore to regard the strange Monotremata as the last survival of that most imperfect, lowest Mammalian group that began to evolve from the Amphibia at the end of the primary or at the beginning of the secondary period, the group from which later on the Marsupialia evolved as a more advanced offshoot. In all probability that group developed during the secondary period into a vast number of genera and species. But the strata of that long age only enclose for the most part remains of sea-dwelling organisms. No fossil remnants of the Monotremata that dwelt on land or were amphibious have come down to us. The Monotremata in their whole organisation, and particularly in certain important features thereof, approach more nearly the lower Vertebrata, especially the Amphibia, than the higher Mammalia; whilst, on the other hand, they present a number of marks in common with the Marsupialia that the Placentalia no longer possess. Hence the opinion arises that the Monotremata living to-day are but slightly altered lineal descendants of that ancient ancestor of the Mammalia that marked the transition from the Amphibia to the Marsupialia. The Monotremata therefore stand in the same relation to the rest of the Mammalia as the Pharyngobranchii (Amphioxus) to the rest of the Vertebrata. And in regard to the pedigree of man they have this special interest, that they bring before our eyes to-day a far-off picture of that lowest step in the Mammalian organisation whence, in the beginning of the secondary period, our ancestors arose.

The Didelphia, or Marsupialia, constitute the second sub-class of the Mammalia. They stand midway between the first and the third sub-classes, between the Monotremata and the Placentalia, and probably form the connecting link between these, not only anatomically but genealogically. The Marsupialia are children of the Monotremata, parents of the Placentalia. As well-known examples of this group I need only mention the Kangaroo (Halmaturus) and the Opossum (Didelphys), that are seen in every zoological garden. The Marsupialia have received their name from the fact that their young, born in a very undeveloped condition, are for a long time after birth carried about in a pouch of the mother until they are fully developed. The geographical distribution of this group is very limited. The majority of the Marsupialia still living inhabit New Holland and the adjacent islands. Only a very small number occur in the Sunda Islands and in America. But in the dim past, long before the appearance of the human race, they had a much wider range. Fossil remains of Marsupialia are found even in Europe. In their anatomy and in their development the Marsupialia rise considerably above the Monotremata, whilst they are still far below the Placentalia. Hence we conclude that they in turn form the transition between these two groups genealogically, as well as systematically. It is clear that the placental Mammals, earlier or later (at the commencement of the tertiary period), sprang from the Marsupialia in the same manner as in yet earlier time (at the commencement of the secondary period), the latter sprang from the Monotremata. This opinion is confirmed in striking fashion by palæontology. For all the fossil remains of Mammalia that we find during the long age of the secondary period (Triassic, Jurassic, Cretaceous strata) belong to the Marsupialia. But all the fossil remains of the Placentalia known to us have been found in the strata laid down during the succeeding tertiary times. Hence we conclude, with tolerable certainty, that the Placentalia evolved from the Marsupialia early in the beginning of the tertiary or at the end of the secondary period. The ancient forerunners of the human race, during the secondary age, belonged at all events to the Marsupialia, even if they presented many important external points of difference from the kangaroo and opossum of to-day.

The third and last sub-class of the Mammalia, the placental Mammals (Monodelphia or Placentalia) includes all Mammalia except the Monotremata and Marsupialia. This is by far the most extensive of all the three sub-classes. It is also the most important for us, as it includes Man. This class receives its name from a special and very important organ that marks it off from the Marsupialia as well as from the Monotremata. This organ bears the name of placenta or afterbirth. It is a spongy white and red body of varying shape, consisting in the main of very convoluted and peculiarly arranged blood-vessels. Its function is to nourish and to bring the maternal blood to the young placental animal during the time before birth whilst it is within the mother.

The varying structure and external form of this organ are very characteristic in the different groups or orders of placental Mammals. These can be divided into three different legions, each comprising a group of orders. These three legions, expressing three different twigs of that branch of the genealogical tree that constitutes the Placentalia, bear the names Villiplacentalia, Zonoplacentalia, Discoplacentalia. In the first legion the placenta is composed of many separate scattered tufts ; in the second legion it is girdle-shaped, in the third discoid.

The legion of the Villiplacentalia, or the animals with cotyledonary placentas, includes three orders, the Edentata, Ungulata, Cetacea. To the Edentata, an order far more strongly represented in the diluvial past than to-day, belong the ant-eater, armadillo, sloth, and their allies the gigantic Macrotherium, Megatherium, Mylodon, Glyptodon, etc., of the tertiary age. The order Ungulata is generally sub-divided into three groups, the single-hoofed animals or horses (Solidungula); those with two hoofs, the ruminating animals (Ruminantia); and lastly those with more than two hoofs, the thick-skinned animals (Pachydermata). To this last the pig, rhinoceros, hippopotamus, and others belong. In the present day these three sub-orders of Ungulata appear in truth as distinct and clearly marked off one from another. But as soon as they are compared with their dead and gone ancestors of tertiary times, many of whose fossil remains are known to us, it becomes clear that the three sub-orders are closely interconnected by a series of intermediate transitional forms that have perished. We may therefore conclude that all Ungulata have sprung from one stem, that the three sub-orders now existent are but three individual branches of that common stem. The third order of the Villiplacentalia (that of the Cetacea), is very nearly allied to the Ungulata. To this the whale, dolphin, sea-hog, porpoise, sea-cow, belong. These marine animals only resemble fishes externally. By the whole of their internal structure, and by their development, they give clear evidence that they are Mammals, and that they are placental Mammals most nearly allied to the Ungulata. We are entitled, on fairly certain grounds, to hold that the Cetacea have taken origin from the Ungulata, that they are allies of the Ungulata which have become adapted for an aquatic life, and have in consequence taken on a fish-like structure. All Cetacea, Ungulata, Edentata, agree in that their placenta consists of many separate tufts, and in that respect, as in the constant absence of a decidua, it is essentially different from that of the Zonoplacentalia and Discoplacentalia. In the two latter divisions the placenta is always single and simple, and a decidua is always present.

The legion of the Zonoplacentalia, in whom the placenta takes the form of a ring-like enclosing girdle, includes the Carnaria alone. These animals would seem, from the characteristic structure of their teeth and brain also, to be a special natural group, all of whose members are related by descent. They present two orders: the land beasts of prey (Carnivora), and those that inhabit the sea (Pinnipedia). To the latter the seal, sea-bear, sea-lion, walrus, belong; to the former, cats, dogs, martens, badgers, bears, and many others. These two orders are as like one to the other as the Ungulata and Cetacea. Externally, again, the land and water carnivora are very unlike. But all their internal structure and their development prove to us, beyond a doubt, that they are very closely related in blood, and that the Pinnipedia have become so diverse from the Carnaria, their ancestors, only through adaptation to aquatic life. The habit of dwelling in the water, and the continual swimming therein—these alone have, under the influence of Natural Selection, fashioned some of the Carnivora into Pinnipedia, some of the Ungulata into Cetacea. Moreover, animals intermediate to the land and water forms of both groups are even now known; among the Ungulata, the hippopotamus; among the Carnivora, the otter (Lutra), and yet more notably the sea-otter (Enhydris).

The extensive legion of the Discoplacentalia, third and last of the three legions of the Placentalia, is the largest, most important of all; for to this legion belongs the human race, and from its lower forms that race has been developed. The placenta of man has exactly the same shape and structure as that of all apes, monkeys, bats, insect-eating and rodent animals. On this ground, then, we cannot separate the genus Homo from other Discoplacentalia. In all these animals the placenta has the shape of a simple round disc or cake, and this shape occurs in no other living beings. In their possession of a desidua the Discoplacentalia are closely allied to the Zonoplacentalia, so that these two groups appear to be more closely related one to another than they are to the Sparsiplacentalia, or Mammalia with a diffuse and non-deciduate placenta.

Usually the Discoplacentalia are divided into five orders: (1) Rodentia—squirrels, mice, porcupines, hares, etc.; (2) Insectivora—shrewmouse, mole, hedgehog; (3) Cheiroptera—insectivorous bats, or Nysterida, and frugivorous bats, or Pterotocyna; (4) Quadrumana—Prosimiæ, Apes or Simiæ; (5) Bimana—Man.

The first three of the five Discoplacental orders, the Rodentia, Insectivora and Cheiroptera, we can leave unaltered in the position next one to another hitherto accorded them. But the Discoplacentalia of the fourth and fifth orders must be arranged in another manner. First of all, we must separate the lemurs (Prosimiæ) as a special order from the true apes (Simiæ). The former are very remarkable and important. In the earlier tertiary times, in all probability, many genera and species of Prosimiæ lived. But at the present day this order is represented by a few living forms which have withdrawn into the wildest regions of Africa and Asia, into Senegambia and Madagascar, Upper India and the Sunda islands, and in these wildernesses live for the most part a nocturnal life. The different genera of the Prosimiæ present very striking transitional forms, connecting that sub-order with other Discoplacental orders. Thus the Chiromys of Madagascar is related to the Rodentia, the Otolicnus and Tarsius to the Insectivora, the Galeopithecus of Sundaisland to the Cheiroptera, and finally the Loris (Stenops), Indris (Lichanotus), and Makis (Lemur) to the true Simiæ. Upon these and upon other grounds we are compelled to regard the still living Prosimiæ as the last remnant of an ancient ancestral group, for the most part long perished, whence by evolution in different directions the other four orders of the Discoplacentalia have branched off. The parent forms of the Rodentia, Insectivora, Cheiroptera and Simiæ may therefore be regarded in a certain sense as four children of the same family having their common origin, their mother, in the Prosimiæ.

Whilst on the one hand we seem by our separation of the Prosimiæ and Simiæ to increase the number of the five Discoplacental orders by one, we reduce the number on the other hand to five once more, by uniting the order containing man alone (Bimana) with the order containing the true apes (Simiæ). The celebrated English zoologist, Huxley, has shown, for the first time, in his remarkable "Evidences as to Man's Place in Nature," that we can no longer regard these two orders as distinct one from the other. For the Simiæ have, like man, two hands in front, two feet behind, and it was a blunder in anatomy when, in earlier times, the Simiæ were credited with four hands, and their feet, as if opposed in nature to those of man, were named hands. In addition to this, we have the much more important fact that the most recent investigations of all the special anatomical peculiarities of man and of the true apes have led Huxley to the following conclusion: "The anatomical differences that separate man from the highest apes (gorilla and chimpanzee) are not so great as those that separate the highest apes from the lower." In fact, considering any part of the body, we may, from the most recent investigations, conclude that man is more nearly allied to the highest apes than are these to the lowest. Hence it would be altogether forced and unnatural if man were separated from the apes as a special order in the zoological system. Rather is scientific zoology compelled, willy-nilly, to place man in the order of the true apes (Simiæ). Then we recognise springing from the Prosimiæ as the common ancestral group the following five orders of Discoplacentalia: (1) Prosimiæ; (2) Rodentia; (3) Insectivora; (4) Cheiroptera; (5) Simiæ (including man).

If now we again call to mind that the natural system of animals is no other than their genealogical tree, we come to the conclusion that the human race have to seek their ancestors among the Discoplacentalia, first among the true apes, yet farther back among the Prosimiæ. Shocking and impossible as this truth may seem to the majority of men, it can no longer be doubted at the present time. Nay, zoology is even in a position to define directly this important offshoot of the human genealogical tree with more precision and certainty than is possible in many other cases. With this end we must enter somewhat more at length into the systematic arrangement of the Quadrumana.

The division of the true apes or Simiæ is to-day arranged in two sub-orders, the Platyrrhini and Catarrhini. The group Platyrrhini includes all the apes of the new world (America), amongst others the howlers, the weepers, capuchins, and squirrel-monkeys. The group Catarrhini, on the other hand, includes all the apes of the old world (Asia and Africa). To it belong the tailed baboons, the macaques, and, most important from our point of view, the remarkable family of the tailless anthropoid apes; the gibbon (Hylobates), orang (Satyrus) in India, the chimpanzee (Pongo troglodytes) and gorilla (Pongo gorilla) in tropical Africa.

The Platyrrhini of America and tne Catarrhini of Asia agree in many important points. For example, in both groups all the fingers and toes are provided with nails as in man, and not with claws as in the monkeys. But on the other hand, the two sub-orders exhibit many characteristic differences, especially in the structure of the teeth and of the nose. In all old-world apes the two nasal apertures look, as in man, downwards, and the vertical partition that separates them is narrow and thin ; hence their name Catarrhini. On the other hand, the nasal partition in all the new-world apes is broad and largely thickened below, so that the two apertures do not look downwards, but sideways and outwards; hence the name Platyrrhini. The apes of the old world resemble man also in their teeth as well as the construction of the nose. They have thirty-two teeth, viz., in each jaw, in upper as well as in lower, four incisors, two canines, four premolars and molars. On the other hand, the apes of the new world have thirty-six teeth. They have an additional molar in each jaw on both sides. These anatomical distinctions show plainly that the American apes have developed on their own continent independently of the old-world apes. Yet it is probable that the ancestor of the American ape sprang from the Asiatic, and wandered over from Asia to America; or perhaps the converse of these propositions is the truth.

In all the anatomical relations mentioned above, man is exactly like the old-world apes, and it may further be laid down as assured that he is actually descended from these. The most detailed and exact investigations of late years, viz., those of Huxley, have proved to demonstration that all the differences of form separating man from the anthropoid apes (the gorilla, chimpanzee, orang), are less than those differences (especially as regards the structures of the limbs and of the skull) which separate the highest known tailless apes from the lower tailed apes or baboons. If, therefore, all the apes of the old world, from the lowest baboon to the most highly-developed gorilla, are, as is usually the case, included in one and the same group, the Catarrhini, it is not possible to exclude man from this same group. As to the genealogical tree of the human race, the inevitable conclusion is that we must seek our nearest brute ancestors among the Catarrhini. It is self-evident that none of the apes now living can be regarded as these ancestors. More probably these last have perished long since, and at the present time a gap separates man from the gorilla wide as that between the baboon and the gorilla. But in this fact there is not the slightest evidence against the well-grounded conclusion that the most ancient Catarrhini form of the Prosimiæ was the ancestor common to all other Catarrhini, including man. It was a branch still unknown, and certainly long dead, of this extensive catarrhine group, that under favorable circumstances, by Natural Selection, evolved the ancestor of the human race. At all events, this transformation was of vast duration, and as yet neither place nor time has yielded us any fossil apes. But in all probability it occurred in Southern Asia, in which region many evidences are forthcoming that here was the original home of the different species of man. Probably Southern Asia itself was not the earliest cradle of the human race; but Lemuria, a continent that lay to the south of Asia, and sank later on beneath the surface of the Indian Ocean. The period during which the evolution of the anthropoid apes into ape-like men took place was probably the last part of the tertiary period, the Pliocene age, and perhaps the Miocene age, its forerunner.

As we look upon the apes that inhabit the earth to-day, and among other Vertebrata of the present time, we see but few races that are unaltered descendants of those Vertebrata that, according to the genealogical tree now in construction, we have to regard as ancestors of the human race. In like manner, we are hardly able to point out with certainty, amongst the many fossil remains of Vertebrata that we find in the layers of the earth's crust, individual species as forerunners of the human race. Nevertheless we are in a position to state, with at least some certainty, the approximate ancestral series of man in the Vertebrate system generally, the system which reveals to us in outlines the natural genealogical tree of the Vertebrata.

The attempt that is here made, for the first time, I have worked out more fully in my "General Morphology" (1866), and later in my "Natural History of Creation" (1868).

Regarded as a whole, the series of the animal progenitors, or ancestral chain of man, can be brought under two groups, of which one includes the Vertebrata only, the other all those invertebrate animals out of whose gradual transformation and advancement the parent of the Vertebrata first originated. We may designate these invertebrate ancestors of the Vertebrata and of man as Prochordata.

Until recently we could only make guesses very uncertain and vague in regard to these Prochordata. Suddenly the deep darkness of our invertebrate genealogy was lightened by an unexpected discovery of the greatest value. From the observations on the development of the lancelet (Amphioxus) and the simple Ascidioida (Ascidia, Phallusia), published by Kowalewski in 1867, the extraordinary and significant fact was ascertained that the ontogeny of these two beings, apparently so different, agreed in the most remarkable manner. The invertebrate Ascidioida are Vermes of the old class Tunicata, hitherto inaccurately referred to the Mollusca. In their adult state the Ascidioida are shapeless little masses affixed to the sea bottom, in which superficial observation would scarcely imagine that an animal existed. But these dull, inert masses arise by a retrograde metamorphosis from free-swimming active larvæ, and these larvæ develop after the same fashion as the lowest vertebrate, the Amphioxus. They possess, in fact, a rudiment of a spinal cord and of the chorda dorsalis that lies between the cord and the intestine. But these are the most characteristic and special parts of the body of Vertebrata. Hence it may be concluded with absolute certainty that the Ascidioida have, of all the Invertebrata, the closest blood-relationship to the Vertebrata.

The Ascidioida, like the rest of the Vermes, have evolved, in all probability, from lower, more primitive forms, nearly allied to the Turbellaria and Gastrœada of to-day. We must regard as forefathers of these last such very simple, unicellular animals as the Amœbæ, that are found in all water at the present time. That the earliest ancestors of the human race were such simple, primitive animals, whose whole structure was a single cell, is strongly confirmed by the incontrovertible fact that every human individual is developed from an ovum ; and this ovum is, like the ovum of all other animals, a single cell. Here, at once, the intimate causal connexion between the individual development of the particular organism and the historical development of its race leaps into view, and the simple connexion of ontogeny and phylogeny becomes of greatest significance. If, therefore, people find our theory of the origin of the human race "abominable, revolutionary, immoral," they must, in like manner, regard as "abominable, revolutionary, immoral," the facts, certain, demonstrable by a glance through the microscope, that the human ovum is a simple cell, that this cell is in no wise different from the egg of other Mammalia, and that in the former, as in the latter, a multicellular body develops that repeats in brief, during the course of its embryonic growth, every link in the ancestral chain of the Mammalia in the most important particulars. In this ancestral chain, or series of forefathers, we can, in the present state of our knowledge, mark off approximately twenty-two steps, of which eight belong to the Invertebrata, fourteen to the Vertebrata.

Ancestral Series of Man.

First Division of the Chain of Ancestors of the Human Race.

Invertebrate progenitors of man (Prochordata) :—

First stage.—Monera. Organisms of the simplest structure conceivable, like the present Protamœba, Protogenes, Bathybius, made up of a shapeless minute mass of living protoplasm. The earliest Monera, from which later on the first cells evolved, can only have arisen by evolution from inorganic matter.

Second step.—Amœbæ. Organisms consisting of a simple, naked cell, made up of a shapeless mass of living protoplasm, and an enclosed nucleus. Probably these unicellular primal animals were not very different from the Amœbæ of to-day, as the human egg is not essentially different from an Amœba surrounded by a membrane.

Third stage.—Synamœbæ or colonies of Amœbæ, consisting of a collection of similar naked cells, like the Labyrinthula of to-day, or like the morula stage of the fertilised egg.

Fourth stage.—Ciliata or Planæada, like the ciliated larva or blastula of Amphioxus and many invertebrates. Multicellular, hollow organisms, whose surface is beset with vibratile cilia.

Fifth Stage.—Gastrœada, like the Gastrula stage of Amphioxus, evolved from the Planæada by the formation of a mouth and internal cavity.

Sixth stage.—Turbellaria, or at all events certain low Vermes, at present unknown, of very simple structure, that are the next stage in complexity to the Gastrœada, and are most closely allied to the Turbellaria of the Vermes known to-day.

Seventh stage.—Scolecida, forming the transition between the Turbellaria of the sixth and the Himatega of the eighth stage.

Eighth stage.—Himatega or sack-worms, standing nearest to the Ascidioida, and especially to the Ascidians among known animals. Like these they had evolved a rudiment of the spinal cord, and the subjacent chorda dorsalis.

Second Division.

Vertebrate progenitors of man (Vertebrata) :—

Ninth stage.—Acrania. Vertebrata destitute of head, skull and brain, central heart, jaws, limbs, allied to the lancelet or Amphioxus of to-day.

Tenth stage.—Monorrhini. Vertebrata with head, skull, brain, central heart; without a sympathetic system, jaws, limbs; with a simple single nasal cavity. Allied to the Myxinoids and Lampreys (Petromyzon) of to-day.

Eleventh stage.—Selachii. Primitive fishes, closely allied to the sharks of to-day, with swim-bladder and two nasal cavities, two pairs of limbs (fins), and jaws.

Twelfth stage.—Dipnoi or mud-fish. Vertebrata that are midway between Pisces and Amphibia, with gills and lungs, allied to the Ceratodus, Lepidosiren, and Protopterus of to-day.

Thirteenth stage.—Sozobranchii. Amphibia with persistent gills, allied to the Proteus of the Adelsberger grotto.

Fourteenth stage.—Urodela or Sozura. Amphibia with transitory gills but persistent tail, allied to the Triton and Salamander.

Fifteenth stage.—Protamnia. Forms intermediate between salamanders and lizards; losing their gills completely and possessing an amnion. These represent the parent form common to the three higher vertebrate classes, all of which have an amnion.

Sixteenth stage.—Promammalia, the parent-forms of the class Mammalia. To these the Australian Monotremata (Ornithorhyncus and Echidna), with a cloaca and marsupial bones, but without a placenta, are most nearly allied.

Seventeenth stage.—Marsupialia, allied to the kangaroo and kangaroo-rat, with marsupial bones, without cloaca, without placenta.

Eighteenth stage.—Prosimiæ, allied to the Loris (Stenops), and Makis (Lemur), without marsupial bones and cloaca, with placenta.

Nineteenth stage.—Tailed apes or Menocerca. Catarrhine apes with thirty-two teeth, with tails, allied to the Semnopithecus, Cercopithecus, and Colobus.

Twentieth stage.—Men-apes or Anthropoida. Catarrhine apes, without cheek-pouches or tail, allies of the orang, chimpanzee, gorilla.

Twenty-first stage.—Ape-men or commencing men (Alali), allied to the lowest human races of the present time (Papuans, Hottentots, Australian negroes), but still destitute of true articulate speech.

Twenty-second stage.—Men who have risen from the rudimentary condition of the preceding stage by the development of human speech and a simultaneous advance in brain-evolution connected therewith.

When we have considered the stages as they are known to us, of the series of forms that the ancestors of man have assumed, from the Moneron to the Ascidian, from the Amphioxus to the Gorilla, it behoves us to go a step further, and to discuss the different species of the human race and their unity of origin. As these questions have, during the last ten years, been very eagerly debated, a hurried glance may be of use at the light thrown upon them by the study of descent. But here it must be said that the decision in these matters is very indefinite and uncertain, inasmuch as the results bearing on the questions obtained from comparative anatomy and ethnography, comparative philology and archæology are contradictory and at cross purposes. Accordingly as the particular observer assigns greater weight to one or another ground of proof, his decision will vary. Here, more than at any other part, our present theory will seem still very unsatisfactory.

Comparative philology, so important for the knowledge of the true relationship of the younger branches of the human ancestral tree—*e.g.*, the different branches of the Indo-Germanic stem—leaves us altogether in the lurch as far as concerns the momentous inquiry into the origin of the various human species. For it seems fairly certain, from many facts, that human speech was evolved after the marking-off of the different species had occurred. The primitive men whom we regard as the ancestral form common to the five to twelve species or races to be mentioned immediately, probably had no true speech.

Next it may be remarked that the different forms of the human race that are usually regarded as races or varieties of a single human species (Homo sapiens), appear really to be good species. For the differences in color of skin, nature of the hair, and build of the skull, are not less marked than those differences by which many species of animal genera in a wild state are distinguished.

It is well known that, according to Blumenbach, five races of man are distinguishable, which we may regard as so many species of the genus Homo. These are: (1) The white or Caucasian race (Homo albus); (2) The yellow or Mongolian (Homo luteus); (3) The red or American race (Homo rufus); (4) The brown or Malay (Homo fuscus); (5) The black or African (Homo niger).

The Englishman Pritchard, who after Blumenbach, has made the most extensive and complete inquiries into the so-called race-differences in man marks off three more races. He regards the Hottentots among the black African race, the Australians and Papuans among the brown Malays, as distinct races. This separation is justified not only by differences in color, in skin, in structure of hair, but by the different conformation of the skulls.

The skull-conformation of man, on which of late extensive investigations and measurements have been made, presents, generally, three chief types, connected, however, by many intermediate forms: long skulls, skulls of medium length, short skulls. The long skulls (Dolichocephali), whose most typical form is seen in the skull of the African negro, are elongated, and are laterally compressed. The short skulls (Brachycephali), most strongly developed in the Asiatic Mongols, on the other hand, appear shortened, cubical, compressed from front to back. Midway between the long and short skulls stand the Mesocephali, well shown in the American aborigines, and in many Europeans.

The differences between dolichocephali and brachycephali, between woolly-haired and straight-haired peoples, between black and white skins that appear so marked in the extremes of the human race, are connected by a mass of gradations and transitional forms in such a way that it is quite impossible to separate the various races clearly one from another. But the same fact holds in regard to many animal forms that are generally looked upon as "good species." On the one hand, therefore, we hold the races of man as "good species."

But, on the other, we see in the intermediate transitional forms sufficient ground for the conception of the unity of origin of all the species of man. By this it is not, however, implied that "all human beings have originated from a single pair." For in that long chain of many generations that formed the transition from the men-apes to the ape-men, and from these last to actual articulate speaking man, no single pair can be designated as "the first pair of human beings."

The primitive human form, whence, as we think, all human species sprang, has perished this long time. But many facts point to the conclusion that it was hairy, dolichocephalic, dark, perhaps brown, of skin. Let us, for the time being, call this hypothetical species Homo primigenius. If, in addition to these, we regard the Eskimos as a peculiar species, we have in all ten different human species, four hairy, six smooth. As to the relationship by descent of these ten, the following approximate statements can be made. The first species, Homo primigenius, or the ape-man, the ancestor of all the others, probably arose in the tropical regions of the old world from anthropoid apes. Of these no fossil remains are as yet known to us, but they were probably akin to the gorilla and orang of the present day. The three following woolly-haired species, and of them the Papuan Negro mentioned next are, among living races, the nearest to Homo primigenius. Like these the primitive man was probably distinguished by crisp, woolly hair and dark or black skin. The skull was dolichocephalic and prognathous : the arms long and strong, the legs short and thin, the calf undeveloped. The hairy covering of the whole of the body was more strongly marked than in any of the living human species ; the gait only half erect, with bowed knees. It would seem that the region on the earth's surface where the evolution of these primitive men from the closely related catarrhine apes took place must be sought either in Southern Asia or Eastern Africa, or in Lemuria. Lemuria is an ancient continent now sunk beneath the waters of the Indian Ocean which, lying to the South of the Asia of to-day, stretched on the one hand eastwards to Upper India and Sunda Island, on the other westward as far as Madagascar and Africa. Of the various human species that evolved from the primitive men by Natural Selection in the struggle for existence, probably two, at first the most widely divergent from each other, conquered the rest. The one, woolly-haired, migrated in part westwards, to Africa, in part eastwards, to New Guinea. The other straight-haired, was evolved further to the North, in Asia, and also peopled Australia. Persistent forms of both stems are in all probability still surviving, of the former in the Papuans and Hottentots, of the latter in the Australians, and in one division of the Malays.

We can next separate from Homo primigenius, as a second species, the Papuan men (Homo papua), and in this more extended sense, that we include under the name not only the more fully developed Papuan negroes of the present time, but also their lower, more ape-like ancestors that correspond with that woolly-haired division of the primitive species which moved from east to west. The present aborigines of New Guinea, New Britain, Salamon's Island, and so forth, and the vanished peoples of Tasmania (Van Dieman's land), seem to differ very slightly from these most ancient and least-exalted species of man. They all have woolly hair, and dark brown or quite black skins. They are all prognathous dolichocephali. Whilst the Papuans of to-day migrated from the original home of primitive man towards the rising sun, a branch of this stem probably moved westwards, and laid the foundations of the African population. The Hottentots seem to be direct descendants of this latter branch.

The Hottentots (Homo hottentotus) we regard as a third species. Not only the Hottentots, but the Bushmen and certain allied and low races, all confined now to Southern Asia, belong to this division. Prichard has, ere now, separated these from the genuine negroes with whom Blumenbach had classed them. They are more nearly allied to the Papuans than to the negroes in many respects, especially in the tufted growth of the hair on the head.

The true negro, or the man of Middle Africa (Homo afer), forms a fourth species, exhibiting the dolichocephalic skull in its extremest form. This species, like the three preceding, has crisp hair. The color is, for the most part, black, modified however, not infrequently, to brownish and sometimes almost fair, yellowish brown as in the Hottentots. To this Ethiopian species belong the majority of the inhabitants of Africa, save the inland denizens of the north and the Hottentots of the south. Probably this species should be divided into two, the true negro (Homo niger), dweller in the mid-regions of Africa, between the equator and 30° N. lat. and the Caffre (Homo cafer), dweller in the southern part of the continent, between 30° S. lat. and 5° N. lat.

With the man of New Holland (Homo australis), a very low fifth species, we commence the series of straight-haired men. We consider the Australians of to-day as the lineal descendants almost unchanged of that second branch of the primitive human race mentioned above, that spread northwards, at first chiefly in Asia, from the home of man's infancy, and seems to have been the parent of all the other straight-haired races of men. The Australians, like the four previous species, have dolichocephalic, prognathous skulls, and a black, blackish-brown, rarely clean brown skin. But they differ from these others in the smooth, straight hair, which is no longer woolly, as in the four previous species.

As the Polynesian or Malay man (Homo polynesius), we may mark off in the sixth place next to the Australian the species that still remains of Blumenbach's brown or Malay race, when the Australians and Papuans are eliminated. There is much likeness between these last and the Aborigines of Polynesia, that Australian island-world that seems to have been once on a time a gigantic and continuous continent. To the Polynesian species belong the people of New Holland, Otaheite, and most of the small isles of the South Sea, as well as a great part of the Aborigines of Sunda island and Malacca. From this species also the Madagascar people sprang. They have, in general, a clear brown skin, like the preceding set, and a less pronounced dolichocephalism. Many of them are rather mesocephalic, many even brachycephalic. In these, and in other peculiarities, as *e.g.*, the larger size of the brain, they seem to constitute the transition to the Mongolian and Caucasian races.

The yellow or Mongolian man (Homo mongolus) forms a seventh species, covering the greater part of Asia. To it belong the Indo-Chinese, Coreo-Japanese, and men of the Ural and Altai, *i.e.*, all the dwellers in northern and middle Asia, except the polar men ; also a great part of Southern Asia, and in Europe, the Lapps, Finns, and Hungarians. The broad shortened skull is very characteristic of this species ; certainly two divisions of it are mesocephalic, but none is truly dolichocephalic. The color of the skin is generally yellow or brownish-yellow, sometimes bright yellow, the hair straight, black, generally thin. In all probability the Mongolian species has evolved in Southern Asia from the Polynesian or Malay, and has spread thence east and north.

We regard the Polar man (Homo arcticus) as an eighth species of man. Here we place the Eskimos and the Hyperboreans, the closely-related inhabitants of the North-pole regions in both the eastern and western hemispheres. Clearly this species has arisen, by special adaptation to the Polar climate, from some branch of another human race, that had wandered northwards and had spread east and west. Probably it was a branch of the Mongolian species that settled in this region, and became the ancestor of Polar men. Usually the Eskimos are classed with the Mongolians, with whom they agree in the possession of a yellow complexion and straight, black hair. But they are separated from the Mongols by their long skull, and by other peculiarities.

The red or American man (Homo americanus), the ninth species of the human race, includes the Aborigines of the whole of America, always excepting the Eskimos in the northernmost part. These red-skins, as they have been called, have certainly not originated in America itself from an anthropoid ape of that continent. They have assuredly wandered thither from the old world. The most probable descent of the American Aborigines is from Mongols that have passed over from Asia. The Mongolian, of all the other human races, stands nearest to the American. Most of the Aborigines of the new world are mesocephalic; their skin is reddish or red-brown, more rarely yellow-brown. Some races in America seem to show that, besides the Mongols, Polynesians and mid-continental men wandered in the dim past into America and mingled with the former.

We regard as a tenth and last species the so-called Caucasian or mid-continental race, the white man (Homo Mediterraneus). This species has evolved farther and to greater beauty than all others, mainly by adaptation to the favorable conditions of existence afforded by Europe with its temperate climate and advantageous geographical conformation. In all probability this human species evolved in Asia, and clearly in its south-western part, either from a branch of the Polynesian (Malay) species, or from some more ancient parent form. During the time that the mid-continental species was wandering from Asia to Europe, and later on also, after repeated immigrations, it divided into a great number of different branches and twigs, whose ancestral relationship is yet, for the most part, to be worked out by the investigations of comparative philology. The Caucasians, pure and simple, the Basques, the Semitic peoples, and the Indo-European, can be marked off as four distinct races of this species. But, in addition to these, two "good species" of the human genus have to be separated and marked off from the mid-continental men. On the one hand is the Nubian (Homo Nuba) in Northern Africa (Dongolesi in the east, Fulati in the west). On the other hand are the Dravidians (Homo Dravida) in southern Asia, the aborigines of Ceylon and of the Deccan in Lower India.

It is of no great moment whether the human race is divided into the ten species just enumerated, or into a larger or smaller number. In consequence of the variable nature and the brief duration of any organic species, this question will always be as difficult of decision in respect to the human genus as to the genera of plants and animals. This inquiry, further, has no bearing at all on the idea dealt with in this lecture, that of the single origin of the human race and the subsequent radiation of its different species from a single original place, a so-called centre of creation. Of the many important proofs that support this view, I refer only at the moment to the recent interesting conclusions arrived at by Weisbach, as result of many comparative measurements of the body of different species of men (made by Scherzer and Schwarz in the Austrian Novara expedition).

That immense superiority which the white race has won over other races in the struggle for existence is due to Natural Selection, the key to all advance in culture, to all so-called history, as it is the key to the origin of species in the kingdoms of the living. That superiority will, without doubt, become more and more marked in the future, so that still fewer races of man will be able, as time advances, to contend with the white in the struggle for existence. Of the ten species of man mentioned above, the first, primitive man, is dead this long time past. Of the nine others, the next four will pass in a shorter or longer time, the Papuan, Hottentot, Australian, American. Even now these four races are diminishing day by day. They are fading away ever more swiftly before the o'ermastering white invaders. On the other hand, the rest of the human races are still to the fore for the present. The Ethiopian in mid-Africa, the Arctic man in the Polar regions, the Malay in southern Asia, the Mongol in Asia, will, for a long time yet contend, not without success, in the life-battle with the mid-continental man, because they can adapt themselves better than this last to the conditions of life in those regions, and especially to the climate.

Melancholy as is the battle of the different races of man, much as we may sorrow at the fact that here also might rides at all points over right, a lofty consolation is still ours in the thought that, on the whole, it is the more perfect, the nobler man that triumphs over his fellows, and that the end of this terrific contest is in the vast perfecting and freedom of the human race, the free subordination of the individual to the lordship of reason.

APPENDIX I.

Systematic Résumé of the eight Vertebrate Classes.

Acrania ...			1. Lancelet or Amphioxus.
Cranista ...	Monorrhina ...		2. Cyclostoma.
	Amphirrhina	Anamnia ..	3. Pisces.
			4. Dipnoi.
			5. Amphibia.
		Amniota ...	6. Reptilia.
			7. Aves.
			8. Mammalia.

APPENDIX II.

The fourteen Mammalian Orders.

I. Monotremata...	1. Water-Monotremata ...	Ornithorhyncus.
	2. Land-Monotremata ...	Echidna.
II. Marsupialia ...	3. Plant-eaters	Herbivora.
	4. Animal-eaters	Carnivora.
III. Placentalia...	Villiplacentalia	5. Prosimiæ.
		6. Ungulata.
		7. Cetacea.
	Zonoplacentalia	8. Carnivora.
		9. Pinnipedia.
	Discoplacentalia	10. Edentata.
		11. Rodentia.
		12. Insectivora.
		13. Cheiroptera.
		14. Simiæ.

APPENDIX III.

The Species of Anthropoid Apes and Men of to-day.

Anthropoida.	Asiatic (Satyri) Brachycephali ...	1. Lesser Orang (Satyrus morio).
		2. Greater Orang (Satyrus orang).
	African Pongines Dolichocephali ...	1. Chimpanzee (Pongo troglodytes).
		2. Gorilla (Pongo gorilla).
Homines.	Woolly-haired (Ulotrichi) Dolichocephali	1. Papuan (Homo papua).
		2. Hottentot (Homo hottentotus).
		3. Caffre (Homo cafer).
		4. Negro (Homo niger).
	Straight-haired (Lissotrichi). Mostly Brachycephali or Mesocephali, a few Dolichocephali ...	5. Australian (Homo australis).
		6. Malay (Homo polynesius).
		7. Mongol (Homo mongolus).
		8. Polar man (Homo arcticus).
		9. American (Homo americanus).
		10. Caucasian (Homo mediterraneous).

IV.—THE DIVISION OF LABOR IN NATURE AND IN MAN.

THE DIVISION OF LABOR IN NATURE AND IN MAN.

"In the study of Nature we must ever treat the one as we treat the many. There is no within or without: that which was internal is external. With speed then seize this holy, open secret."

TO choose division of labor as the subject of a scientific lecture may seem strange, or at least unnecessary, to not a few. For nearly every one is supposed to be sufficiently well versed in the nature and working of this important principle from the experience of every-day life. It is only necessary to cast a glance over any association of human beings in our civilised age to see everywhere division of labor, the various activities of the individuals that are working together for a common end, as one of the mightiest forces in civilisation.

In every workshop, in every factory, on every farm, a wise apportioning of different tasks to different workers is the first essential for a prosperous issue to the labor. Division of labor is of such fundamental importance in the evolution of the civilised life of man that its extent may be used as measure of the stage to which civilisation has advanced. The savage peoples, who have remained even down to the present day, standing, as it were, at the foot of the ladder, are as wanting in division of labor as in culture. Or that division is, as in the majority of animals, limited to the diverse occupations of the two sexes. On the other hand, we can find the main cause of the gigantic advances made during the last fifty years in our civilised life directly in the extraordinarily high degree of division in our modern work, especially in the regions of natural science and its practical application. Modern science, with its microscopes and instruments, modern commerce, with its railroads and telegraphs, modern war, with its needle-guns and mines—these are possible only as results of the infinite, wide-reaching division of labor of this our day, are possible only in that each instrument, each machine, each weapon, sets in motion in various wise, hundreds of human hands. How many new forms of labor and trades have evolved of late, what transformations have these wrought in the products of modern toil and in the characters of the toilers!

Besides these relations of division of labor that are known to the many, in Nature and in the life of man, occurs a series of special instances of that division not less significant but none the less wholly ignored, as a rule. Nay, strange as it may seem, these phænomena of division of labor that are the most important of all, the most widely-reaching, are actually not known to the majority of men. They have been in part discovered during the last ten years by the labors of scientific men. To this category belong especially those cases called by naturalists differentiation, specialisation, polymorphism of individuals, divergence of characters.[1]

I want in this lecture to awaken an interest wider and well deserved in these cases, of which so little is known, and the knowledge of which is of the highest moment to the understanding of human life.

Here it seems wisest to start from those conditions encountered in the life of animals lower than man, that appear most nearly related to the division of labor as known in human life. For here, as in so many other

[1] Darwin, in the fourth chapter of his celebrated work on the "Origin of Species," gives the name of "divergence of character" to that kind of division of labor that occurs between contemporaneous individuals of the same species in the same place, and which in their struggle for existence leads to the formation of varieties, and further of new species. This divergence of character, like the differentiation of organs, the key to comparative anatomy, depends as a morphological process on physiological division of labor. In both cases, as I have clearly shown, in the nineteenth chapter of my "Generelle Morphologie" (Berlin: Reimer, 1866, vol. ii., p. 253), the essence of the process is "the production of unlike forms from like foundations."

cases, the unprejudiced eye of the naturalist sees that human life-conditions are repeated in the life of lower forms of animals, and that the simpler structure of these last leads to the right understanding of the more highly-developed organs of man. Unfortunately it is too clear that the prejudice is still wide-spread that sees in the phænomena of human life something altogether special and supernatural, and that blinds men to every relationship and comparison between the phænomena of man and of other animals. Nevertheless the knowledge of the common basis of all phænomena, including those that have to do with man, a knowledge advancing with gigantic strides, is day by day destroying that artificial barrier. It is teaching the unbiassed inquirer that man is certainly the organism foremost in advancement, highest in development, but still only an organism having form and composition, functions and origin, in common with other animal organisms. The same laws of Nature, eternal, immutable, that reign over plants and animals, govern the whole life of man in its advancing Evolution.

"We must all trace out the circle of our destiny according to mighty, eternal venerable laws."

The phænomena of the division of labor are especially fitted to strengthen this conclusion. For higher organisation in animals, as in man, is essentially dependent upon the more marked degree of division of labor. Very many kinds of animals exist in whom the division of labor amongst the gregarious individuals is, as among the rudest savages, confined to that most simple social form, the diverse occupations and specialisations of the two sexes—in a word, to marriage.[1] But there are also many kinds of animals in

[1] Marriage—the different functions and specialisation of the two sexes—on which the family of man and other animals depends, is one of the earliest and most widely-spread forms of social division of work. In most animals this has led, as it has in man, the highest animal, to the remarkable differences in the bodily form and mental character of the two sexes. But these differences fail us in many of the lower animals, as the two sexes—recognised by the different forms of the reproductive organs—are not distinguishable externally. On the other hand, the sexual division of labor that constitutes the original

whom the division of labor amongst the individuals living together in a community goes much further, and leads to the organisation of those higher associations that we call states.[1]

The best known of these animal communities is the monarchical bee-state. At its head is a queen, in the strictest sense of the word, the mother of all her people. There are from 15,000 to 20,000 workers, from 600 to 800 drones or males. All the burden and toil of the hive falls upon the busy workers: the gathering of pollen, the preparation of honey and wax, the making of the comb, the care of the young. The lazy drones form the courtly household of the queen, and, like such a household among men, live only for pleasure, and have as sole office the reproduction of the species.

The economy and the remarkable social relations of the bee state are so generally known that we need not here lose time by a further consideration of them. Less well known, but still more interesting, are the communities met with in many other species of insects, especially the ants and the Termites, or white ants. In these insects we find in one and the same com-

essence of marriage has gone much farther in many animals than in man, and has given rise to bodily structures so wholly different in the two sexes that zoologists, before they knew their connexion, have very often described the male and female of a species as two distinct species, or even as animals of two distinct classes—as, *e.g.*, in many of the lower parasitic Crustacea and other parasitic animals. The moral basis, by which, in the more highly-civilised men, marriage has been improved to a great extent, is altogether wanting in many of the lower savages—the American Indians, many Negroes, the Australians, etc. Among these brutish men, with whom the female holds the position and receives the treatment of a useful domestic animal, there can be no talk of marriage on any moral basis. This could more easily be discussed in regard to the lower animals that live in rigid monogamy, as the doves, parrots and many other birds. Sexual choice, the sexual selection of Darwin, has, in addition to the sexual division of labor, influenced and altered in notable fashion the two sexes. On this the nineteenth chapter of my "Generelle Morphologie" treats (vol. ii., p. 244).

[1] On the communities of the lower animals—*e.g.*, of the bees and the ants—and their analogies with human states, *cf.* especially the "Untersuchungen der Thierstaaten" of Carl Vogt and Ludwig Büchner's "Geistesleben der Thiere" [translated by Annie Besant as "Mind in Animals," vol. i. of this series].

munity at least three, often four, and even five, different forms of individuals that have been evolved as results of a regular division of labor. The three forms always present in an ant community are : 1. the winged males ; 2. the winged females ; 3. the wingless workers. Of these the last far exceed the other two in number. If four forms are found the wingless workers divide again into two groups, workers pure and simple and soldiers. Each of these is of very different build from the other.

As with the bees, all the burden and toil of life falls on the indefatigable workers among the ants and Termites. The three other classes live for the most part for pleasure. The winged males and females that have as sole function the reproduction of the species, amuse themselves in the fine weather with pleasure flights and dances in the sunny air. The soldiers, whose function is to guard the state, can take no part in pleasures such as these, for they are, like the workers, wingless. So much the more, then, do they give themselves up to eating the sweet food, with which the community is continually supplied, even to excess, by the workers.

The food of ants consists, as is well known, of all kinds of plant and animal matters. Sweet juices are the favorite food, and amongst these stands foremost as the choice national dish a honey-like juice that the Aphides or plant-lice furnish. These little insects have two ducts opening on the back, whence this pet delicacy of the ant exudes. The ants suck the sweet Aphis honey just as we take milk from the cows. By stroking the Aphides with their feelers the ants induce them to yield up their honey. The most energetic farmer can be no more careful in the rearing and breeding of his cows than the ants in the rearing and breeding of their milk-providers. If a branch of the shrub on which the plant-lice dwell becomes withered the ants carefully remove the Aphides on it to a fresh green branch. They construct very cleverly covered ways from their nest to the shrub. Nay, they even place such Aphides as are housing at the base of the nest side by side with those already in their nests, building there special stalls, so as to have the valuable milk-producer always at hand.

Whilst thus some of the workers in the ant community carry on the breeding of animals or provide the hive with other food, another part is concerned in the maintenance, cleansing, and extension of the dwelling wherein all the people of the ant community are gathered together. What are our mighty palaces, castles, cathedrals, hotels in comparison with these buildings, in which many thousands of individuals live together in peace? It is true that on the exterior the houses of most species of ants seem sufficiently rude and shapeless. But within them lies hidden a labyrinth of many hundred winding ways, corridors, roofs, connected in most convenient fashion by thousands of rooms and chambers. Many of these are nurseries in which the young progeny are reared.

The care of these latter, and in especial of the chrysales, generally known by the false name of ant-eggs, falls to another part of the workers. These nursemaids, filled with the tenderest love for their charges, drag them out into the fresh air in fine, sunny weather; but as soon as the chill of evening comes on, they take them back again into the warm interior of the hive. The soldiers, though they are bigger and stronger, take no part in all these arduous labors.[1]

There are, besides, other species of ants, amongst

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[1] Division of labor reaches its highest development in the Sahubæ, the leaf-carrying ants of the Brazilian woods (*Œcodoma cephalotes*). In these there are not less than three kinds of workers, altogether distinct in size and shape; so that, including the winged males and females, not less than five different forms of ants are living together in the same community. The larger number are small-headed workers, that strip the trees of their foliage, biting off the leaves and carrying them off to line their artificially constructed homes. Amongst these, larger workers are running about with very large, smooth, bright heads, that seem to superintend and direct the work, and perhaps also to serve as protection for the little workers. Nothing certain is known up to the present time as to the significance of the third form of workers, that differ from the second in the thick, hairy covering of the colossal head, and one large median frontal eye. On these Sahubæ, and on the robber-ants or Ecitones, *cf.* the very interesting observations of Walter Bates, in his excellent work of travel, "The Naturalist on the Amazons."

whom all the workers have become soldiers. These, therefore, have already realised that human ideal of civilisation of this later age, the modern military state. Hence these soldier-communities are obliged either to carry off the domestic workers as slaves, or to live by theft and plundering. The notorious South-American robber ants of the genus Eciton follow the latter plan. Here, again, we encounter in this species four different forms, the winged males and females, and two kinds of wingless workers, differing widely in shape and size. The smaller workers, who form the chief part of the whole Eciton community, serve in a body as common soldiers. The larger workers, on the other hand, distinguished chiefly by a very large head and by immense mandibles, serve as officers to the army. Generally there is one officer to a company of some thirty men. On the march, the officers are ranged on both sides of the long column of warriors, and often climb to high standpoints, whence they can overlook and direct the march of the troops. Commands and plans, as is general with all intellectual communications, are given in these, as in other ants, so far as we know, not by voice, but by a speech of gesture and touch. Especially are the antennæ of use, partly as telegraphic instruments, that give by their vibratory movements signals at a distance, partly for the communication, by immediate contact, of wishes, feeling, and thanks to those at hand.

The army of robber ants on its march, like the Vandals and Huns in the age of migrating peoples, devastates all regions that it traverses. They are with reason objects of exceeding dread to the Brazilian Indians. All living things that cross their path are, without remorse, without mercy, seized and slain. Spiders and insects of every order, especially larvæ and pupæ, even birds and small mammals succumb to their attack. The man who is unfortunate enough to happen upon such an army of nomads is surrounded in a moment by dense black swarms, that run by the thousand, with incredible anger and swiftness, up his legs, and bite into his flesh with their sharp teeth. The one remedy is to run with all swiftness to the rear of the army, and to tear away at least the distal part of the warrior that has bitten his way into you. Head and jaws, as a rule, remain embedded in the wound, and often give rise to unpleasant sores.

Terrific, blood-thirsty, as are these nomad hordes on the war path, they are equally amusing and merry when they bivouac; when satiated with food, in the best of humors, they give themselves up to peace and pleasure in the sun-lit sylvan places. At first they clean their antennæ with their front legs. They lick the dust off one another's hind legs. In this they give evidence of petulancy and humor, and not unfrequently the soldiers, carrying their sport beyond bounds, fall a-brawling.

More noteworthy even than the military communities of the Brazilian Eciton are the slave communities, the so-called Amazon states, met with among several of our native ants, especially the blood-red and light-colored ants (*Formica rufa* and *Formica rufescens*). Among these ants we find only three forms, *i.e.* only one form of wingless workers besides the winged males and females. But these not only labor; they steal, from the hives of other smaller blacker ants, the pupæ. These they rear; these they compel to perform, like slaves, all the work of the strange hive in which they are. As a rule the slave foray of these Amazon ants is carried on in such a way that the whole force of the black ants is engaged in free fight in the open by the main body of the lighter-colored ants, and in the meantime a small band of the latter falls upon the home of their foes, and steals the pupæ from the hive deserted of its defenders. The study of the bitter contest is very interesting. The wounded, even the corpses of the warriors that have fallen, are as once on a time in the Trojan War, carried off by their friends from the bloody turmoil of battle and brought into safety behind the lines of the contending hosts. But the most remarkable thing is that the black slaves that are bred from the stolen pupæ not only do all the work of the nest for their masters, building, food-gathering, attending to and rearing the young, but even later on aid them in their marauding excursions, and carry off the stolen youth of their own race into slavery.[1]

We find, then, in the Amazon communities of the German ants the same system of slavery that was brought to an end in the States of North America by the late war. Generally laborious efforts are made to designate as the outcome of "instinct" these and similar arrangements in the lower animals that astound man by their undeniable identity with his own institutions. There is a belief that the word "instinct" is an explanation. Few words have led to so vague, so perverted a conception of a vast domain of momentous phænomena as this word "instinct." When the word is used, the notion is that every kind of animal was by a single act of creation sent into the world with a definite sum of impulses and faculties, that it had a special mode of existence marked out for it by its creator, a sort of inexorable law of life, and that it must live after this definite plan, rigidly, unalterably. Nothing is more erroneous, more opposed to the truth than this wide-spread idea. Just as the individual species of animals have not been created as they now are, so their special instincts, the mental stock in trade of the species, have not been thus created. They have evolved from one common fundamental condition by division of labor in the central nervous system of the different species of animals, as their whole organisation has evolved.[2] A distinguished philosopher has well said that he who draws a line between instinct and reason gives in himself, in doing thus, the best

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[1] The slave states of the Amazon ants, beyond dispute the most remarkable social arrangement in the wonderful ant-world, had been observed during the last century by the celebrated Huber of Geneva. Later these observations were confirmed by Latreille, Carl Vogt, and several other zoologists. See Carl Vogt's "Vorlesungen über nützliche und schädliche, verkannte und verlaümdete Thiere" and Ludwig Büchner's "Geistesleben der Thiere."

[2] The idea of creation is wholly unscientific. In its place true science puts the idea of Evolution. On this point see the first lecture (p. 6) of my "Natürliche Schöpfungs-geschichte," a series of popular scientific lectures on the study of Evolution in general, on the writings of Darwin, Goethe, and Lamarck in particular, as to the application of Evolution to the origin of man. and on other related fundamental questions of science. (Berlin: Reimer, 1868. Sixth Edition, 1875.)

proof that he has never observed carefully with keen, unbiassed eye the life and labors of the lower animals, and especially of insects.

If the state organisation amongst ants and bees just described, if, as a whole, all the different economical and life relations of the lower animals, if in especial their division of labor are to be regarded as the outcome of "blind instinct," with equal justice must we call it "blind instinct," when the Eskimos make their tents of reindeer skins, the North-American Indians theirs of buffalo-hides, the red-skins of Brazil theirs of palm-branches and the leaves of the banana. We must, in like fashion, call it "blind instinct" that many South-Sea Islanders live almost wholly on fish, that the Chinese eat little but rice, and the Gauchos of the South American pampas little but meat. We must, in like fashion, call it "blind instinct," that the peoples of Europe, with a single exception, have retained the monarchical form of government, like the bees; and that the peoples of America, again with a single exception, have preferred the republican form of government, like the ants.

The fact is that in this, as in all things, custom and adaptation to surrounding conditions determine the mode of life and social arrangements of man as of other animals, and that this mode of life becomes at last, by usage and habit, second nature. It takes root in this way the more firmly in the race the larger the number of the generations through which it has been transmitted. Adaptation and heredity, in their eternal mutual action and re-action, *i.e.*, Natural Selection in the struggle for existence, are the eternal formative impulses, the Evolution forces, that give rise, by purely mechanical laws, to all the endless variety, both in the organisation and modes of life of animals, and in their soul-life, the so-called instinct.[1]

Every scientific man who is intimately acquainted

[1] I have shown in the eleventh lecture (p. 203) of my "Natürliche Schöpfungs-geschichte," that the action and re-action between the internal formative impulse of heredity and the external one of adaptation, can give rise to all the endless variations of the plant and animal organisation in a purely mechanical way, *i.e.*, according to

with the history of Evolution in animals is convinced that all these various ant species, with their varied kinds of labor, have evolved from common ancestors, long dead, who had not these different divisions of work. Those red primordial ants that lived for many thousands of years, probably in the Cretaceous epoch, had as slight a foreshadowing of the advanced division of labor, seen in the various ants of these days, as our old German forefathers of the Stone Age had of the lofty civilisation of the nineteenth century. The men, like the ants, have slowly, gradually toiled up the pain-haunted path of advancing Evolution. Even at this hour some ants exist that know nothing of the highly-developed division of labor met with in the civilised ant communities, and bear to these last a relationship none other than that of the red aborigines of Australia and Africa, to the civilised nations of our own time.

If we turn to cast a glance over the mental Evolution of man in that grey past in which the ancestors of the civilised races of to-day had not advanced beyond the brute conformation of the rudest savages, the Australian negro, the Papuan, the Bushman, etc.; if we observe how slowly, how gradually the human race has, in the struggle for existence, gained by infinite effort its specially human character, we see clearly that the soul-life of man has evolved from the same crude foundations as that of other animals, and that the "instinct" of these latter is distinct from the reason of man in quantity only, not in quality, in details, not in essence. This holds as to the soul-movements of sensation and will as of those of thought, of judgment, of reason. But it will be yet clearer to any one that the phænomena of division of labor referred to have evolved in human life in the same way as they have in that of lower animals, in consequence of kindred conditions of adaptation, if he studies the phænomena of comparative division of labor that are even now to be discussed.

Let us pass in thought from the hot tropical woods

physical and chemical laws. In my "Allgemeine Entwickelungsgeschichte (vol. ii., of "Generelle Morphologie," p. 223, *et. seq.*), I have given proofs of this in detail.

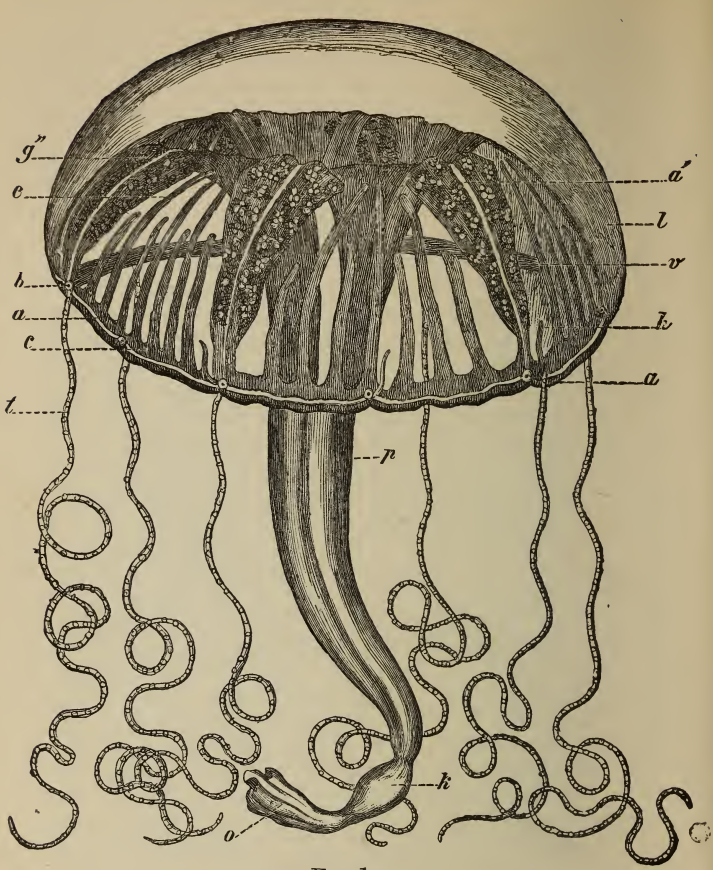

Fig. 1.

A free-swimming Medusa (Carmarina hastata) of the family Geryonidæ. *a*. Nerve-ring, within the margin of the umbrella; *a′*. Radiating muscles; *b*. Auditory vesicle; *c*. Circular vessel within the margin of the umbrella; *e*. Centripetal canals given off from the last; *g″*. Triangular, leaf-like ovary; *h*. Circumferential organs of the umbrella; *k*. Stomach; *l*. Gelatinous mass of the umbrella; *o*. Mouth; *p*. Peduncle of the stomach; *t*. Tentacles or feelers; *u*. Outer wall of the umbrella; *v*. Velum or swimming membrane.

of Brazil, where the robber ants and the Sahubæ lead their checkered lives, to the cool shore of our northern German coasts, when a fresh north wind has thrown up on the sandy strand a number of so-called sea-nettles or jelly-fish (the Medusæ of the zoologists). Whoever has walked with eyes open on the shore of the Baltic or of the North Sea, is acquainted assuredly with these jelly-like animals that are often cast up by the thousand from the waves. When we see them lying there in heaps, a slimy, shapeless mass of jelly, we can form no clear idea as to the wondrous beauty that these Medusæ swimming in the sea, exhibit. But if they are placed with some of the water in which they swim in a large glass vessel, we are filled with wonder at the grace of their swift movements, the delicacy of their shimmering hues, the elegance of their flower-like form (Fig. 1).

The commonest of our large North-German Medusæ is called Aurelia aurita. Fig. 2 in vertical section, Fig. 3 seen from below.

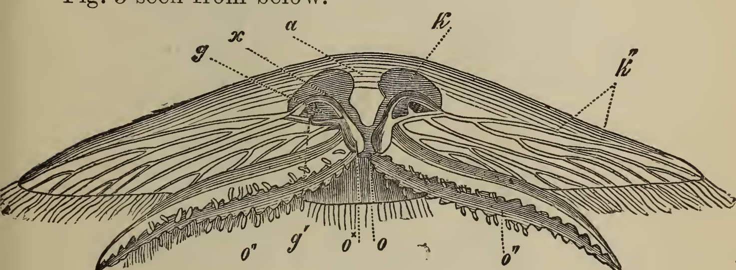

Fig. 2.

An eared jelly-fish (Aurelia aurita), from the Baltic, in vertical section. *a*. Gelatinous umbrella; *o*. Mouth; *o″*. Two of the four oral tentacles, beset with sexual buds; *o′*. Section through their bases (the pillars of the mouth); *g*. Ovary; *k*. Stomach; *k″*. Branching vessels running from the stomach to the margin of the umbrella; this last beset with many delicate tentacles.

The gelatinous, transparent body of this Aurelia has on the whole the shape of a shallow glass bell. In the middle of its under surface is the mouth (Fig. 2 *o*), surrounded by four long, very mobile tentacles (Fig. 2 *o″*,

Fig. 3 *b*.) From the circumference of the bell-shaped disk or umbrella hang many very fine tentacles (Fig. 3 *t*.) Further, eight sensory vesicles (Fig. 3 *a*) are placed at regular intervals within the margin, and probably function as both eyes and ears. The mouth *o*, leads into a stomach (Fig. 2 *k*, Fig. 3 *v*), whence many radiating, branching, digestive canals (Fig. 2 *k*, Fig. 3 *gv*) run to the margin of the disc, uniting there into a single circular vessel. Around the stomach lie four pouches (*c*) placed in the form of a cross. In these the eggs of the Medusæ are formed (Fig. 2 *g*, Fig. 3 *n*.)

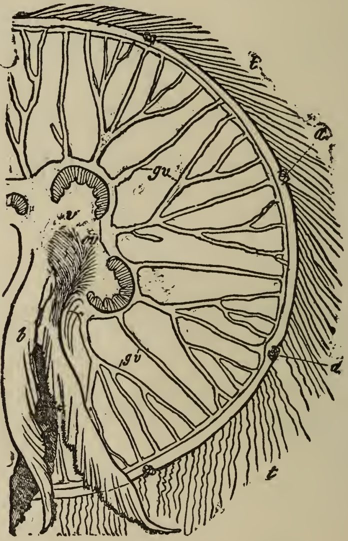

Fig. 3.

The same, seen from below: the lower half has been removed. *a*. Sense-vesicles (eyes and ears) on the margin; *t*. Tentacles; *b*. Oral tentacles; *v*. Cavity of the stomach; *ov*. Ovary in the lower wall of the last; *gv*. Branching radiating canals, running from stomach to margin and there combining in a circular vessel.

The division of animals to which the Aurelia and its allies, the jelly-fish, belong, bears the name of Hydromedusæ. To the same group belong the Hydroid-polyps, altogether dissimilar from the free-swimming jelly-fish in external aspect, attached to the sea-bottom, or sedentary on seaweed. A solitary little animal, belonging to this group, the small fresh-water polyp or hydra (Fig. 4), lives, and is widely distributed, in our ponds and ditches. This elegant little creature is found very frequently on the under aspect of duckweed or the leaves of the water-lily. In the contracted state

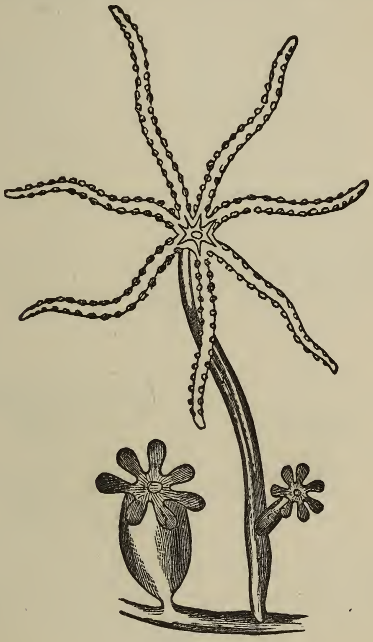

FIG. 4.

(Fig. 4 to the left) it is a green or orange-red little mass, the size of a pin's head. Extended (Fig. 4 to the right) it is a thin thread, an inch in length. By one end it is firmly fixed. At the other is the mouth, surrounded by a circle of from four to eight tentacles. The mouth in this case leads into a simple gastric cavity. Our fresh-water polyp reproduces itself in the simplest fashion. Either by eggs or by budding, it is ever producing creatures like itself. But in the sea live many hydroid polyps, scarcely distinguishable from the fresh-water one, but nevertheless reproducing themselves in a manner very remarkable and very different, *i.e.* in connexion with the Medusæ just described.

For from the eggs of the Medusæ other Medusæ do not arise, but hydraform polyps, and these latter produce by gemmation not polyps but Medusæ again. Hence in these Hydromedusæ the daughter does not resemble the mother, but the grandmother. The first generation is like the third and the fifth, the second generation as the fourth and sixth. But the two kinds of beings of one and the same species are so different that they were regarded in earlier days, ere their relationships were understood, as two entirely different groups of animals, Medusæ and Polyps.

Among the higher Medusæ or Acraspeda, to which our Aurelia (Figs. 2, 3) belongs, a hydra-polyp is developed from the egg (Fig. 5) and multiplies by gemmation.

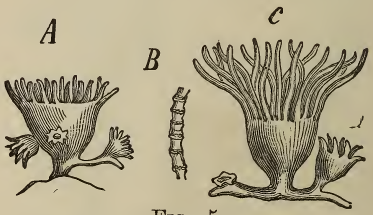

FIG. 5.

Hydra-polyps (Scyphistoma), developed from the eggs of an acraspedote Medusa. A. A polyp with three buds. B. One tentacle of the last, strongly magnified. C. A polyp with stolons, whence two buds take origin.

From the oral extremity of each bud grows a series of young Medusæ, forming a body not unlike the cone of a fir (Strobila, Fig. 6.)

One after another the ripe young Medusæ detach themselves from the inferior part of the Strobila and set out on their wanderings as the far more highly organised acraspedote form (Figs. 2, 3.)

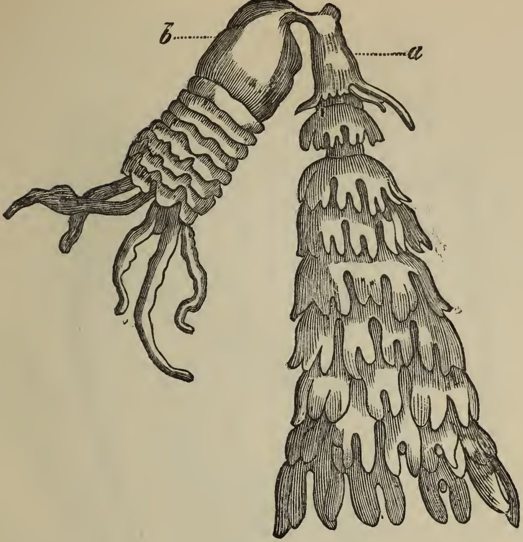

FIG. 6.

Two Medusæ cones (Strobilæ), developed by distal gemmation from two hydra polyps (Fig. 5 c.) Each Strobila consists of eight young Medusæ, placed in a row, one after the other, like links in a chain. *a* the older, *b* the younger Strobila.

Amongst the lower or craspedote Medusæ, on the other hand, to which the Carmarina belongs, the polyps, or first generation that are developed from the Medusæ eggs, give rise, by gemmation, to a tree-like, branching or creeping colony. From this colony, again, Medusæ spring, detaching themselves later on ; or special buds (metamorphosed polyps), in each of which many Medusæ originate by gemmation (Fig. 7 *f.*)

Such a colony may, therefore, bear two different organisms, wholly unlike externally, that have sprung by division of labor from the same original hydraform polyp. The one set of polyps, the long-stalked food polyps (Fig. 7 *a*, *b*) are concerned only with eating, drinking, digestion, but can form no more eggs. They possess an open mouth and a circle of tentacles, but

FI 7.

A creeping polyp colony (Campanularia Johnstoni). On the creeping root stock (*e*) are placed two hydra polyps that are as result of division of labor wholly diverse in their development. The long-stalked are food polyps (*a-d*), the short-stalked are reproductive (*f*.) The latter form buds that develop into Medusæ, and swim away (*g*.) The former are able to withdraw (*b*) their outstretched bodies within a horny envelope (*c*.) Their stalk (*d*) is annulate at top and bottom.

they have lost the power of reproduction. The second set of polyps, the short-stalked reproductive ones, or "nurses" (Fig. 7 *f*), have lost their tentacles and their oral openings are closed. On the other hand, many buds arise from the wall of their gastric cavity, that detach themselves later on (Fig. 7 *g*), and develop into free swimming Medusæ that still later carry eggs.

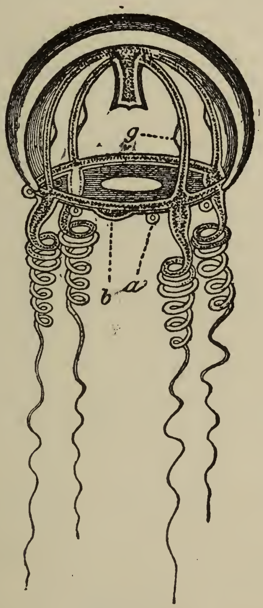

FIG. 8.

A Medusa (Eucope). In the middle of the bell-shaped body hangs the stomach, whence four digestive canals run to the margin of the umbrella. In the middle of these canals lie the eggs (*g*.) From the margin of the umbrella (*b*) hang four tentacles. Behind these are eight auditory vesicles (*a*.)

A similar series of alternations between two or even three generations widely differing is very general among the lower animals, and is known as alternation of generations. But these remarkable alternations may be regarded as the result of division of labor, in short, as a division of labor that comes into play in the domain of developmental life.[1] The two distinct forms, the Medusæ, from whose eggs the polyps arise, and the polyps, from whose buds the Medusæ arise, are two different forms of one and the same species, evolved through division of labor from a common ancestor, in the same fashion as are the different kinds of workers in the ant community.

The clearest light is thrown upon the successive alternations of generations in the Medusæ and polyps by the marvellous free-swimming colonies of the Hydromedusæ, that the zoologists call Siphonophora or jelly-fish communities. These are amongst the most magnificent sights of the southern seas. They appear at certain times in dense swarms in the Mediterranean, *e.g.* in the straits of Messina. As a whole they may be compared to a swimming flower-stem laden with beautiful flowers and fruits of every hue, all whose parts seem fashioned out of transparent crystal, whilst they have an animal's life, soul, spontaneous movement, sensation, consciousness. Let us look a little more closely at the complex organisation of one of these wondrous colonies. (See the succeeding figures from 9 onwards, and the accompanying explanations.[2])

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[1] Rudolph Leuckart, in his work on "Polymorphismus der Individuen, oder die Erscheinungen der Arbeitstheilung in der Natur" (Giessen: Ricker, 1851), has clearly explained this idea, that "the alternation of generations in animals has originated through division of labor in the domain of developmental life." Correct as this idea is in many cases, it cannot lay claim to accuracy in all instances. There are, in fact, many cases of alternation of generations that are clearly to be looked upon as periodic reversions or atavism, and are explicable on the principle of suspended or latent heredity ("Generelle Morphologie," vol. ii. p. 181, and "Natürliche Schöpfungsgeschichte," p. 161.)

[2] A more detailed account of the free-swimming Siphonophora colonies and their marvellous division of labor may be found in the

Fig. 9.

A Siphonophora (Physophora) swimming in the sea. *a*. Pneumatophore or swimming bladder at its upper end. *m*. Nectoca-

work of Leuckart, already referred to, on Polymorphism (p. 119), and at p. 104 of Carl Vogt's essay on the complex animal colonies (third part, p. 162.)

lyces or swimming balls. *o*. Opening of the umbrella. *t*. Tactile polyps. *g*. Egg-forming female individuals. *n*. Nutritive individuals.

Around one of the elastic central stems, often many feet in length, of the common axis are arranged hundreds, often thousands, of Medusæ and polyps, that have by division of labor attained very different shapes and structures. The central stem itself is no other than a very elongated simple polyp body, closed below, but expanded above into a swimming bladder, or pneuma-

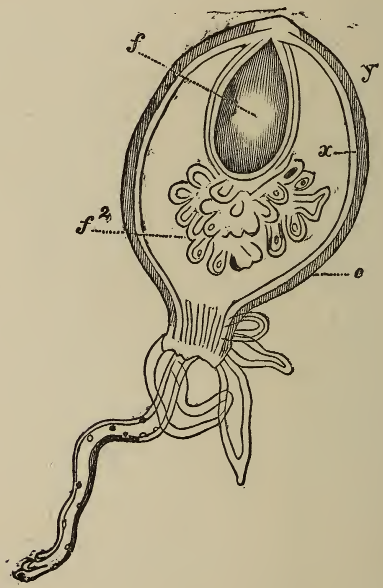
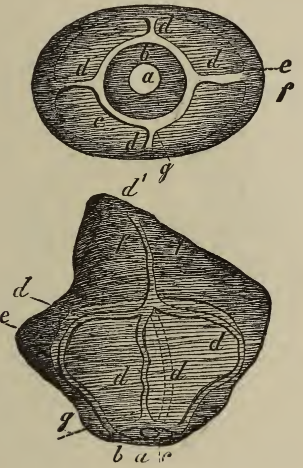


Fig. 10.

Swimming bladder or air bladder of a Rhizophysa. *c*. External wall. *f*. Large air bladder enclosed in an air sac. f^2. Tufted appendages from its inferior aspect. *xy*. The two body layers, formed from the primary layers of the blastoderm. *x*. Endoderm or digestive layer. *y*. Ectoderm or epidermal layer.

tophore, filled with air. This, buoyant upon the surface of the sea, supports the whole colony (Fig. 10.) Below this air vesicle is a double row of bell-shaped Medusæ. These, by their common contractions, that are subordinated to the will of the animals, move the whole community through the sea, and hence take the name of motor polyps (Fig. 9 *m.*) Each motor polyp (Figs. 11, 12) is essentially a simple Medusa, but without arms, without organs of digestion or of reproduction. Whilst they are formed solely for swimming,



Figs. 11 and 12.

A swim-bell of a compound Hydrozoön (Forskalia.) Fig. 11 from below, Fig. 12 side view. *a.* Opening of the cavity whence in swimming the water is driven out. *b.* Swim-membrane or velum. *c.* Circular vessel in the margin of the umbrella. *d.* Four radial vessels. *e.* Swim-sac. *f.* Cartilaginous tissue of the bell. *g.* Eye-spot.

they have lost the other functions of the Medusæ. Their motion forwards results from the repulsion of the sea-water, which is expelled by regular contractions from the opening of the bell (Fig. 11 *a*, 12 *a*) as they swim along.

Below the double row of swim-bells are a number of different animals of various colors ornamenting the whole of the inferior part of the stem. First there is a dense mass of leaf-like or bract-like pieces, grouped round the axis, like the leaves of a fir-cone. Beneath these, when danger threatens, the other individuals can flee for protection. These so-called bracts or hydrophyllia are retrograde Medusæ that have taken on the sole function of passive organs of protection, of shield-bearers (Fig. 13 *k*.) They consist for the most part

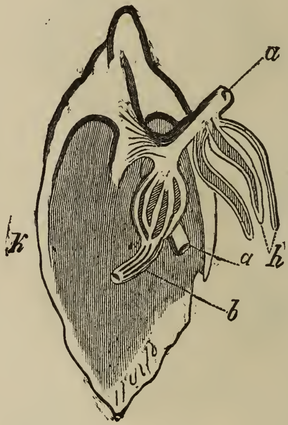


FIG. 13.

A bract or shield-bearer (*k*) of a hydra-colony (Stephanomia.) A nutritive polyp (*b*) and several tactile polyps (*h*) are protected by it.

simply of a cartilaginous jelly-like mass traversed by a nutritive canal. Beneath their umbrellas we find hidden a number of pear-shaped bodies, with a mouth opening, that seizes food greedily, and with digestive cells of a hepatic nature. It can attach itself firmly by suction by means of its octagonal oral margin (Fig. 14 *f*), which is capable of extraordinary expansion. These have, as feeding polyps, the duty of taking in

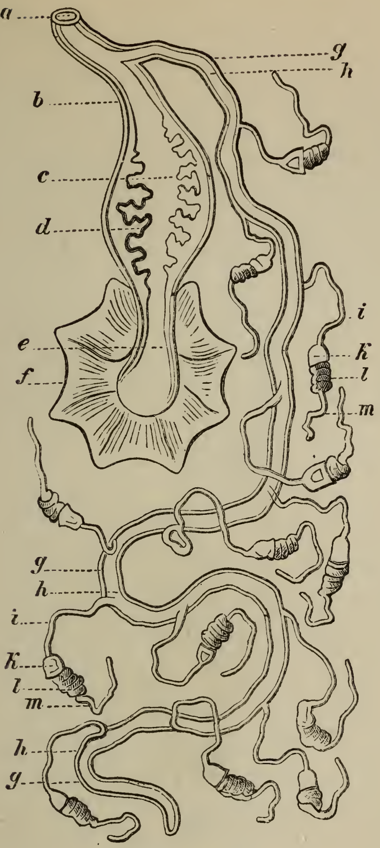


FIG. 14.

A nutritive polyp and tentacles of a hydra colony (Anthemodes.) *a.* Point of attachment of the polyp to the stem; *b.* Body-wall of the polyp; *c.* Its gastric cavity; *d.* Hepatic cells. *e.* Proboscis. *f.* Mouth aperture extended into the form of an octagonal disk, and attached by suction. *g.* Wall of the tentacle. *h.* Its cavity. *i.* Secondary tentacles. *k.* Bell-shaped investment of the thread-cell battery. *l. m.* Terminal thread of the latter.

and digesting food for the whole colony. A very long, exceedingly mobile tentacle (Fig. 14 *h*) is attached close by the base of each nutritive polyp. This is beset with many finer tentacles of a secondary order (*i*), each of which bears a battery of thread-cells, of very complex structure. The thread-cells, of which each battery contains several hundreds, are delicate microscopic poison darts, beset with hooks, and connected with a poison vesicle. They produce a burning sensation in the human skin like that due to stinging-nettles. With these terrific lethal weapons the long tentacle on the look-out for prey fishes ever in the water around, ready in a moment to embrace the unsuspecting victim that approaches it, and to pierce it with thousands of deadly poisoned darts. In Anthemodes (Fig. 14) the battery, densely filled with thread-cells, has the form of a spirally-twisted ribbon (Fig.

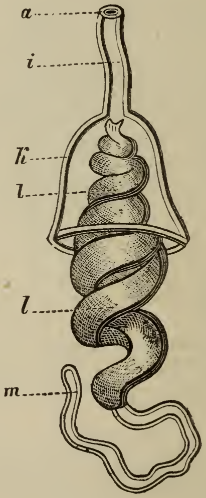


FIG. 15.

A secondary tentacle (*i*) from Fig. 14 highly magnified. *a*. Point of attachment to the tentacle. *l*. Battery in the form of a spirally-rolled ribbon. *k*. Bell-shaped investment of the upper half. *m*. Terminal thread of the battery.

15 *l*), hidden in its upper half by a little bell (Fig. 15 *k*), extended into a fine terminal thread (*m*) below.

With these terrible robber hordes harmless polyps are commingled in larger numbers. These represent the intelligence of the community. They have their internal and external body-layers adapted to testing and forming judgments, after the fashion of sense-organs. They feel, will, and think for the rest of the

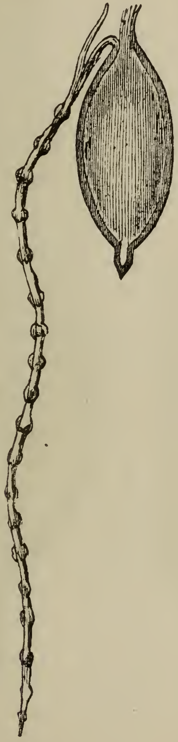


Fig. 16.

A tactile or sense polyp of a compound Hydrozoön (Agalmopsis). A knobbed tentacle is attached to its base.

citizens of the state, amongst whom these mental functions are developed either far less strongly or not at

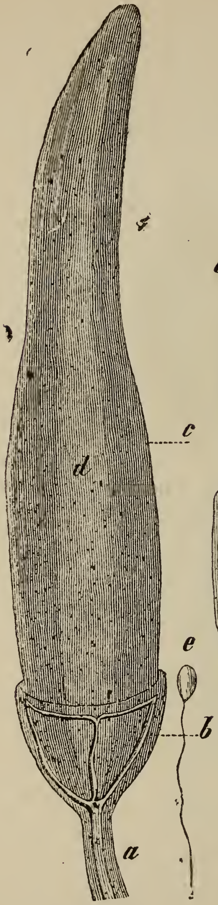


FIG. 17.

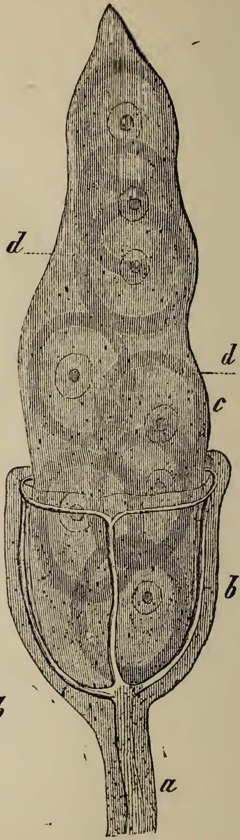


FIG. 18.

Fig. 17. Male of a Compound Hydrozoön (Hippopodius.) *a.* Stalk by which the Medusa bell (*b*) is connected with the

stem. Four radiating canals, connected at the margin by a circular vessel, traverse the disk. *d.* Gastric cavity ending blindly. *c.* Spermatozoa, formed in the wall of the latter.

FIG. 18. Females of the same. References as in Fig. 17. Eight large eggs (*c*) are visible in the wall of the gastric cavity (*d.*)

all. These sense polyps or tactile individuals (Fig. 9 *t*, Fig. 16) are like their nutritive fellows, but mouthless, and are provided with one long, delicate tentacle, endowed with very sensitive properties in place of the armed predatory tentacles. Finally, we find amongst all these different forms of individuals borne on the same stem the two sexual animals (Fig. 9 *g*) whose function is the reproduction of the whole colony. These are very generally placed in groups, like bunches of grapes, near a tactile polyp. Male (Fig. 17) and female (Fig. 18), very dissimilar in form, nevertheless, like the swimming motile polyps, are based upon the fundamental plan of the bell-shaped Medusæ. In the wall of the gastric cavity of these sexual Medusæ the reproductive cells are developed. The mouth is closed. The males are in general elongated, the females more rounded in shape.

Different as all these various individuals of the Siphonophora community are in shape and in function, they none the less are all so intimately connected one with another that the older observers regarded the whole colony as a single individual, and the separate individuals in the colony, the Medusæ and the polyps, as organs of that individual. Certain individuals are hollow internally, and their cavities communicate freely with the cavity of the central stem, with the cavity, in short, of the chief polyp, on whom these others are placed. The nutritive fluid prepared by the feeding polyps is transmitted from them to the central stem-polyp, and thence is given out in portions to the other individuals of the community as from a central soup-kitchen. Each gets as much of this Spartan diet as its interior, *i.e.* the cavity of its body, can contain.

Further, the intimate communal connexion of all the individuals shows itself also in the fact that a common volition animates the whole colony. After violent injury to one individual the pain is shared, as it were, with all the rest, causing the whole swimming community to contract or to flee hastily away. In all this the voluntary movements of the citizens of this state are clearly co-ordinated. But, without any interference with the collective will of the state, each adult citizen has, to a certain extent, an individual will also, and can, if by accident or voluntarily it is separated from the rest, live an independent life for a long time.

The strikingly different structure and function of the different individuals of the Siphonophora are entirely the result of division of labor carried out very completely. All these various forms can be traced back to two fundamental ones; the first, polyp-shaped, fashioned like the Hydra, and the second Medusiform, fashioned like the Aurelia. From the hydraform polyp originate by specialisation: 1. the central stem or central polyp with the pneumatophore (Fig. 9 *a*); 2. the nutritive polyps and their prehensile tentacles (Fig. 14); 3. the tactile polyps with their sensory tentacles (Fig. 16.) On the other hand have arisen, by specialisation, from the Aurelia-like Medusæ: 1. the swim-bells or motile polyps (Figs. 11, 12); 2. the bracts or protective individuals (Fig. 13); 3. the male Medusæ (Fig. 17); 4. the female Medusa (Fig. 18.) And even the two fundamental forms, the Medusa and the hydra-polyp, are again developed primarily from an earlier primal polyp-form of the simplest nature.

Not only does Comparative Anatomy teach us with certainty that actually in the grey past, many millions of years ago, only simple polyps existed as representatives of the whole class of Hydromedusæ, and that from these later on the simplest Medusæ, and much later the connected Siphonophora colonies, evolved by gradual advances in the division of labor. The history of the development of the individual Hydromedusæ teaches us the same truth, with the same certainty. For ontogeny, or the individual evolution of each organism, *i.e.* the series of forms through which it passes from the egg to the adult condition, is for us a replica in the briefest of time, and in broad, general outlines of its phylogeny, its ancestral history, its palæontological evolution, *i.e.* in other words, the series of forms through which the ancestors of this organism have passed in succession since the appearance of organic bodies on the earth.[1]

If we now, keeping in mind this important connexion between ontogeny and phylogeny, between the evolution of the individual and of his ancestry, glance at the individual evolution of the Siphonophora, we find that from the impregnated egg of the Siphonophora colony nothing more than a very simple polyp develops. This elongates and becomes the central axis of the whole colony, giving rise by gemmation to all the other individuals, polyps and Medusæ alike. At first, in the young bud-state, these are very similar and indistinguishable. Presently and gradually each individual, increasing in size, takes on by division of labor its own special form. Of course, this division of labor, as it advances during the first few weeks in the course of the evolution of the egg, is at first acquired by inheritance from the ancestors. But this inherited division of labor of the Siphonophora community reminds us, beyond a doubt, of the original specialisation arising from adaptation among the earlier Hydromedusæ, a specialisation that has been evolved in the course of thousands of years by adaptation, by use, by habit.

The remarkable specialisation of the Siphonophora, the association of the differently constructed individuals in a single state, whose citizens are connected not only intellectually but bodily, seems, perhaps, at first an extraordinary and mysterious phænomenon of nature. In reality a similar kind of specialisation is

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[1] In the twelfth lecture of my "Natürliche Schöpfungs-geschichte" (p. 227), and in chapter xxiii. of my "Generelle Morphologie" (vol. ii., p. 371), I have dealt in detail with the exceedingly important causal nexus between ontogeny and phylogeny, *i.e.* the internal causal connexion between the evolution of every organic individual and the evolution of the series of its ancestors since the commencement of organic life on the globe (a connexion that, in consequence of the action and reaction of the laws of heredity and of transmission, is of necessity mechanically conditioned).

very widely spread. In truth, all the higher plants present us with something of the same kind, for every branching flowering plant, every blossoming tree, every flower-stalk, is in all essentials composed after the manner of the Siphonophora colony. The vegetable individual that corresponds with the single polyp or the single Medusa is the shoot, *i.e.*, every branch, every independent axis bearing leaves. A flowering plant is made up of just as many individuals as it has branches and twigs or independent axes. Some of these individuals bear green leaves only, and are concerned in the nutrition of the plant, like the nutritive polyps. Others form many-colored flowers, with stamens and carpels, and are concerned in reproduction, like the two kinds of sexual Medusæ of the Siphonophora colony. In the case of the flowering plant also the distinction between the two individuals, the nutritive leaf shoots and the reproductive flowering shoots is not noticeable at first. It is acquired later on by specialisation.[1]

But with these the widest domain of specialisation is by no means exhausted. Comparative Anatomy and the study of Evolution teach us rather that its influence reaches much further afield. Every animal and vegetable individual, whether it lives solitary, like the unbranched plants and most animals, or is associated with its fellows in a community, like the Siphonophora and the majority of plants, every individual is again made up of many similar and dissimilar parts. These parts or organs subserve in their far-reaching specialisation those co-ordinated functions of the organism that we name in a single word, "life." Life is no mysterious product of a mystical life-force, but the totality of the functions of different organs marked off one from another by specialisation. The unity of organism in the individual in its narrower sense, *i.e.* the person, arises by the co-ordination and specialisation of the organs, as the unity of the colony or of the state

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[1] Alexander Braun, in his admirable "Betrachtungen über die Erscheinung der Verjüngung in der Natur" (Leipzig), has dealt in detail with specialisation in plants.

arises by the co-ordination and specialisation of the persons.[1]

In the vegetable kingdom all the different forms of the nutritive leaf-bearing shoots and of the reproductive flower-bearing shoots arise by specialisation of two simple fundamental organs, the leaf and the stem or axis. These two organs again have arisen by specialisation from one common, original, fundamental organ, the thallus. In like manner in the Arthropoda—the Insecta, Myriapoda, Arachnida, Crustacea—all the various jointed appendages of the body, the antennæ, mandibles, maxillæ, maxillipedes, and the true ambulatory limbs have originated by specialisation from one and the same original fundamental form of simple limb, from a primitive appendage.

What is the origin of these primitive or fundamental organs, that form by their continued specialisation all the various parts of the body, and by their co-ordination the complex organism of the "person." These simplest fundamental organs are in their turn again the complex product that results from the combination into an aggregate, and from the specialisation of very many small organic individuals. These elementary units, that can generally only be distinguished by aid of a microscope, are generally known as cells. All organisms, all plants and animals are composed of many cells, except the very simplest, such as the Monera and those that are in composition only a single cell. The apparent unity of life of every multicellular organism is, like the political unity of every human state, the compounded resultant of the connexion, and of the specialisation of these little citizens. They are the veritable elemental organisms, or the individuals of

[1] To explain clearly the immeasurable significance of the principle of specialisation of organs in the formation of the more highly developed co-ordinated animal body, the person, it would be necessary to go through the whole account of the structure of the various organisms. As, however, this inquiry, interesting as difficult, would carry us much too far at present, I must refer the reader for its details to the third book of my "Generelle Morphologie." In this I have worked out both the relation between the physiological and the morphological entities and the six different stages of the organic individual: 1. Plastids; 2. Organs; 3. Antimeres; 4. Metameres; 5. Persons;

the first order.[1] The organic cells may, in consequence of adaptation to the life conditions of their environment, assume forms the most diverse. But the original cell-form, whence all others are later on evolved by specialisation, is a small mass of jelly-like matter, a minute particle of albuminoid semi-fluid matter, the material of the cell or protoplasm. This little body, generally, but not always, invested by an external envelope, the cell-wall or membrane, contains a smaller body more solid, and also albuminoid, the cell-nucleus. But even these two most essential constituents of every cell, the outer cell-substance and the inner nucleus, are not distinct one from the other in the simplest and most primitive of all organisms, the Monera and other Protista. They have risen originally from the exceedingly simple and homogeneous protoplasmic structures of these beings by specialisation of the minute, invisible albuminoid particles, the plasm-molecules or plastidules.

Every cell in the plant and the animal body has, to a certain extent, its own independent life. It feeds and grows on its own account. It multiplies by reproduction for the most part by fission. Even the function of performing movements is originally the property of the cell substance of all cells. But it is generally limited to the withdrawal and enclosure of the cell within a self-made prison, within a rigid capsule or cell-membrane. Finally, every cell has a certain amount of irritability or sensibility, that in the most perfect of all cells, those of the animal brain, rises to the height of self-consciousness.[2]

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6. Communities. See further my essay on "Die Individualität des Thierkörpers." (Jena, Zeitschr. für Naturw., 1878.)

[1] In reality the individuals of the first order are generally called plastids. Besides the true nucleated cells the non-nucleated cytods come under this category. On this see my "Plastiden Theorie" (in the Biological Studies); also the thirteenth lecture of my "Natürliche Schöpfungs-geschichte" (p. 286), and the "Generelle Morphologie" (vol. i., p. 269).

[2] The cells, or in a more general sense, the plastids (*i.e.* the cells and cytods), are the actually living units, the elemental individuals, and the forms and functions of the multicellular organism are the resultant, whose components are the form, connexion, function of all the cells associated in that organism. This cell-theory, so highly important to the mechanical or scientific conception of life (in a

That specialisation of the cells, or cell metamorphosis, which must be regarded as one of the first and most important causes of the endless variety in organisation, is far more marked in the animal than in the plant kingdom. If the body of a higher animal, *i.e.*, a dog, is resolved, by aid of the microscope, into its elemental constituents, an extraordinary number of different kinds of cells are met with in the various organs. The hair, cuticle, claws of the dog are made up of many different horny kinds of cells, that have all originated by specialisation from one common kind of epidermal cell (Fig. 19.) The skeleton, that forms with its bones,

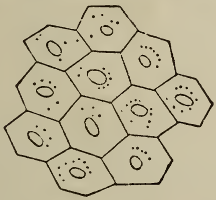

FIG. 19.

B. A small piece of the cuticle, made up of flat, angular, epidermal cells. Each cell encloses its round nucleus. (Highly magnified.)

cartilages, tendons, and ligaments the solid framework of the whole canine body, consists, again, of different kinds of bone-cells; cartilage-cells, connective-tissue-cells, that have all originated from a single primal species of connective-tissue-cell (Fig. 20). The red flesh or muscle that covers the bones and executes voluntary movements is made up of very elongated and transversely striped cells (Fig. 21). The pale yellow muscles, on the other hand, that enter into the

broader sense, this plastid theory), is grasped by no one so thoroughly as by Rudolph Virchow. It has been applied more thoroughly by him, especially in relation to the human organism, than by any one, and his "Cellular-Pathologie" laid the foundation of a new epoch in scientific medicine. See also his excellent essay "Ueber die Einheitsbestrebungen in der wissentschaftlichen Medicin" (Gesammelte Abhandlungen, Frankfurt, 1856), and "Vier Reden über Leben und Kranksein," Berlin, 1862, especially the second discourse, "Atome und Individuen."

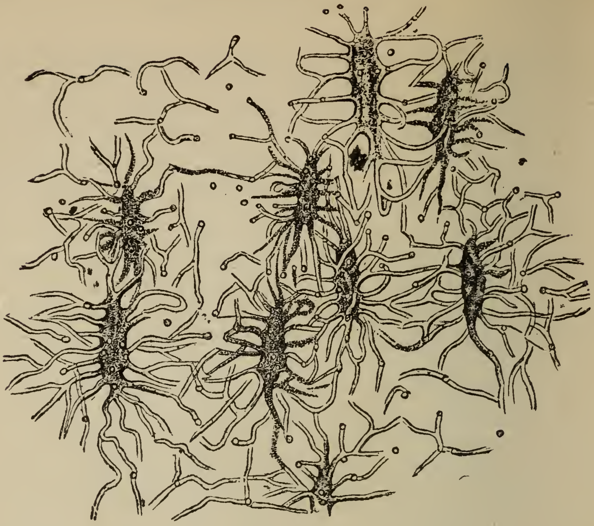

FIG. 20.

A small piece of bone, presenting nine stellate bone corpuscles, connected by radiating offshoots, and lying imbedded in the osseous ground substance. (Highly magnified).

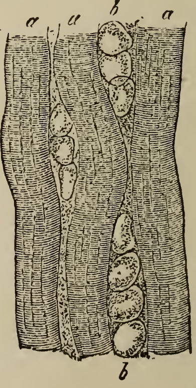

FIG. 21.

Three transversely striped muscle fibres (a) with several fat cells (b) lying behind them.

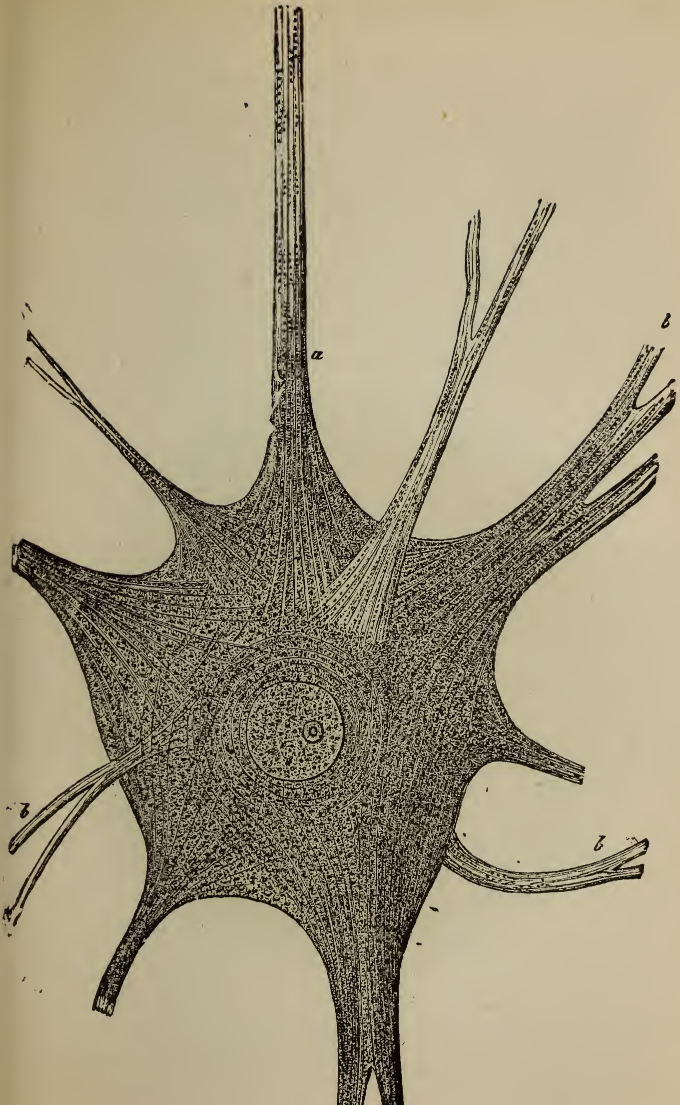

FIG. 22.

FIG. 22

A soul-cell or ganglion-cell from the brain of an electric fish (Torpedo). In the middle of the large ramified cell lies the nucleus, enclosing a nucleolus and most internally a nucleolinus. The protoplasm of the cell is traversed by many very delicate fibrillæ. The poles or extensions of the branching cell go partly to nerve-threads (*a*), serve partly (*b*) for putting this particular soul-cell into relationship with others.

walls of the stomach and effect the involuntary movements of this organ, are made up of smooth, unstriated, fusiform cells. Finally, the nervous system, highest set of organs in the animal body, subservient to sensation, will, thought, consciousness, in a word, to the so-

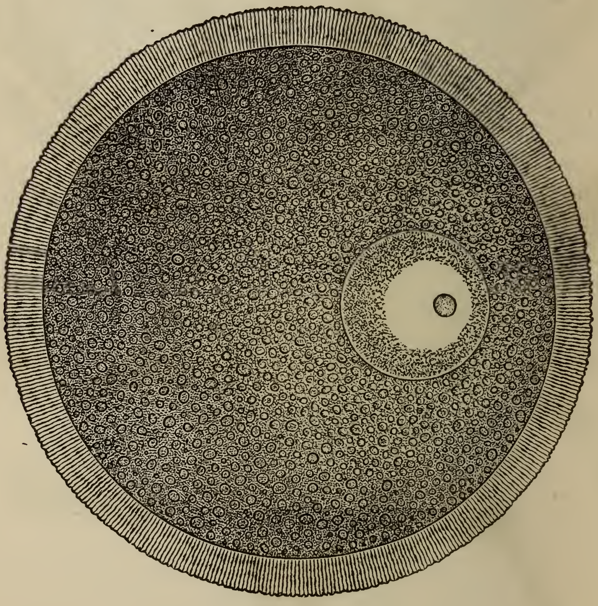

FIG. 23.

The ovum of man, very strongly magnified. The ovum-cell (1-5th inch in diameter) is surrounded by a finely striated yolk-membrane, and contains a clear germinal vesicle with a dark germinal spot.

called soul-functions or spiritual life, is composed of large stellate cells, of soul-cells, whose ramifying extensions are connected with the nerve-fibres or delicate albuminoid fibres, extending from the cells (Fig. 22).

Different in kind as are the above-named cells, that on microscopic investigation we find interwoven one with the other, all have but evolved by specialisation from a single primitive form of cell, viz., from that homogeneous, simplest cell to which the egg, at the commencement of the animal's development, gives origin. Every animal is at the commencement of its individual existence a simple ovum (Fig. 23). But this egg is in its turn a simple cell, consisting of the same essential parts as every other cell of the gelatinous cell-substance (here called yolk), and the included cell-nucleus, which in the ovum is called the germinal vesicle. Frequently, but not always, the animal ovum is enveloped by a special investment, the yolk-membrane (Fig. 23).

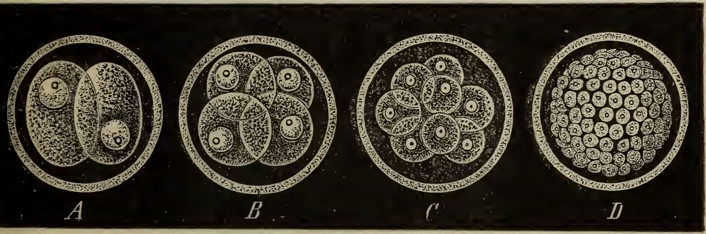

Fig. 24.

Segmentation or continued fission of the egg at the commencement of development. The ovum divides at first into two cells (A), then into four (B), eight (C), and finally into many cells (D).

As soon as the ovum of the dog or of any other mammal begins to evolve into a new individual, it divides by fission into two similar halves (Fig. 24 A). Without doubt the germinal vesicle or nucleus divides first, and then the investing cell-substance, the yolk. Each of the two daughter-cells thus produced divides again into two cells (Fig. 24 B). From these four, eight are soon formed by continuous fission, from the eight, sixteen; from the sixteen, thirty-two, etc. Hence is formed at last from the simple egg or ovum a globular heap of very many and very small cells, that resembles a blackberry or a mulberry—the mulberry mass or Morula (Fig. 24 D).

At first all these many cells are alike in form and in size; soon, however, they begin to think of organising themselves into a state. They behave like a number of colonists who wish to found a well-ordered state, and betake themselves accordingly to the work necessary to that end. At first the cells of the Morula group themselves into two chief sets, separating later by a species of foliation into two layers, lying one under the other, and known as primitive layers, or layers of the blastoderm. The exceedingly important form called Gastrula (Fig. 25) consists of these two primitive layers

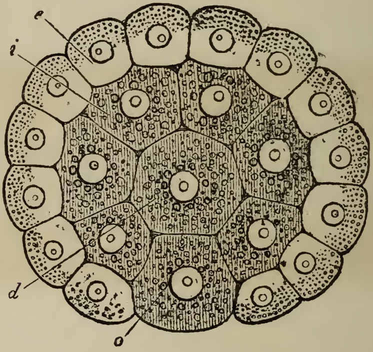

Fig. 25.

B. Gastrula of a mammal (rabbit). The whole body (shown in vertical section) consists of ninety-six cells, *i.e.*, sixty-four clearer, smaller, ectoderm cells (*e*) and thirty-two darker and larger cells of the endoderm (*i*). These last fill up the gastric cavity (*d*) and oral aperture of the Gastrula (*o*).

alone. The exterior layer, epidermal, ectoderm (*e*), furnishes the animal cells for the organs of sensation and movement, skin, nervous system, etc. The inner layer epithelial, endoderm, furnishes the vegetative cells for the organs of digestion, nutrition, and breathing : intestine, lungs, heart, etc.

Later on the division of labor among these cells goes still further. The first set of cells undertake the protection of the animal organism and form the cuticle, hair, nails, claws. A second set form the solid framework of the body, as they are transformed into the cells of bone, cartilage, connective tissue. A third group extend into the long transversely-striated fibres that make up the flesh or muscles, and by virtue of their special contractile faculty effect the movements of the different parts of the body. Finally, a fourth group of cells, the most specialised, the most highly endowed cells, form the nervous system, and take on the highest functions of the animal body, those of volition, sensation, intellect (Fig. 22). Thus the various organs that compose the adult animal body arise solely by continued multiplication, connexion, specialisation of the cells. By specialisation of these organs, again, is produced the complex machinery of the composite organism that we see in each individual animal.

The specialisation of cells and organs, as it can be traced out step by step in the evolution of every individual is, of course, not due solely to the adaptation of the animal to the conditions of existence of the surrounding outer world. It is rather transferred from the parents and ancestors of the animal under consideration by heredity. Of these inherited specialisations of cells and organs the same thing is true that was said above as to the inherited specialisation in the Siphonophora. It leads us back to that original division of labor in ancestral forms acquired by direct adaptation, and developing itself slowly during many millions of years under the pressure of external conditions of life in the struggle for existence. That which holds in regard to the development of the whole vegetable or animal organism, holds also as to the development of all its individual organs and cells. The development of each separate cell (the ontogeny of the cell) repeats in swift succession and in broad outlines the history of the upbuilding of its ancestors (the phylogeny of these cells). Therefore, from the simple fact that every animal is developed from a single simple cell, and from the manner in which this is brought about by specialisation of cells and of organs, we can draw this immense conclusion, that the earliest ancestral forms common to all animals were very simple cells, and that from the descendants of these simplest unicellular animals, by the collocation and continued specialisation of the cells, the higher multicellular forms of animals have evolved.[1]

At the end of a lecture that has only traversed a small region of the immeasurable fields of division of labor, it will probably be found that I have dealt very unequally with the two parts of the subject proposed; that I have said much of specialisation in Nature generally, very little of it in human life. I must, therefore, make confession that I have been indulging in a harmless deception. For in the latter half of the lecture at least I have withal spoken ever of man, even though I named him not. For all that I have said of the composition of the body (and especially that of the dog) as of cells, all that I have said of the division of labor amongst the cells and organs of that body is true, word for word, of man. Our own body, like that of every higher animal, is an organised state, built up of millions of little citizens, the cells. These citizens lead to some extent an independent life. They form in their division of labor different ranks and classes of workers: such are the nervous system, the muscular system of our body, and so forth. The unity of life of the human individual, visible to outward eyes as the simple outcome of a personality, is, in truth, a highly complex resultant, compounded of the collective func-

[1] I have, in my "Natürliche Schöpfungs-geschichte," shown hypothetically how we can form an approximate mental conception of the historical evolution of all the different forms of animals, and generally of all organisms, from common ancestors of a very simple nature, first from the Monera (non-nucleated cytods), next from the simple nucleated cells up to the objects known to us at the present day. The fifteenth lecture, on the genealogy and history of the Protista; the sixteenth, on the vegetable kingdom; the seventeenth, on the invertebrate animals; and the eighteenth, on the Vertebrata, attempt a sketch of thi Evolution.

tions of all those little citizens, the cells, and of the organs composed of these in specialised forms. If any of these citizens perform their duties imperfectly, or become unfit for work, we fall ill, and if the unified, regular co-working of all, essential to life, comes to an end, we die.

Moreover, that which I have said as to the history of the development of animals, and have illustrated by the dog as an example, all holds, word for word, as to the development of man. Every human being is at the outset of his career, like every lower animal, a simple cell, an egg (Fig 23) ; and as this cell begins to develop, its daughter-cells and their descendants have to solve exactly the same problems in regard to division of labor as those already described in the development of the dog. The earlier stages of development of the egg of the dog, represented in Figs. 23—25, are an exact equivalent of those with which the individual life of every one of us has begun.

In man also, as in his lower fellows, the manifold series of forms through which the organism passes during its individual development from the egg, presents us, approximately and in outline, with a picture of the series of forms through which its ancestors have passed in the course of measureless ages. And this is a clear proof : first, that our race has evolved in relation to, in connexion with, lower organisms, and in most intimate connexion with the Vertebrata ; second, that our most ancient common forefathers had but the structure of a very simple cell. But the mighty law of Nature, under which from an origin thus simple have evolved all the forms, endless in number and in variety, of the animal world, and at its head the different races of man, so far surpassing all other beings, is the great law of division of labor or of specialisation.

V.—CELL-SOULS AND SOUL-CELLS.

CELL-SOULS AND SOUL-CELLS.

THERE is no subject in the whole range of man's knowledge on which, in former times and even to-day, men's views have differed so widely as the subject of the existence of the soul. What is the soul? Whence comes it? Whither goes it? Has man alone a soul, or do other animals also possess one? And where in the animal kingdom are to be found the limits, the beginnings of existence of the soul? We encounter even to-day these and kindred questions, as we have encountered them for one or two thousand years, without receiving an answer that has met with general scientific approval.

This persistent obscurity, as to one of the most important and most difficult questions in the whole range of human knowledge shows itself in nothing so clearly as in the circumstance that psychology, even at the present time, occupies a very vague position amongst the rest of the sciences. The majority of scientific men at present regard the soul-activity of man and other animals as a real phænomenon of nature, and therefore believe that only through the investigations of science is there any possibility of lightening the darkness that overhangs the subject. On the other side the majority of the psychologists range themselves. These, appealing to the list of philosophers who have dealt with the history of the soul, take the opposite view, and look upon the existence of the soul—at least in man—as a supernatural, a spiritual phænomenon, conditioned by forces altogether different from ordinary physical forces, and that mocks, in consequence, all explanation that is simply scientific. According to the opinion of these men—an opinion still largely prevalent—psychology is in part or in whole a spiritual science, not a physical one.

Despite the opinion so widely spread, so influential, despite the distrust with which every scientific man enters upon the subject of the soul, a subject involved in obscurity, we will none the less venture on the attempt to penetrate these very mysteries by aid of the light of scientific method. We find at once an invitation to this inquiry, and a warrant for it, in two fundamental facts. First, in every living being the soul undergoes a consecutive development. The soul has its developmental history. Secondly, a part at least of the soul-functions is connected with definite body organs, and is not conceivable save in connexion with those organs. This part, at least, of soul-phænomena is immediately reachable by scientific investigation. Further, the fact is now generally admitted that at least parts of the soul-functions, especially will and sensation, are performed in the higher animals in the same fashion as in man ; and a physiological comparison of different animals shows us a long scale of varying grades of development in regard to the souls of animals. Hence it is for the zoologist, who makes the investigation of animal life in its every phase his life-work, not only a privilege, but a duty, to study the origin and limits of soul-existence in the animal kingdom.

Without doubt the untrodden path upon which the zoologist thus enters is very different from the highway along which the multitude of psychologists have serenely ambled. It is well known that these thinkers hold self-consideration, observation, and reflexion on the human soul alone as the most important, frequently as their only end and aim. Hence the soul, as generally analysed and described in the text-books on psychology, is the soul of man alone—is, for the most part, the highly-cultured soul of a philosopher learned and skilled in thought. Assuredly the accurate knowledge of a soul thus highly-cultured is of greatest value ; but it never touches many of the momentous questions of our knowledge ; it is wanting in that very particular on which the science of to-day rightly lays the greatest stress, the knowledge of development.

Development, long, gradual, ascending, is at the basis of the soul in each individual man, as in every other animal. That is a psychological fact of fundamental significance. The greatest thinkers of all ages, Aristotle and Plato, Spinoza and Kant, have once on a time been children; their mighty universal minds have been evolved by infinite ascending stages. The zoologist who turns his attention to the investigation of the soul is compelled by these facts to use, more than all other means, that most important method of inquiry, the study of development. He will work out the comparative evolution of the soul in man and in other animals, and will examine the comparative anatomy and evolution of those organs of the body which in animals as in man, the highest of animals, are concerned directly in the functions of the soul. The comparative morphology of the soul-organs, and the comparative physiology of the soul-functions, both founded on Evolution, thus become the psychological problem of the scientific man.

I.

The first, most general, and most important fact that the scientific student encounters at the very outset of his psychological inquiries is the dependence of all functions of the soul on certain known material parts of the animal body, called organs. In man and in the higher animals such organs occur—the sense-organs, the nervous system, the muscular system. In the lower animals we meet with groups of cells, or even individual cells, which have not yet differentiated into nerve and muscle. Every expression of the soul-life, every psychical working, is indissolubly connected with such an organ, and is not thinkable without it. Therefore nothing should be said on the subject of the existence of the soul unless we recognise the way in which the Ψυχη (Psychē or soul) is bound up with its organs. But it is not superfluous to lay stress on this fundamental physiological fact at a time when the most crass superstition, in the shape of Spiritualism, raises once again its head, and we see not only many thousands of civilised and uncivilised men, but even scientific men of repute and knowledge, falling in blind frenzy at the altar of this superstition.

Within the last few months, to our shame be it said, we have seen that the American Spiritualist, Slade, after he had acquired in England considerable wealth by his juggling with the "spirits," and at last had been unmasked as a bare-faced impostor, continued his swindling trade in Germany with the like success. He was even able to befool not a few scientific men of some repute. And do we not also see that a special literature of Spiritualism, represented by numerous periodicals, aims at dressing up this incredible swindle in the garb of special science? In the century of railroads and telegraphs, of spectrum analysis and of Darwinism, in the age of the monistic conception of Nature, such reversions to the dark superstitions of the middle ages seem scarcely conceivable. They are only to be explained by reference to the "mystic nightside" of the human soul, that fatal inclination towards the supernatural and the mystic, which religious superstition has most carefully fostered these thousand years. It is certain that this tendency to mysticism takes root in this ineradicable fashion because it is strong with the bequest of a thousand years, and has been continually strengthened and sanctified anew by pretended revelations, *i.e.*, by mental phænomena of a pathological nature.

In opposition to all those pretended spiritual manifestations of Spiritualism, which, like the miracles of Louise Lateau, or the Madonna of Marpingen, are founded partly upon unconscious illusion, partly upon conscious fraud, one clear physiological fact stands firm as first essential of all knowledge of the soul. That fact is, that every kind of soul-function is inseparably connected with certain parts, or organs, of the body. Our first duty, therefore, must be to make ourselves somewhat better acquainted with these organs. The organs of our soul-life—viz.: 1. the sense organs; 2. the nervous system; 3. the muscles—constitute one large apparatus, that we designate in a word as the soul-apparatus. In man, as in all the higher animals, this armory of the (mental) functions shows us a marvellous congeries of the most complex organs and tissues, and without doubt the complexity is greater and more intricate the higher and more perfect the working of the apparatus, that is, the higher and more perfect the working of the soul (Fig. 26).

A voyage of discovery in this wonderful labyrinth is most attractive, most instructive, but it is at the same time very difficult. Instead of this, it will answer our purpose much better to look at the far more simply constructed apparatus met with in some lower animal. We choose, therefore, a lowly-developed worm, not so much because man, according to Faust, "is like the worm that crawls in the dust," nor because phylogeny to-day, in dealing with man's genealogy, tells us of a series of worms among our ancestors, but rather because the lower worms show their soul-organs as structures very simple and very easily seen ; thus they facilitate in most excellent fashion the difficult study of the highly complex organs of higher animals.

Let us study under the microscope such a simple worm, *e.g.*, a Rotifer or a Turbellarian (Fig. 27). We see in front and above the mouth a small white swelling, whence fine cords radiate in all directions to the different parts of the body. That white swelling above the mouth is a soft mass of nerve-tissue, and is the centre of the whole soul-apparatus, a brain of the simplest kind. The fine cords, which radiate from the brain to all regions of the body, are nerves. We distinguish two different sorts of nerve-fibres. Some are the organs of the will, motor nerves, or nerves of motion. They run from the brain to the muscles, whose fibres, the muscle-fibres, are caused by the motor-nerves to contract. The others, on the contrary, are instruments of sensation, or sensory nerves. They carry the different sense-impressions from the external skin and the sense-organs to the brain, and thus bring that organ into relation with the environing external world. The sense-organs of so low a worm as this we study are of course still very simple, but for that very reason they are deeply interesting. In many worms the external integument plays the part of a general sense-organ, and responds to sensations of different

Fig. 26.
Nervous system of man. The white nerve-fibres radiating from the brain and spinal cord to different parts of the body are represented on the black picture of the body.

kinds, especially alterations of pressure and changes of temperature. In other worms are added to this general sense-organ, the skin, special feelers or tentacles, and in addition eyes of the simplest kind, dark specks in the skin, enclosing a refracting lens. Ears, also, of the simplest kind, appear, viz., a pair of depressions or vesicles in the skin, which are lined with minute delicate hairs; auditory cilia, that are thrown into vibration by sound-waves in a special manner.

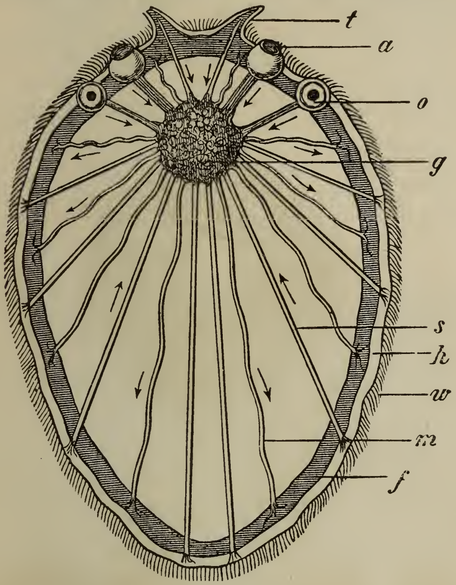

FIG. 27.

Nervous system of a Turbellarian. Two kinds of nerves radiate from the simple nerve-ganglion, or brain (*g*): the centripetal sensory nerves (*s*) pass to the integument (*h*), the tentacles (*t*), the auditory vesicle (*o*), the eyes (*a*), : the centrifugal motor nerves (*m*) pass to the flesh, to the sub-integumental muscular layer (*f*). *w*. Cilia on the integument.

It is a fact of the greatest significance that these organs of the higher senses, eyes and ears, in the lower worms are nothing more than a specially developed part of the external integument. For the far more highly developed and more perfect eyes and ears of the higher animals and of man originate in the most external layer of the integument, and do not clash with the law only recently discovered, and of such vast importance—the law of the development of all sense-organs from the skin. *All the different sense-organs of an animal are originally only specialised parts of its sensitive external integument.*

But further, the organs of movement, those servants of the will, called muscles, are originally in closest relationship to the outer skin.

In our low worm the whole muscular system is

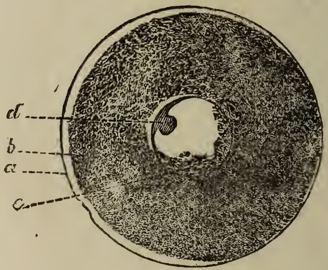

Fig. 28.

Ovum-cell of a worm. The globular cell-body (*b*), consisting of protoplasm, is surrounded by a delicate membrane (*a*), and contains a cell-nucleus (*c*) and uncleolus (*d*).

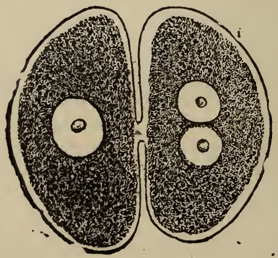

Fig. 29.

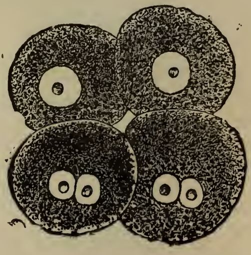

Fig. 30.

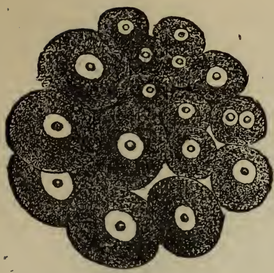

Fig. 31. Fig. 32.

Division of the ovum or segmentation at the beginning of development. From the simple cell (Fig. 28) arise by repeated division, first two segments (Fig. 29), then four (Fig. 30), eight, sixteen (Fig. 31), finally many cells (Fig. 32). The mulberry-like, multicellular, globular body or Morula thus formed (Fig. 32) passes later into the cup-shaped Gastrula (Fig. 33). (See my "Anthropogenie," 3rd edition, 1877, chapter viii.)

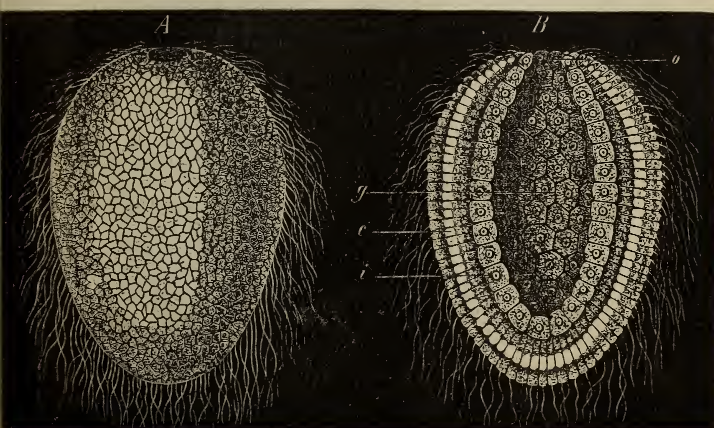

Fig. 33. Fig. 34.

Gastrula of a calcareous sponge (Olynthus). Fig. 33 (A) external view. Fig. 34 (B) longitudinal section through the axis. *i.* Inner cellular layer or mucous layer (endoderm).

e. Outer cellular layer or epidermal layer (ectoderm). The two layers surround the gastric cavity (*g*) of the animal, that opens externally by the mouth (*o*).

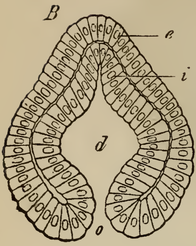

Fig. 35.

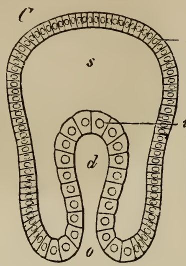

Fig. 36.

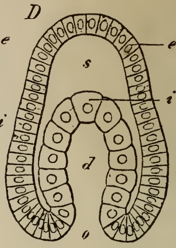

Fig. 37.

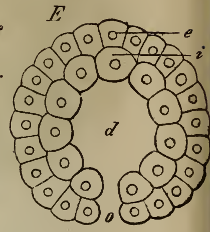

Fig. 38.

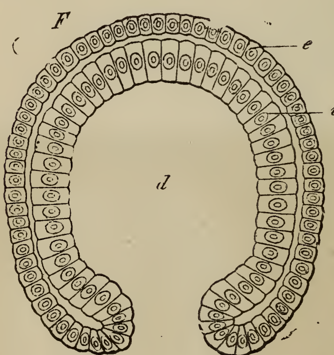

Fig. 39.

Longitudinal sections through the Gastrulæ of animals belonging to five different classes. Fig. 35 Vermes (Sagitta B). Fig. 36. Echinodermata (Uraster, C). Fig. 37. Crustacea (Nauplius, D). Fig. 38. Gasteropoda (Linnæus, E). Fig. 39. Vertebrata (Amphioxus, F). In all, *e* is the epidermal or outer layer of the blastoderm. *i.* Mucous or internal layer. *d.* Gastric cavity. *o.* Oral aperture.

represented by a thin layer of muscle, that extends continuously beneath the skin (Fig. 28). Generally, this "dermo-muscular layer" of worms is divided into two distinct layers, an outer layer of circular fibres and an inner layer of longitudinal fibres, although it is not yet differentiated into distinct groups or muscular bands, as in the higher animals.

We must call especial attention to the fact that all the nerves, both the centripetal sensory fibres, which run from the brain to the skin and the sense-organs, and the motor fibres, which run from the brain to the muscles, are in immediate connexion with these peripheral parts. If, agreeably to nature, we conceive all the soul-apparatus as one united whole, the sensory sense-organs are nothing more than special terminal expansions of the sensory nerves, the voluntary muscular fibres are nothing more than special end-organs of the motor nerves. The brain is intercalated between these two sets of organs, as a central point of junction, as a direct connecting structure.

If we wish to obtain a clear idea of the functions of such an apparatus, of the nature of soul-life, the familiar comparison with an electric-telegraph system is of greatest service. Not only does this well-known comparison hold throughout all the structure of the soul-apparatus, but in the performance of its functions ; in truth, electric currents play a part of the greatest importance. But the simile has its full significance only when we by aid of microscope have studied the very fine structural elements of the nervous system. The microscopic structural elements of the soul-apparatus are none other than those of which the other organs of the animal body are composed—the so-called cells. Here, as everywhere in natural history, it is that cell-theory of Schwann and Schleiden, enunciated forty years ago, which opens to us, as with a master-key, the principal door that leads to more accurate knowledge. Diverse as are the innumerable forms of small cells in the different tissues of plants and animals, yet all agree in the main fact, that every single cell has a certain degree of individual independence, has its own shape, lives its own life. As Brücke has put it in a notable phrase, every microscopic cell is an elementary organism, "an individual of the first rank." Nay, as we shall soon see, we must even ascribe to every cell an independent soul—a cell-soul.

Countless as the stars in heaven are the endless myriads of cells which compose the frame of a whale or an elephant, of an oak or a palm. And yet the gigantic body of either of these most gigantic organisms, like the invisible minute form of the smallest of organisms, at the commencement of its existence only consisted of one small cell, the ovum, invisible to the naked eye (Fig. 28). This cell begins to develop, and from it arises, in a very short time by repeated division, a large mass of similar cells (Figs. 29—32). These arrange themselves in leaf-like layers, one within the other, the so-called germ-layers, or layers of the blastoderm. At first all the cells are alike : each individual cell is of the very simplest form and composition : a round, white, albuminoid spherule or small mass of protoplasm that encloses a solid nucleus. But soon dissimilarities and differences appear ; the cells begin to take part in the work of life and assume different shapes and qualities. Alimentary-canal-cells undertake digestion, blood-cells the transformation of material, lung-cells respiration, liver-cells the secretion of bile. Further, the muscle-cells dedicate themselves exclusively to movement, sense-cells to the various sensations : the tactile cells of the skin learn to recognise alterations of pressure and of temperature, the hearing-cells learn to distinguish sound-waves, the visual cells to distinguish light-waves. But the nerve-cells enter upon a career at once the most difficult and the most splendid, and amongst these it is the brain-cells that gain, as in a noble strife, the highest prize, and as soul-cells rise high above all other kinds of cell.

This division of labor in the cells, or, as the anatomist calls it, tissue-formation, so full of meaning, is performed in a short time in the individual development of every animal and of every plant under our very eyes. It commences with the development of the animal from the egg, even at that early time when the progeny of the ovum, the so-called embryo-cells (Fig. 32) separate into layers. The embryo has at this time the form of a double-walled cup, and the two walls of this cup or of the Gastrula (Figs. 33, 34) are the two primitive layers of the blastoderm. From the inner or mucous layer (endoderm, Fig. 34 *i*) the organs of nutrition and digestion, the organs of the vegetative functions, develop. From the outer layer of the blastoderm, the epidermal layer, or sense-layer (ectoderm, Fig. 34 *e*), arise the organs of the animal functions, muscles and nerves, skin and sense-organs—in a word, the soul-organs. We must call attention to the fact, as of greatest significance, that in all multicellular animals, from the Hydra to man, the specialisation of the cells begins on this wise, with the separation of the two primitive layers of the blastoderm, and that the soul-apparatus always takes origin from the cells of the ectoderm. In animals of every class, nerves, sense-organs, muscles, arise from the sense or epidermal layer of the Gastrula (Figs. 35—39).

The tissue-formation, that we see take place under the microscope with astonishing rapidity, is only a repetition in brief, conditioned by heredity, of a long and often-repeated historic process, a replica of an ancestral process which has taken millions of years to arrive at the present condition, and during which the specialisation of the cells, in the most exact sense of the phrase, by adaptation to the different life-functions of the cells, has gradually been evolved in the struggle for existence. The cells, therefore, behave like the cultured citizens of a well-organised, civilised country. In fact, our own life, like that of all the higher animals, is exactly such a civilised cell-state. The so-called tissues of the body, muscle, nerve, glands, bone, connective tissue, etc., answer to the different ranks or bodies of the state, or still more accurately to the hereditary castes that we meet with in ancient Egypt, and even at the present day in India. The tissues are hereditary cell-castes in the civilised state of the multicellular organism. But the organs, which are composed on the other hand of different tissues, may be compared to the various offices and institutions. At the summit of all is the mighty central director, the nerve-centre, the brain. The higher the development of the animal the more complete is the centralisation of the cell-monarchy, the mightier is the directing brain, and the more grand is the construction of the electric-telegraph apparatus of the nervous system, that brings the brain into connexion with its most important subjects, the muscles and the sense-organs.

In comparison with all this, the arrangement of the soul-apparatus in our worm, mentioned above, is very simple, though not different in essentials. If we irritate the animal in any way—if we touch its delicate integument with the point of a needle or with a piece of ice, the changes of impression or of temperature resulting from these stimuli are instantly perceived by the sensitive cells of the skin, that as sentinels guard at all points the layer of the skin; they, in contact with the exterior, telegraph at once their perceptions through the nerves of the skin to the brain. In like fashion the waves of sound that strike upon the auditory vesicle are perceived by the auditory cells of the latter as noises or as musical sounds, and are notified by the auditory nerves to the brain in telegraphic fashion. Not less swiftly the visual cells of the eye, which are impinged upon by a ray of light, send a telegram of light or color to the brain. Here is placed the head government of the cell-state, consisting of a few great stellate cells whose radiating extensions are in immediate connexion on the one hand with the nerves of sense causing sensation, on the other with the motor-nerves that excite movement. As soon as a telegram from the sense-nerves as to any change in the surrounding world has arrived at the central office, this information is communicated from the first brain-cells or ganglion-cells that receive the stimulus to others, and the chief counsellor now determines what is to be done. The result of this determination is telegraphed as will through the motor-nerves to the muscles, that at once obey the command sent to them by the contraction of their fibre-cells, by motion.

Without doubt the nerve-cells of the brain, the ganglion-cells, or soul-cells (Fig. 40), with their radiating poles, connected one with another by a branching net-work, play the most important part in the life of the soul. They form, in fact, the central directing organ of the whole of the multicellular body. They gather together all the reports from the external world that are sent to the brain *viâ* the centripetal telegraph-wires or sensory nerves. They convey, in like manner, all the orders of the will that pass out to the muscles by the centrifugal paths of the motor nerves. And, in addition, these notable soul-cells of the brain effect that most important and enigmatical work that we denote by the

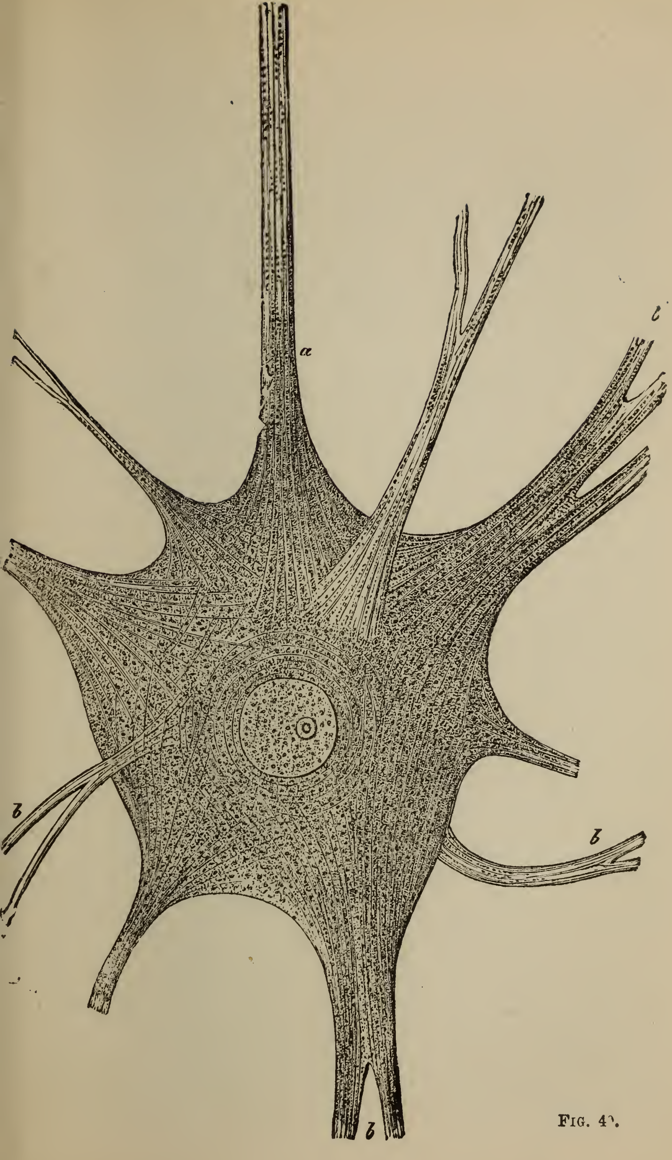

FIG. 4[illegible].

Fig. 40.

A soul-cell or ganglion-cell from the brain of an electric fish (Torpedo). In the middle of the large ramified cell lies the nucleus, enclosing a nucleolus and most internally a nucleolinus. The protoplasm of the cell is traversed by many very delicate fibrillæ. The poles or extensions of the branching cell go partly to nerve-threads (*a*), serve partly (*b*) for putting this particular soul-cell into relationship with others.

word Ideation. They, in the higher animals, as in man, effect that most exalted of all functions of the soul—that of thinking and of perception, reason and consciousness.

Whilst we are now dealing with the loftiest regions, and the noblest workings of soul, life, reason, and consciousness, we must further state that in truth the exact nature of these difficult cell-functions is as yet wholly unknown, but that we are in a position, by the aid of comparative physiology and the history of development, to throw a clear light on this intricate question. For, in the first place, the study of the souls of animals reveals to us a long series of evolution, in which every conceivable grade of reason and of consciousness is represented, from beings wholly without reason to those whose reason is most highly developed, from sponges and polyps to the dog and the elephant. In the second place, we see in every child, and in the earlier condition of all higher animals, that reason and conscience are non-existent at birth, and that they develop only slowly and gradually. In the third place, we regard it as a fact that a hard-and-fast line between unconsciousness and conscious soul-functions is as little existent as between irrational and rational thinking, that these opposed functions rather touch one another at innumerable points without presenting any defined limits—that, in short, they glide one into the other.

It is well known that the obscure question of the nature of consciousness plays a chief part in the psychological contests of the present day. The celebrated physiologist, Du Bois-Reymond, has pointed out, in his expression "Ignorabimus" (we shall not know), to the scientific congress at Leipzig, that consciousness is an entirely insoluble problem; a boundary of our knowledge that the mind of man, even in its most expanded development, will never pass. Many others consider consciousness as a special prerogative of man, wanting altogether in other animals. This latter opinion assuredly no one will share who has observed steadily and attentively the conscious and carefully considered actions of the dog and the horse, of bees, ants, and other reasoning animals. But the first opinion also is not tenable. Attentive observation of ourselves teaches us that our innumerable conscious and unconscious actions glide continually one into the other. Numberless acts of our daily life, *e.g.*, the use of cup, knife, fork, reading and writing, the playing of musical instruments, and the like, depend upon complicated functions of nerve and muscle that have to be learnt originally by careful and conscious attention, but by degrees have grown unconscious from use and habit. Every morning, when we wash and dress, rise up and go out, we perform quite unconsciously hundreds of complex movements that originally had to be consciously learnt, with pains and by degrees. On the other hand, these various unconscious acts at once come into distinct consciousness as soon as, from any reason, our attention is directed to them, and our self-observation is aroused. As soon as we make a false step on the stairs, or notice a false note on the pianoforte, we at once become conscious of the unconscious actions. Besides, we can also unerringly trace out step by step the gradual development of consciousness in every child. Resting on these facts, we no longer doubt, therefore, that consciousness depends upon a complex function of the soul-cells, which was at first gradually acquired through adaptation, and through the inheritance of recent adaptations has been slowly extended. The comparative study of development of the soul-life in the animal kingdom teaches us the same truth. The complex molecular motions in the protoplasm of the soul-cells, whose highest consequence is imagination and thinking, reason and consciousness, have been gradually acquired, in the course of many millions of years, by Selection. The brain also, organ of these functions, has developed in the course of these long periods, at first slowly and gradually, from the simplest to the most perfect form. And in this, as ever, the evolution of the organ goes hand in hand with that of its function: the implement improves with use.

For confirmation of this view, from which such important consequences follow, the comparative observation of the nervous systems of different animals is of the greatest moment. The simple brain of the worm, with the nerve-cords radiating thence, has been the starting-point for many different sorts of complex arrangements in the nervous systems of the higher animals. These latter bear the same relation to the early forms of the same order as the grand telegraphic system of the Germany of to-day, with its hundreds of stations and thousands of workers, bears to the first simple model of an electric telegraph by means of which the discoverer, forty years ago, introduced one of the most momentous improvements in the exchange of thought between the nations. The more highly-developed the sensation, volition, intellect in an animal, the more complex and the more centralised is the arrangement of the soul-apparatus that does this psychological work, the more prominently does the nerve-centre assert itself; for upon it depends the unity of direction of the whole system.

We are for the most part accustomed, therefore, to name the centre of the nervous system, the brain, in its wider sense, as the seat of the soul. Yet in truth this common expression is inaccurate, and we can only grant it a figurative meaning in a kindred sense to that in which we speak of an able woman as "the soul of the house," an all-powerful minister as "the soul of the State." As we will not deny to others their individual soul, so we dare not deny that the soul exists in the millions of cells that constitute the nervous apparatus of the higher animals, whose brain we therefore name the seat of the soul. When in the Franco-Prussian war, in 1871, Paris, that is in truth the soul of centralised France, and, according to Victor Hugo, is even the soul of the world, was rigidly blockaded by our victorious army, when telegraphic communication with the rest of France was wholly cut off, in the severed limbs of France nevertheless the ramified network of the telegraphic system worked away unceasingly, and the dauntless soul of Gambetta organised new armies for the relief of the beleaguered capital. In like manner physiological experiments on decapitated frogs and insects teach us that despite the removal of the brain the soul-life can last for a long time in other parts of the body. The unifying central director of the whole alone is destroyed; only the highest soul-functions, reason and consciousness, are thereby in part or as a whole annihilated; the other functions continue. If we place a drop of corrosive acid on the skin of the headless frog he wipes it off just as skilfully as if he were still possessed of a head. If we hold a headless beetle fast by one leg, he tries to escape with the five other legs as quickly and cleverly as if he had not lost his brain at all. Sense-function and feeling, will and muscular movement, will last a long time after the brain is removed. With the brain only unifying consciousness and centralisation are lost. We are bound, therefore, to distinguish clearly between these conscious central souls of the multicellular animal and the separate souls of its innumerable cells; the latter, indeed, are subordinated to the former, but are always to a certain extent independent.

The organ of the central soul is the collection of soul-cells, the ganglionic cells of the brain; on the other hand, the organ of the single cell-souls is the very body of the cell itself, protoplasm and nucleus or some part of these.

II.

Perhaps no class of animals is, after the Mammalia, of such importance in the comparison of the lower and higher stages of development of the soul-life as the class Insecta. For although the numberless different sorts of insects only furnish endless variations of a single original theme, although recent study of pedigrees derives all butterflies and beetles, flies and bees, Orthoptera and Neuroptera, from one common stock, nevertheless the variations in development of their soul-functions are very extraordinary. The familiar contrasts between the stupid goose and the hawk, acute of sense, between the dull rhinoceros and the clever elephant, seem insignificant in comparison with the immense contrasts furnished by the soul-functions of the various insects. On the one hand are many lower insects, *e.g.*, plant-lice, the cochineal insect, bugs, and generally parasitic insects of different kinds. These occupy a very low position in Evolution, not higher than that of the majority of the Vermes. Their one desire is to eat and drink. On the other hand the higher insects, and especially the social insects, the bees, wasps, ants, white ants, with their complex states, rise to a height of mental function that can only be compared with that of the civilised peoples who form like states. A wondrous division of labor, especially among the ants, leads to the organisation of their state into different ranks, whose members are distinguished by special marks and peculiarities. Among them we distinguish not only males and females, but also soldiers and workers, peasants and artisans, governors and slaves. Their operations of agriculture and gardening are not limited to the laborious collecting of stores and preserving of fruits. They rise to the height of actual cultivation of vegetables and the careful breeding of plant-lice, their cows, whose sweet honey-fluid they suck. No less marvellous is the architectural skill of the ants and Termites, that is shown in the plan of their grand palaces with their thousand rooms and chambers, corridors and steps, doors and windows. In addition to these arts of peace, we call to mind their skill in the rude art of war, whilst the strategic ability with which armies of ants engaged in warfare try to surround and enclose one another day after day, shows clearly that they also are children of this iron nineteenth century. In some South American species, indeed, as consequence of excessive military exercises, an exclusively military spirit has arisen, which has led to the abandonment of the early peaceful occupations, and to a robber life, as of Circassian hordes. Finally, we remember how even that institution of human civilisation, slavery, has been in vogue among the ants longer than in our own highly-civilised feudal race.

There are ant-colonies that carry on formal slave-hunts, steal from other species their young and carry them off as veritable slaves: nay, these slaves, in fact, later on, repudiating all ties of nature, regard the advantage of their cruel masters as of more importance than that of their own race, and actually help to steal fresh bands of slaves in the predatory expeditions. Although these highly interesting facts in regard to the mental life of ants have been discovered by Huber and other entomologists for more than a hundred years, they were held for a long time as fabulous products of the fancy. But of late the numerous inquiries of more recent times have thoroughly confirmed the old discoveries, and added to them new and more extensive observations.

Certainly the intellectual contrasts between the shrewd ants and their stupid cows, the plant-lice, are more marked than the immense distance between the god-like genius of a Goethe or a Shakspere and the poor soul of a Hottentot or an Australian aborigine. And yet, in the one case as in the other, a long series of connecting links presents itself between the two extreme terms of the series. None the less the fount of origin of them all is the same. As the majority of men derive our race from one common ancestor, so all zoologists with one accord hold firmly that all the different orders of insects spring from one common ancestral insect. Consequently the very different soul-functions of these same insects must have been gradually evolved by adaptation to varying conditions of life, and by continued inheritance have grown to the so-called Instincts.

No idea has given rise to so many errors and misunderstandings in the comparative study of soul as this so-called "Instinct." As long as the older natural history held that all the different kinds of animals with their special natures arose by a supernatural act of creation, it was obliged to hold in like manner, that the specific soul-function of each species had been created once for all, and that thus every step in the life of the animal had been immutably determined beforehand. The totality of the instincts, which on this view ought to determine, unalterably, unfailingly, the nature of the actions of any species of animal, amongst which the most noteworthy are the so-called artistic instincts of the nesting birds and of the bees—this sum of instincts was considered as a primarily created thing. This wide-spread view has become altogether untenable since we know, thanks to Darwin, that neither individual animals are created as such nor are their special instincts invariable. We now know that all species of a given class of animals take origin originally from one common stem, and that, like their other qualities, their instinct undergoes change and transformation under the mighty influence of Natural Selection. When animals are placed in new unusual conditions of life they adapt themselves to these, new thoughts arise, they make new inventions, acquire new instincts. Necessity is the mother of invention, and practice makes perfect. The hard fight for existence makes at all times and at all places such powerful demands on the instinct of self-preservation of animals that they are compelled, even as is man, to learn and to labor. It is not true, though it is frequently asserted to-day, that the beaver builds its water palace, the swallow its nest, the bee its honey-comb, in the same fashion in all ages and in all countries, the same to-day as it has been these 2,800 years. Further, we know through reliable observations that these highly developed artistic instincts undergo very remarkable changes, and adapt themselves to the conditions of individual localities. The last of the Mohicans in the shape of beavers that live in certain parts of Germany at the present day, have adapted themselves to the police regulations of civilisation, and no longer build those magnificent water palaces after the manner of their forefathers during the last 2,000 years. Whilst the cuckoo with us in Europe lays its eggs in a strange nest it has not acquired this bad habit in America. Every experienced bee-fancier knows how the special habits of bees are often lost in individual hives. It is a well-known fact that nightingales, finches, and other birds of song learn new melodies, master by the process of imitation new successions of notes, and therefore change their musical instinct. And do we not see plainly, in our house dogs, hunting dogs, badger dogs, sheep dogs, that instincts new and different have been learnt by education, by use, by habit ?

Comparative experimental inquiry, unprejudiced, free from bias, renders it certain that the "instinct" of animals is no other than a summary of soul-functions which have been originally acquired by adaptation, strengthened by habit, and handed down from generation to generation by inheritance. Many instinctive acts of animals, originally performed consciously and with reflexion, have in course of time become unconscious, after the manner of all the accustomed acts of reasoning in man. We might with equal propriety consider these last as expressions of an innate instinct, for unconsciousness often occurs in connexion with the "instinct" of self-preservation or of maternal love and with social instincts. Consequently neither is instinct an exclusive quality of animal brains, nor is reason a special prerogative of man. Rather is it that in the unbiassed comparative study of souls we find a long, long series of gradations, of gradual improvements and higher developments in soul-life, which pass down from higher to lower men, from perfect to imperfect animals, step by step, even to that simple worm whose single nerve-ganglion is the starting-point for all the numberless forms of brain in the vast series.

As, in fact, no break occurs anywhere in this series, and as in the simple soul-apparatus of our worm are already contained all the structural elements—nerves, sense-organs, muscles, out of which are constructed, in most complex fashion, the marvellous soul-apparatus of ant and man—scientific men, by common agreement at the present hour, hold that in all these animals that are provided with a nerve-apparatus a soul-life or a soul exists.

III.

But what is to be said of those lower animals in which a nervous system, even of the simplest nature, is wanting—the corals, polyps, sponges ? Does the want of a nervous system in these denote the lowest limit of soul-life? Or is there in these cases a soul without any nerves? Well-known scientific men—*e.g.*, B. Virchow and Du Bois-Reymond—answer the latter question in the negative, and maintain that no one can speak of a real soul-life in these nerveless animals. We are of a different opinion, and we found it on the general opinion of all zoologists who have employed themselves for a long time and with great perseverance in close observations on these animals destitute of nerves. Nay, we are convinced that these animals, without nerves and yet alive, are actually of the deepest

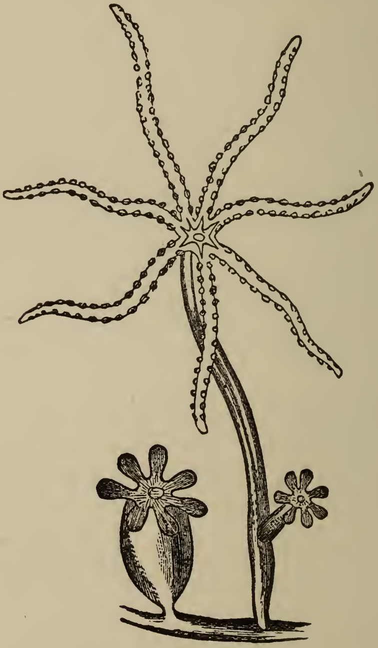

FIG. 41.

Two fresh-water polyps (Hydræ), one on the left contracted, one on the right expanded: the latter bears a bud that has already seven short prehensile tentacles.

moment in comparative physiology, and yield us the true key to the comprehension of soul-development.

The member of these important classes of lower animals most instructive, best known, and most closely studied, is the common fresh-water polyp, the Hydra (Fig. 41). This delicate little being, only a millimetre long, is diffused everywhere in our lakes and ponds, and can be had at any time in large quantities. Few would anticipate the wealth of disclosures of an important nature that this insignificant being yields in regard to the most important mysteries of life. Its simple body has the form of an elongated cup, colored sometimes grey or green, sometimes brown or red. The cavity of the cup is the stomach of the Hydra, its opening is the mouth. Around the mouth is placed a circle of fine threads, 4—8 in number, that serve both as tactile organs and as prehensile structures for the seizing of food. We look in vain for eyes and ears, muscles and nerves in our Hydra, and yet we are certain that it is sensitive and motile. If we touch the slender outstretched body but gently with the point of a needle, it contracts instantly into a round globular mass (Fig. 41, to the left). If we place a tumbler containing Hydræ in the window, in a few hours all the polyps are gathered together on the side of the glass nearest the light. They are sensitive to light though they have no eyes. They crawl towards the light although they have no muscles. Sensation and definite movement, therefore, the most important signs of the soul-life in animals, are present, beyond a doubt, despite the fact that the special organs of the soul, muscles and nerves, are wanting in them. How is this enigma to be solved? Have we here a function without a corresponding organ, soul without soul-apparatus?

The microscope gives a decisive answer to this question. The cup-shaped body of the Hydra in reality is made up of two cups of similar shape placed one within the other, their walls everywhere in close apposition. Essentially it is a Gastrula. If we now observe the thin double wall of the Hydra body in fine sections under a high power, we see that each of the two cups is composed of a special layer of cells. These two cell-layers have altogether different nature and significance. The cells of the inner layer effect exclusively the vegetable functions of nutrition, digestion, metastasis. The cells of the outer layer, on the other hand, perform the animal functions of sensation and motion. If we tease out this external layer with needles, we see on many of the cells thus isolated one or more long thread-like exten-

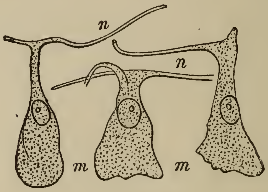

FIG. 42.

Three neuro-muscular cells of Hydra. The outer nucleated part is sensitive, nervous (*n*) : the inner filamentous part is motile, muscular (*m*).

sions (Fig. 42). Close investigation shows that these fine threads run in a circular direction between the two walls of the cup-shaped body, and, like a muscle, effect the contraction of those walls, whilst the external rounded nucleolar part of the same cell is sensory. We are here encountered by the noteworthy and deeply momentous fact that a single cell effects in its solitary self the most important functions of the soul ; the external rounded part of the cell, sensation, the internal filamentary part, the will and spontaneous movement. The outer half of the cell is nerve, the inner muscle ; with rigid accuracy, therefore, the discoverer of these structures, Kleinenberg, names these soul-cells of Hydra "neuro-muscular cells." The whole of the soul-apparatus of our polyp consists of nothing more than a single simple layer of such neuro-muscular cells, and each one of these cells does in most simple fashion that which the complex soul-apparatus of higher animals, with its different nerve-, muscle-, and sense-cells does in a more perfect manner. But in this case, as might be expected, a central apparatus or brain is wholly wanting. Instead of a brain the whole external layer of the body is in our minute polyp the seat of the soul. We therefore cease to wonder at those astounding capabilities of division of the Hydra that have been known, thanks to the experiments of Trembley, since 1744. If we cut a fresh-water polyp up into fifty little pieces, within a few weeks as many complete polyps are developed from the fragments. Every portion of the cup-shaped body grows straightway into a complete animal. The cell-souls of all the individual neuro-muscular cells are equally complete.

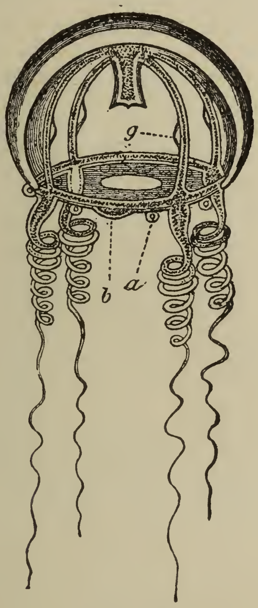

FIG. 43.

A Medusa (Eucope). The stomach, whence pass four nutritive canals to the margin of the umbrella, hangs in the middle and upper part of the bell-shaped body. In the middle of the canals lie the eggs (*g*). From the margin of the umbrella (*b*) depend four tentacles, and between these are eight auditory vesicles (*a*).

The neuro-muscular cells of the Hydra are also, to borrow a housewifely phrase, "maids of all work." Each individual in the soul-economy of this little polyp effects all the various labors that are shared in the higher animals among the muscle-, nerve- and sense-cells of different kinds. All the latter sorts of cell, differing so widely one from another, have therefore arisen by division of labor from simple neuro-muscular cells.

The umbrella-shaped sea-bells, stinging-fish or Medusæ, present us with the first result of this division of labor. These animals are closely related to the Hydra-polyps, but are much more highly developed (Fig. 43). Any one who has spent a few weeks on the sea-shore will certainly have seen now and again fleets of these beautiful, bell-shaped, jelly-like animals, and any one who has come, when bathing, into unpleasant contact with them will remember the disagreeable burning sensation that resulted, as if from the touching of a stinging-nettle. The order to which the Medusæ belong is therefore called Acalephæ. If by means of a glass vessel we cautiously remove such a Medusa from the sea, and investigate more closely its structure, we find peculiar soul-organs. On the margin of its umbrella-shaped body are true eyes of a simple order and ear-vesicles, and nerves put into connexion sense-cells and muscle-cells. The latter effect the powerful swimming movements of the Medusa. But here also muscles and nerves are in most intimate relation with their place of origin, the external skin, and a specialised brain or central organ of the whole soul-apparatus is still wanting.

Compared with the simple, minute, stationary Hydra, the gigantic, beautiful, free-swimming Medusa appears to us, beyond doubt, a much higher and more perfect animal. Nevertheless these two beings, placed by man formerly in different classes, are in the closest connexion, for in the course of its history the Medusa-form has evolved from the Hydra-form. Nay, even to-day the majority of the Medusæ take origin directly from polyps. From the stomach-wall of the little sea-polyp, kinsman of the Hydra (Fig. 44), a bud develops, which gradually becomes a Medusa, and later falling off like the ripe fruit of a tree, swims freely hither and thither. But from the ova of this Medusa no Medusæ arise, but polyps, buds (Fig. 45), that fix themselves and grow up into the Hydraform cup. From this well-known "alternation of generations" result in regular succession two animal forms, widely differing one from another. The great grandmother resembles the mother, the grandmother resembles the daughter, but the two series are very unlike one another. The first, third, fifth, seventh generations

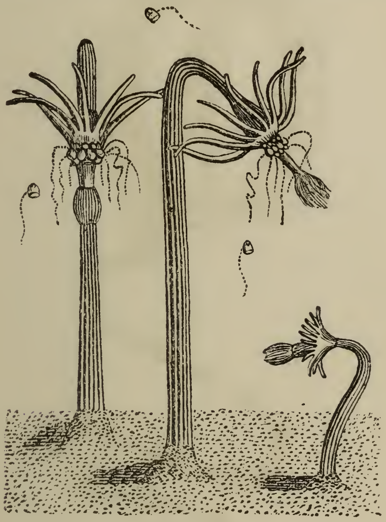

FIG. 44.

Three Hydraform polyps (Corymorpha) fixed to the sea-bottom. Two of them are putting forth Medusiform buds (Steenstrupia), three of which have already become detached.

are minute, lowly-organised, fixed polyps (Fig. 44); the second, fourth, sixth, eighth, on the other hand, are represented by large, more highly organised, free-swimming Medusæ (Fig. 45). And, what is more interesting to us in this connexion, the latter have nerves, muscles, sense-organs, the former have in place of these a delicate membrane, consisting of a layer of neuro-muscular cells. Both generations have souls, both possess will and feeling. But, not unnaturally, the simple lower soul-life of the polyp does not rise to the height of the Medusa-soul ; the latter has evolved from the former and long after the former in the course of time.

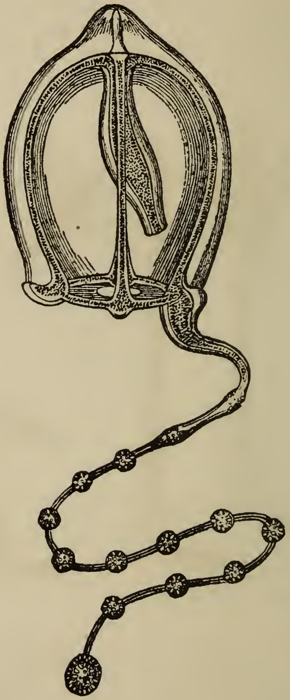

Fig. 45.

A Medusa (Steenstrupia) formed by gemmation from the polyps of Fig. 44. The stomach, whence four canals run to the circumference of the disk, depends from the middle of the bell. On the circumference are placed four eyes, but only one long tentacle.

In yet another significance is the notable class of Hydro-medusæ of deepest interest for the comparative study of the soul. For from it the Siphonophora have evolved, those swimming colonies of animals that are of extraordinary importance in the study of the physiological division of labor. The Siphonophora are found swimming about on the smooth surface of warm seas, but only at certain times, and not in large numbers. They belong to the inexhaustibly rich wonder-world of Nature, and whoever has once had the good fortune to observe for any length of time living Siphonophora will never forget the glorious spectacle of their marvellous forms and movements. Such a Siphonophoron is best compared to a swimming flower-stem, whose variegated leaves, blossoms, fruits, are exquisitely shaped, delicately colored, and as if built up of polished crystal (Fig. 46). Every individual flower-like or fruit-like element of the swimming stem is really a Medusa individual, *i.e.*, a Medusiform animal. But the different Medusæ of the colony have, as result of division of labor, assumed altogether different forms. Part of these Medusæ attend simply to the swimming (*m*), another set to nutrition and digestion (*n*), a third to sensation (*t*), a fourth to offence and defence, a fifth to egg-formation (*g*). Those various vital functions that every ordinary single Medusa performs for itself, are here shared amongst the different individuals of the colony. These latter have modified their bodily structure in accordance with their peculiar individual functions.

Just as in the ant-kingdom, so in the Siphonophora kingdom many animals of various form but of one kind are connected in a lofty social community. But whilst in the much higher ant-state the ideal band of social interests and the feeling of duty to the state binds together the free citizens, in the Siphonophora-state the individual members of the community are directly forged together into a bodily whole, bound as slaves to the yoke of the chain of state. Here, in truth, every single individual has its own personal soul; if separated from the stock it can move and feel independently. But in addition the whole stock has a single central will upon which the individual polyps are dependent, and a general sensibility which com-

FIG. 46.

A Siphonophoron (Physophora) swimming in the sea. *a*. Pneumatophore or swimming bladder at its upper end. *m*. Nectocalyces or swimming bells. *o*. Opening of the umbrella. *t*. Tactile polyps. *g*. Egg-forming female individuals. *n*. Nutritive individuals.

municates every perception of one individual instantly to all the rest. Each of these Medusa-beings of the Siphonophora stock can say with Faust: "Two souls dwell, alas, in my breast." The egoistic soul of the individual lives in compromise with the social soul of the stock or state.

Woe to that Medusa of the colony who wishes, in fatuous egoism, to free itself from the general community and to live a free life on its own account! Unable to perform all the separate functions that are necessary to its existence, the functions performed for it by its different fellow-citizens, separated from these last, it soon comes to grief. For one Medusa of the colony can only swim, a second only feel, a third only eat, a fourth only seize prey and ward off foes. The harmonious co-operation and the reciprocal help of all the individuals of these swimming brotherhoods, the common feeling, the central soul that connects them all one with another in a true affection—these alone give the life of the individuals and the life of the great whole lasting stability. In like manner the true fulfilment of all civic and social duties on the part of the citizen constitutes the stability of human civilised states.

IV.

The most important fact with respect to our inquiry into the soul that we gain from the observation of these remarkable Siphonophora is the conviction, full of meaning, that the single soul of an apparently simple animal can be made up in actuality of many different souls. The unity of the soul is so pronounced in the delicate sensations and free movements of the Siphonophora, that the earlier zoologists regarded the whole colony as a single simple animal, as an individual, and this inaccurate opinion still has supporters of some eminence. Dissections and the study of development carried on by men free from prejudice, easily convince us that the apparently simple soul in these animals is in truth but the sum of the conjoined single souls. Strange as the fact appears at first, we find something akin to this in all social animals, and even in man. Do we not speak of the heart of the people, of the feeling of the community, of a national will? Do we not see in a thousand historical instances the way in which this heart of the people, this national spirit, feels as one, and thinks, wills, acts as a single man? As one man, a whole nation rises from beneath the oppression of a cruel despot, breaking the throne of the tyrant into fragments. As one man a wronged nation feels the disgrace of wounded honor, and takes vengeance on the insulter. When for 1,400 years the resistless flood of migrating tribes overflowed all Europe, when in like irresistible fashion in the year 1848 all the nations of Europe won for themselves new freeways for their political development; in such moments of the world's history as these the single might of an idea, of a distinct form of thought, in its vast fulness meets us face to face. And yet this apparent unity of idea is in reality the sum of many thousand isolated ideas that have risen in the individual souls of all the citizens, or at least of an overwhelming majority, all struggling towards the same goal.

As with the soul-life of the nation on the large scale, so is it with the spiritual life of the individual man and of the higher animals generally on the small scale. For here also to the far-reaching glance of the zoologist the apparent unity of the soul merges into the individual cell-souls, the separate soul-functions of the countless cells of which the whole multicellular organism is composed. Of course we could designate the cells of the brain of man and higher animals as "soul-cells" in a more restricted sense, in that they represent very especially the unity of the cell-state, and perform the unifying direction of that state. Still we must not on that account forget that this lordship over the functioning soul-cells has been acquired through wide-reaching specialisation and centralisation, and that, despite this fact, the special soul-life of every single cell of every other tissue still endures. Each blood-corpuscle, each cell of bone or skin, retains its own independent method of feeling and volition, until at a certain point it becomes subordinate in the highest issues to the all-pervading influence of the governing brain-cells.

The soul of the cell is therefore a quite general, the cells of the soul, on the other hand, a quite special development of organic life. We are compelled finally to locate in every single living cell a soul; special soul-cells, on the other hand, are only met with in the higher animals in a central nerve-system, and there perform unceasingly in loftier fashion those functions of the soul, which were originally performed by all the cells in a far simpler manner. Nevertheless these most highly-developed aristocratic soul-cells sprang primarily from simple cells of the lowest order, gifted with the non-specialised soul of the individual cell.

Frankly, this our conception as to the cell-soul is not by any means generally accepted to-day. Indeed, it is

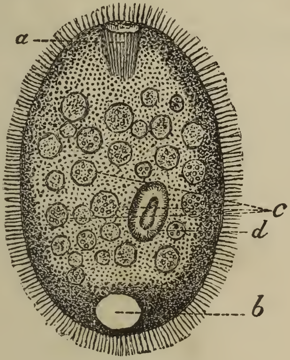

Fig. 47.

A unicellular Infusorium of the order Ciliata (Protodon). *a*. Oral opening of the cell with funnel-shaped gullet. *b*. Contractile vesicle. *c*. Food pellets that have been ingested within the sarcode of the cell. *d*. Nucleus. Delicate hairs or cilia cover the whole surface of the cell, and serve both for sensation and voluntary motion.

vigorously opposed at the present time by well-known authorities, such as B. Von Virchow. But on the firm ground of the modern study of development as reformed by Darwin, we are obliged to maintain that our theory of the cell-soul is a consequence, inevitable as momentous, of the uniform or monistic conception of Nature. I may be allowed, therefore, in conclusion, to glance briefly again at that lowest group of beings that seem to us as if specially designed for evidence as to the truth of these pregnant theories.

Far down among the lowest stages of organic life, midway between the confines of the vegetable and animal kingdoms, connecting those kingdoms as by a bond, ebbs and flows that wonderful world of organisms, microscopic, invisible to the unaided eye, that we name in general, animalcules, Infusoria, Protozoa, Protista. The large majority of these Protista remain their lives through in the form of a single simple cell. Yet it is beyond dispute that this cell possesses both sensation and real movement. Among the ciliated Infusoria (Fig. 47) these soul-functions are exhibited so clearly in these strange beings that Ehrenberg, the celebrated investigator of the Infusoria, held firmly,

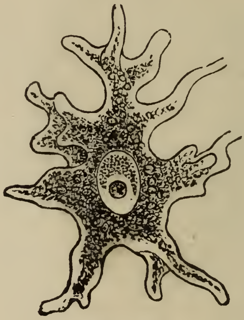

Fig. 48.

A creeping Amœba, a simple, unicellular Protist that ceaselessly alters its shape, giving out extensions of its sarcode that are not persistent; in the middle lies the cell-nucleus with its nucleolus.

and in the most positive way, that in these animals nerves, muscles, brain, and sense-organs are to be found. Yet, in point of fact, no trace of these organs is visible. The protoplasm of the cell-body, the matter of the cell nucleus enclosed therein, these, and these alone, are in this case the material substratum of the soul-life, and form a soul-apparatus of the simplest kind. And if we but convince ourselves that there are even in these one-celled Infusoria widely different characters and temperaments, individuals clever and stupid, strong and weak, lively and dull, light-seeking, light-shunning, we can only realise the many gradations in the soul-life of these little beings by accepting as a fact the idea that fine differentiations obtain in their protoplasmic bodies.

Amongst these unicellular Protista the so-called Amœbæ are of special interest. These animals are to be seen under the microscope everywhere, in fresh water and in the sea (Fig. 48). The naked simple body has no definite shape. It alters its form continually in spontaneous fashion, as it stretches out, sometimes from this region, sometimes from that of its surface, a transitory finger-shaped process. These transitory pseudopodia, appearing and disappearing in ceaseless change, serve the creeping Amœba both in definite motion, like feet, and in sensation, like tentacles. But further, many independent cells in the body of higher animals are not perceptibly different from these Amœbæ.

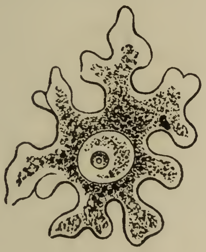

FIG. 49.
Ovum of a calcareous sponge (Olynthus) that undergoes voluntary movements, and feels like an Amœba, and, like the Amœba, has a soul.

As examples of these may be quoted the migratory motile cells. To these amœboid cells belong, *i.e.*, the lymph-corpuscles in our lymphatics, and the white blood-corpuscles of our blood that wander in myriads in the different parts of the body. The young ovum-cells of animals are gifted in like fashion with definite motion and sensibility ; in many sponges these restless spirits wander round freely even in the bodies of their parents (Fig. 49). These ovum-cells, soul-gifted, are therefore of special significance, because all other cells of the organism originate from them.

Soul-function in the wider sense is a general property of all organic cells. But if this is the case we cannot wholly deny to plants a soul-life. Further, the lowest plants are simple cells, and the body of all the higher plants, as of the higher animals, consists of countless individual cells. Only in the latter the division of labor and the centralisation of the state are much more fully carried out than in the former. The government of the animal body is a cell-monarchy, that of the plant a cell-republic. As all the separate cells in a plant remain much more independent than in an animal, the unity of the soul is much less possible in the former than it is in the latter. Only a few special plants, such as the delicate sensitive plant, the fly-catching Dionœa, offer exceptions to this rule. As a consequence the soul-life of plants is much less studied than that of animals, and but few scientific men have turned their attention thither. Amongst these, for example, must be named Professor Fechner, of Leipsic, the acute founder of the science of psychic physics, who has discussed the subject of plant-souls in a series of ingenious works. Besides the necessary acceptance of a plant-soul is also confirmed by the fact that we are not in a position to draw a sharp line of demarcation between the vegetable and animal kingdoms. The unicellular Infusoria or Protista form the bridge that unites the two great kingdoms of organic life into one vast whole. Only the gradation of soul-function is extraordinarily manifold, and differs widely in the two kingdoms.

Amongst the most weighty advances in the new cell-theories ranks the knowledge that the most important substance of the cell, protoplasm, has throughout all living things the same essential nature, whether we study the unicellular Infusoria, isolated plant-cells, or a cell of an animal body. Its essential and most characteristic property is its vitality, or the power of the protoplasm to perceive stimuli of various kinds, and to respond to these stimuli by definite movements. That this property is common to the protoplasm of all cells without exception, we are at once convinced by microscopic observation. On the foundation of this oneness of the living protoplasm we base the hypothesis that the ultimate factors of soul-life are the plastidules, the invisible, homogeneous, elementary particles or molecules of protoplasm, that build up in endless variety the countless different cells.

No reproach is more frequently made against the science of to-day, especially against its most hopeful branch, the study of development, than that it degrades living Nature to the level of a soulless mechanism, banishes from the world the ideal, and kills all the poetry of existence. We believe that our unprejudiced, comparative, genetic study of soul-life gives the lie to that unjust accusation. For if our uniform or monistic conception of Nature is rightly founded, all living matter has a soul, and that most wondrous of all natural phænomena that we usually designate by the word spirit or soul is a general property of living things. Far other than believing in a crude, soulless material, after the manner of our adversaries, we must rather suppose that the primal elements of soul-life, the simple forms of sensibility, pleasure, pain, the simple forms of motion, attraction, and repulsion, are in all living matter, in all protoplasm. But the grades of the up-building and composition of this soul vary in different living beings, and lead us gradually upwards from the quiescent cell-soul through a long series of ascending steps to the conscious and rational soul of man.

Still less can we allow that the poetic and ideal conception of the universe is lessened or endangered by our monistic theory of development. Truly the nymphs and the naiads, dryads and oreads, with whom the streams and rivers of old Greece were alive, who peopled her woods and mountains, are wanting to us to-day. With the gods of Olympus they have long since passed away. But in the place of these anthropoid demigods range the countless elemental spirits of the cells. And if any idea is poetic and accurate alike in highest degree assuredly it is the beautiful thought that in the smallest worms and in the most minute plants thousands of individual delicate souls are living; that in every microscopic unicellular Infusorium a special soul is busy, even as in the blood-corpuscles, ceaselessly travelling in our veins, or in the brain-cells that rise to the highest of all soul-functions, clear consciousness. From this point of view we see in the study of the cell-souls, the greatest step yet made towards the reconciliation of the ideal and the real contemplation of Nature, the old and the new conception of the universe.

PART II.

PREFACE TO PART II.

THE popular lectures on the subject of Evolution that form the second part of this series, have been printed without the introduction of any alterations. As to the reason for this series, and the grounds on which publication without alteration seem desirable, I refer to that which I wrote in the preface to the first part.

The first of the five lectures in this second part is "On the progress and work of Zoology." This was delivered on January 12, 1869, in the university hall of Jena, when I made my entry into the physiological faculty of our university.

It has relation, in the first place, to my undertaking in 1865, the newly-founded chair of zoology. At my entrance into this chair I had at once the opportunity, the duty, the right, to discuss this subject. Nor does this discussion seem superfluous even to-day, if we think how diverse are men's views on the matter. For even skilled teachers of zoology at the present time call themselves professors of zoology and zootomy, and directors of institutes of comparative anatomy and zoology. As though zootomy and comparative anatomy were not parts of zoology! It would be as absurd if a botanist called himself "Professor of botany and plant-anatomy." None the less this fact shows in striking fashion how little even to-day is the great scientific problem of zoology grasped even by its most famous interpreters. I believe that in my Anthropogenie, as well as in other places, I have shown, at sufficient length and in detail, how I have striven to work out this problem, and how I only look upon anthropology as a special branch of zoology. This lecture first appeared in print in the fifth volume of the "Jena Journal of Medicine and Science" (1870), and later as an introduction to the first part of my biological studies (Studies on the Monera and other Protista), which have been out of print for some time.

The second lecture was delivered on November 19, 1875, to the medical and scientific meeting at Jena, as an appendix to recent communications on the history of the Corals. (See my popular lecture on "Arabian Corals. A journey to the coral-reefs of the Red Sea, and a glance at the life of the coral builders." With 7 colored plates and 20 woodcuts. Berlin, 1876). The facts of elementary development, there only hinted at, were worked out more fully in a pamphlet, appearing on May 9, 1876, under the title of "The Perigenesis of the Plastidule, or the Development of Life-Particles: an essay on the Mechanical Explanation of the Elementary Stages of Development." This work was dedicated to the esteemed Curator of the University of Jena, Dr. Moritz Seebeck, on the jubilee or twenty-fifth year of his entrance on his honorable office. As a matter of course, the fundamental idea contained in this work, the regarding a diffused wave-movement of the minutest animate particles or plastidules as the sole effective cause of the commencement of organic development, met with as little acceptance as the attempt made at the same time to explain, in a simple physiological way, heredity as the memory of the plastidule, variability as its power of comprehension. But though I see clearly enough the weakness of this hypothesis, it seems to me even now more reasonable and more in accord with the facts of our knowledge of cells, than the celebrated Theory of Pangenesis of Darwin. The essential antagonism between this hypothesis and mine of Perigenesis I have discussed in the course of the lecture. For this reason, and inasmuch as a third hypothesis on this subject does not, as far as I know, exist, I have thought it wise to reproduce the lecture here without alteration, if it were only for the purpose of arousing more skilled observers to its refutation by a better hypothesis. This much-vilified Perigenesis, like my genealogical trees, will probably result in the fault-finding becoming of less import than the suggestions of improvement.

The third lecture, "On the proofs of Evolution," was delivered on March 3rd, 1876, to the same society as its predecessor, as an appendix to certain communications on the structure of the Gastrula, and on the phylogenetic significance of the earlier ontogenetic stages, in which the difference between the primary Palingenesis and the secondary Cenogenesis is of especial moment. He who is interested in further particulars on this very important subject will find in my "Anthropogenie" (3rd edition, 1877, p. 9 et seq.) a more detailed account. The detailed scientific proofs are in my "Studies on the Gastræa Theory" (Part ii. of the "Biological Studies," 1877, p. 61; "The significance of Palingenesis and of Cenogenesis.") The lecture on the proofs of Evolution appeared for the first time in print in "Cosmos" (Vol. II., Part i., 1877).

The fourth lecture, "On the Present Position of Evolution in relation to Science," was delivered on September 18th, 1877, at the first open sitting of the fiftieth meeting of German naturalists and physicians, at Munich. It appeared also in the official report, and independently in three large editions in September, October, November, 1877 (Stuttgart: Eduard Koch). Although this lecture, in which for the first time the introduction of the study of development into the school curriculum was proposed, is widely read, its place in this collection is justified, first as complement and supplement to the lecture given fourteen years earlier (1863), to the Stettin Association of Naturalists, who printed it in the first part of their collection; second, because of the vigorous and general discussions connected with this Munich lecture. For in reply to it, four days later, Rudolph Virchow, on September 22nd, 1877, brought out his celebrated lecture, "On the Freedom of Science in its Modern Form," in which he made the strongest attack upon our earlier and upon our later theories of development. This lecture I answered in my work, "Free Science and Free Teaching" (Stuttgart: Eduard Koch, 1878). I then declined to enter further into the pedagogic side of the question. This side is, however, thoroughly investigated, and at the same time Virchow's arguments completely refuted, in the brief pamphlet, "Hypothesis in the Schools and the Study of Natural History" (Bonn: Emil Strauss, 1879). The author of this, a head-master in Lippstadt, Hermann Müller, is well-known as one of our ablest instructors, and as one of those German scientists who, like his celebrated brother, Fritz Müller, in Brazil, have furthered with so much energy the Darwinian hypothesis by their own invaluable enquiries. The violent attacks, the disgraceful calumnies to which Hermann Müller and Ernst Krause, the honored editor of "Cosmos" and author of "Werden und Vergeben," have been subjected of late in the Prussian Parliament, will make these excellent authors, as they ought to be, more generally known.

Lastly, the fifth lecture, "On the Origin and Development of the Sense-organs," was given on March 25th, 1878, to the Scientific Club, at Vienna, and appeared, in October of the same year, in the third volume of "Cosmos" (pp. 20 and 99). It stands in close relation to the lecture, "Cell-Souls and Soul-Cells," given about the same time, and included in the first part of this series.

Whilst I desire for this second part of my popular lectures a like kindly reception to that received by the first, I dare to hope that these lectures are carrying the clear light of Evolution into ever-widening circles, and arousing men to the grappling with these high problems of scientific inquiry. That light seems of twofold value, that inquiry of twofold force, in a time like the present. On the one hand the dark clouds of political and intellectual reaction, ever threatening, are gathering. The attempt is being made to rob free inquiry, free teaching of the protection that is guaranteed it by law. On the other hand, is rising a danger far worse, reaching far more widely, from those who more than all others are called upon to guard the right and duty of free knowledge. Inquirers after science of high name and fame, to whose freethinking endeavors, to whose deep-thinking investigations, we were wont to pay highest honor, are quitting their sacred standard, are passing over into the camp of our deadliest foes. They do not simply propose the subjection of free reason to the yoke of the Church's blind dogma. They are not ashamed to cast themselves into the arms of the grossest superstitions of the mediæval times. For Spiritualism, already raising in threatening fashion its hydra-headed crest, is none other than this. It is not enough that many publications are trying to clothe this gross fraud in the garb of true science. Certain naturalists of the foremost rank, as Wallace and Zöllner, have let themselves be caught by the spiritualistic tricks of cunning pick-pockets, and are helping actually to the best of their power in the entrapment of men within the net of these refined deceivers. That a Friedrich Zöllner should fall a victim to the trickery of a Slade is most lamentable, and this the more that the one has rendered to scientific criticism and the true study of Nature so many valuable services, and that the other has ere now been unmasked as a common cheat.

Beyond these sad, these shameful facts, we cast a glance full of hope to the great mass of scientific men, whose heads are free, whose hands are clean. Free Science, free inquiry, free teaching alone can ward off these threatening dangers, and as victors overthrow once again this superstition, the worst foe of human reason. And throughout the wide range of our knowledge nothing can be appealed to for this end with such tremendous effect as our modern teaching of Evolution.

ERNST HAECKEL.

Jena, March 12, 1879.

VI.—THE PROGRESS AND WORK OF ZOOLOGY.

THE PROGRESS AND WORK OF ZOOLOGY.

TO the academic professor entering into a faculty in customary way by a public oration, the most obvious and natural theme is a consideration of the scientific problems that he finds have to be solved in his own special calling, and the manner in which he intends to solve them. Such a discussion may seem trivial and unnecessary in the many branches of science that have long ere this acquired a definite direction, a clear end and aim, and as to whose subject-matter, extent, and treatment, more or less agreement prevails among those that teach them. On the other hand, such discussion would seem to be by no means without value in those studies that have not yet reached this stage of advancement, and are therefore thought of and treated in very different fashion. Of not one of the natural sciences does this hold to such an extent as of zoology. I believe, therefore, that I am doing nothing that is unnecessary when on my entrance into the philosophical faculty to-day I state my own conception of the aims of zoology at the present time, and discuss the manner in which I have endeavored to fill the chair that has been recently founded at Jena in this subject.

In the true understanding of such a demonstration, we can only hope for success if we trace out step by step the historic course of its origin and of its growth. Every thing is, in a word, known only by the history of its evolution. This fundamental law holds of human knowledge as of all other organic functions. It will, therefore, clearly be essential to glance rapidly at the stages of development through which zoology has passed in the course of the civilised life of man.

These stages of development are, in truth, sufficiently strange, and in many respects are unique. For if we include under the conception of zoology, as is natural, the complete knowledge of animal life in all its various forms and functions, the morphology and physiology of animals as a whole, we are encountered at the outset by the wonderful fact, that the different branches of animal study have developed isolated and unconnected one with another in a very remarkable fashion; whilst, on the other hand, they have been on occasion in very close connexion with various other sciences. Thus, the major part of our knowledge of the anatomy and physiology of animals has arisen from the wants of human anatomy and physiology, and these, on their part, have been cultivated in the main on behalf of medicine. This also holds of a part of development, viz., that of the individual or embryology, whilst the other chief division of that subject, the palæontological development of animal species and phyla, stands altogether apart from the former, and is the servant of geology. Psychology, an integral part of physiology, was wholly separated from it, and placed under the guardianship of a purely speculative philosophy that knew nothing of the zoological basis essential to all psychology. Finally, a system of animal classification altogether distinct from all these studies, and having only to do with the description and grouping of the different species of animals, appeared. Although this systematic zoology ignored for the most part the branches of knowledge just enumerated, and chiefly borrowed details from anatomy alone, it claimed none the less to be the "true" zoology. This claim might seem well-established if the amount of zoological literature, and the tables of contents of the handbooks of that science were regarded as the means of estimation. The literature and books have, in fact, been devoted in the main to systematic zoology alone. Of late years, physiology on the one hand, anatomy on the other, have been at warfare on this point, and even now each science is by some regarded as the "true" zoology. So far is this contest from its termination, that even up to the present time among our recognised leaders in science, ideas as to the contents and extent of these two sciences differ widely, and now this part, now that, is put forward as the veritable zoology in opposition to all others.

To the unprejudiced observer, standing without the limits of the contest, this must appear the more strange in that already Aristotle, the mighty naturalist of old, whom a grateful aftertime honors as the Father of Natural History, looked on the study of animals, rightly enough, as the totality of knowledge in respect to animals. His classic "History of Animals," in addition to the smaller writings on special details, his comparative anatomy work on the parts of animals, and his ontogenetic work on their reproduction and development give us a conception of the animal world so universal, so large, that it is not difficult to conceive why this work has during more than fifteen hundred years enjoyed, as a textbook of zoology, an authority altogether without parallel.

Until the sixteenth century no inquirer arose who would undertake to continue the vast work that Aristotle had begun, or even to follow out in detail any special parts of the plan of knowledge that he had sketched. Men were rather contented with transcribing, translating, and annotating the works of Aristotle.

When on the discovery of the new world, and on the discovery of the sea passage to the East Indies, and of many other new routes in the fifteenth and sixteenth centuries, a crowd of new animals and plants, hitherto unknown, were brought to Europe—then Natural History began to awake from its long sleep. The need of distinguishing, grouping, and naming the new forms acted first as a stimulant. This need was the more pressing the greater the number of different plant-species accumulated in the herbariums, or of animal species in the zoological collections. But at the beginning of the eighteenth century came the great reformer of Natural History, who with boldness and strength grasped the gigantic and increasing mass of materials, arranged them with a master hand, and for the first time introduced into our artificial classifications a rigidly logical system. In 1735 appeared the epoch-making work of Carl Linné (Linnæus), and with it the firm foundation for all after systems of classification of animals and plants was laid. The binary nomenclature of Linnæus that was fully worked out in this book, the double method of naming of organic forms, based on the distinction between the species and the genus, proved so practical that down to the present time it is in general use.

Now, it was for the first time possible to arrange the whole mass of animal and plant forms, and to place them in the artificial plan of this system under the particular names of genera and species. Very shortly, as a consequence of this, whole armies of naturalists turned to the newly-discovered domain of the classification of organic beings. On the one hand the distinction between and classification of the many different species of animals and plants, on the other the æsthetic joy in beauty, or even the newborn interest in the strangeness of external form, exercised such a power of attraction that the great majority of naturalists after Linnæus found in this work alone complete satisfaction. Even at the present time, when anatomical and physiological work as opposed to classification has become so strongly developed, the literary ability, and, at all events, the numerical importance of the professors of the latter are so marked that they are still amongst a large number of people regarded as the "true" zoologists. Even to-day more scientific men concern themselves with the collection, preservation, classifying, naming of animal and vegetable forms than with their anatomical and physiological investigation, or with their embryology. Even at the present day these constitute by far the larger part of zoological and botanical literature.

This imposing past, and the powerful position of classification, compel us to state at once our own opinion of this method of study, and the various and widely diverse ideas held as to its value and significance. For whilst some, following Linnæus, see in the systematic arrangement of organic things the real aim of natural history, and others see in such an arrangement only an artificially arranged expression of the sum of our biological knowledge in the manner of the collector of stones, others deny that classification has any scientific value at all.

In order to arrive at a right judgment in this strife of opinions, we must distinguish between those purely artificial systems of a large number of people whose ideal is the most perfect possible zoological museum and herbarium, and the systems of those who see in the natural system of organisms the hypothetical expression of their actual descent, in the approximate determination of which they are pursuing a scientific end as lofty as it is difficult.

Classification of the first order, the museum zoology and herbarium botany, as they have hitherto been carried on to an altogether excessive extent, hardly deserves the name of a science. For science must, as science, be able to show a definite store of general results and laws; it must strive after the understanding of phænomena and the knowledge of their causes; it must never concern itself with the mere knowledge of isolated facts. But this last is in pure classification the sole end and aim. Classification desires nothing further than to know all the separate forms of animals and plants, to describe them, to distinguish them by name. But a merely descriptive natural history of this kind can never be a science. For the conception of a merely descriptive science is a contradiction in terms, a *contradictio in adjecto*. We are far from under-estimating the great practical work of descriptive classification. It is indispensable, both for zoological and botanical collections, and for the special scientific study of animals and plants. It is as indispensable as these very collections, and the whole use of zoological and botanical knowledge in practical life depends upon it. But a science that is put into practice is no longer a pure science. It is an art, and we must consider the purely descriptive classification of organic forms as much an art as are medicine, pharmacy and farming, to all of which it serves also in an especial degree as handmaiden.

That true scientific classification which sees and searches out in the natural system of organic species their actual genealogy is altogether different from artificial, descriptive systematising. This genealogical treatment and conception of the natural system has only become possible in recent times, since Charles Darwin, by his reform of the theory of descent, led us to a true, causal understanding of the phænomena of the organic world. Without doubt, a long time will elapse ere the last branch of our systematic genealogical tree will be perfected, and the end and aim of our genealogical classification be fully attained. But the future belongs to it only by that genealogical conception of the natural system, which sees in the categories or divisions of that system, in the classes, orders, genera, species, nothing but divergent branches of one veritable ancestral tree, which recognises in the relationship of form in organisms their blood-relationships; only by this genealogical conception of the system of forms will classification rise to the height of a true science.

Further, descriptive classification has, during the last century, been compelled to approximate more and more to the true natural system, as it has been compelled more and more to make the collective relationships of structure and development in organic forms the broad basis of their systematic differentiation. The earlier classification of Linnæus was purely artificial in that it made use of single, and by preference external, easily recognised marks for the distinction of species, genera, and even of the larger groups, orders and classes, and dealt with these marks, or at least tried to deal with them rigidly, as one would with a monetary system. More recent classification, especially since the beginning of this century, in lieu of these, rather kept in view the nature of the structure as a whole, and especially the important internal relationships of parts; and during the last ten years has based itself essentially upon embryology. Whilst, at the present time, this last, and especially the history of Evolution as a whole, are more and more understood in their essential worth, classification unconsciously takes its direction more and more decidedly from the genealogical and truly natural system, and in the very doing so of necessity loses, in many instances, its logical character. For a rigidly logical classification must necessarily be often artificial, and for many reasons cannot be reconciled with a genealogical, natural classification.

The synthetic, genealogical classification of the future will therefore aid more than all its predecessors in gathering together the various isolated branches of zoology into one natural centre, the true natural history, unifying them in one all-embracing historic science of animal life. The analytic, descriptive classification of the past did exactly the opposite of this, whilst it was ever striving to press itself forward as the "true" zoology, and to shut out from the domain of the so-called "true" zoology those branches of science which in reality gave it such intrinsic worth as it had, anatomy and embryology. This strange idea explains that isolation in relation to other sciences already mentioned, in which anatomy and the other branches of zoology are in the main evolved.

That part of scientific zoology that more than all others ought to have been cared for by classification, morphology, or anatomy and embryology, has, in fact, up to the beginning of our century worked in absolute independence of the widely prevalent systematic zoology. And even now-a-days we find the question asked by scientists of position, and in handbooks that have many readers, whether, in point of fact, the comparative anatomy of animals belongs to zoology or not.

Of course, Aristotle, long ere the present time, recognised that the natural history of animals involved the knowledge of their internal structure, and he had himself dissected many subjects. Nay, his great predecessor, Democritus of Abdera, founder of the atomic theory, had carried his zeal for anatomical investigation so far that his fellow-citizens thought him mad and banished him. But in the following age the knowledge of the internal anatomy of animals was especially forwarded through medicine, which had, ere this, found the absolute necessity of acquiring a thorough knowledge of the internal structure of the human body. But prejudice and superstition during all the ancient time and the middle ages, put the greatest hindrances in the way of the dissection of human bodies. Hence, men had to take refuge in the anatomy of Mammalia most nearly allied to man ; and from the internal structure of these drew their conclusions as to what ought to be in man. The Roman physician, Claudius Galenus, who lived in the second century after Christ, and whose writings on human anatomy and pathology enjoyed boundless authority up to the fifteenth century, drew his knowledge of human anatomy in the main from the dissection of apes. Even in the fourteenth and fifteenth centuries men only dared carry on the study of human anatomy in secret places ; especially after Pope Boniface VIII. had fulminated the mighty curse of the church against all who dared to dissect human corpses. Hence the physicians, athirst for knowledge, were limited to the anatomy of the dog, the horse, and the allied domestic animals.

In this manner much knowledge, as to the internal structure of the body of the higher animals, was acquired. But, for the first time, in the eighteenth century men began to investigate, and to compare the anatomy of the lower animals. Towards the end of that century Pallas, Poli, and Camper, especially had prepared the ground on which, at the commencement of the present century, Cuvier, for the first time, was able to erect, as an independent edifice, the study of comparative anatomy.

Amid the many and inestimable services rendered by Cuvier to the advancement of zoology, stands out pre-eminently his marking-off the great natural groups that he called branches or types of the animal kingdom, as characterised by certain essential, constant fundamental points in their internal anatomical structure. By this method, the most important general results of comparative anatomy were at once, and for the first time, made of value in the art of classifying animals, and the foundation of a natural system laid. As Cuvier had at once a wide knowledge of animal classification, and a thorough acquaintance with comparative anatomy, the internal connexion between these two studies must have been quite clear to him, so that he was able to speak of comparative anatomy as at once the forerunner and as the goal of zoology.

Nevertheless, this fusion of the sciences was far from being generally recognised. In fact, for a time, there appeared to be a more acute separation made of one from the other, when, on the one hand, men turned their attention to the inquiry into the internal structure, only possible in the higher animals by dissection, *i.e.*, comparative anatomy, and on the other to the description of external forms, that is true or systematic zoology. But in this there was a double blunder. For, in the first place, the mere anatomical dissection of animals, and the description of their internal structure, is not comparative anatomy, but is rather mere zootomy. But zootomy deals simply with analysis and description, whilst comparative anatomy, on the other hand, as its name implies, working synthetically and comparatively, rises to the rank of a true philosophic science, a rank to which the other never can lay claim. Zootomy remains a pure art, like human anatomy, so long as the latter does not work by the method of comparison and synthesis.

But, in the second place, it is also a blunder to comprehend under anatomy, only the knowledge of the internal structure, and not that of external form. Anatomy is rather the sum-total of the knowledge of the fully-developed, or perfect forms of organisms, whether these appear externally on the surface of the body or not. When, *e.g.*, Savigny, in the innumerable and manifold parts of the mouth of insects, recognised one and the same fundamental form, a true so-called type, this was pure comparative anatomy, although the parts of the mouth of insects are altogether external and are, moreover, of constant service in systematic zoology, although this last use is, of course, only in the opposite, analytical, zootomical sense.

Like the study of organs, which forms the chief part of comparative anatomy, the study of their elemental parts, the study of tissues or histology has also, under the stimulus of medicine, taken its origin from human anatomy. It is true that the great Italian, Marcello Malpighi, more than two hundred years ago, began, by aid of the microscope that had just been discovered, to examine the minuter structure of the animal and of the plant body, and the composition of the different tissues. But neither Malpighi and Leeuwenhoeck, nor the microscopists of the eighteenth century, were able to do more than make a heterogeneous collection of disconnected facts. Even after Xavier Bichat, 1801, had given, in his "Anatomie Generale," the first connected account of human histology, nearly forty years passed ere, led by Schleiden's vegetable-cell theory, enunciated a little while before, Theodor Schwann published his epoch-making, "Enquiries into the Correlations in Structure and Growth between Animals and Plants." In this it was shown that the animal body, like that of the plant, was composed of independent elementary organisms, or individuals of the first rank, of cells, and that every multicellular organism arose from a simple cell. This cell-theory, however, did not do its remarkable work nearly so thoroughly or so quickly in zoology as in botany, where, in a very short space of time, the study of cells became so completely the main part of anatomy, that the two ideas were often regarded as identical. But the study of human cells and its companion, the histology of the vertebrate body, soon received an exceedingly powerful impulse, as soon as scientific medicine rightly understood its fundamental significance. The acute Virchow especially, by means of his cellular pathology, was able to grasp and to demonstrate the inner nature of the cell life more completely than the vast array of histologists clinging only to the study of external cell-forms. The histology of the invertebrate animals, however, was very behindhand, and the last century only has begun, in comprehensive fashion, the unveiling of the immense treasures that lie hidden there. It is at all events the greater pity that to-day even the real meaning of cell-life is altogether lost by the majority of the zoologists in name, and that histology is, to a far greater extent than morphology, regarded as a study about which the true zoologist has no need to trouble himself.

The study of the development of animals has grown up yet more widely sundered from systematic zoology than comparative anatomy and histology. This holds good of both its branches, of the development of the individual animal, commonly called embryology, more accurately ontogeny, and of that of animal species and phyla, palæontological development or phylogeny.

The natural history of man, and the interest taken therein by scientific medicine, gave rise to the former. Human anatomists were obliged, of necessity, to consider the structure and development of the human embryo. But as the study of embryonic development in its earliest stages in man and in other Mammalia is a difficult pursuit, men turned at first to those nearly allied Vertebrata, the birds, in whom the development of the egg can with ease be traced from the commencement. Despite the fact, that even in the seventeenth century a number of facts as to vertebrate embryos had been given as result of ancient and of more recent investigation, Caspar Fredrich Wolff was the first to prove in his "Theoria Generationis" (1759), that the true nature of animal development was a veritable Epigenesis. Even then half a century elapsed ere this idea received the recognition it deserved.

When, at the beginning of the present century, embryology received a fresh and powerful impulse, especially at the hands of Pander and Baer, again the Vertebrata, and chiefly the Mammalia and Aves, were the animals about whose development man, having an eye to that of his own species, concerned himself in the main. It is true that the far-seeing Baer, in his "Development of Animals," which dealt principally with the Vertebrata, pointed out in broad outlines the chief characters that distinguished the main groups of the invertebrate animals in their ontogeny. But some ten years later, more detailed and comprehensive studies of the history of development of the different Invertebrata began to be made. Even at the present time, despite the many brilliant discoveries of the past ten years, our knowledge of the development of the Invertebrata, as a whole, is far behind our knowledge of the Vertebrata. But this much at least is gained, that every day in zoology and botany, the real scientific student is learning to recognise development as the essential fundamental through which a true understanding of the anatomy of the adult form can alone be acquired.

It is true, that hitherto the recognition of this fact has been limited to the one branch of development just named, that of the individual animal. The second division of the subject, of no less significance, has on the contrary been, until quite recently, neglected in the strangest fashion ; that is, the palæontological development of animal species, phylogeny. This has to investigate the changes of form that the few principal classes of the animal kingdom, the phyla or stems, have passed through during the long periods of the earth's history in the incessant transformation of species that has taken place.

When first Charles Darwin, in 1859, published his epoch-making theory of Natural Selection, and gave, in the doing thus, to Lamarck's theory of descent, enunciated fifty years earlier, its impregnable causal foundation, it became possible for men to deal in earnest with this momentous, this interesting branch of zoology that had until then not existed even in name. It became clear that the empirical materials of this history of ancestral forms had been accumulated in a very different domain of science, without any apparent connexion with zoology. For the fossil remains of animals that lie buried in the womb of earth, and as "medals struck off at the creation," tell us the history of animals dead thousands of years ago, were studied at first, and chiefly, on account of their bearing on the history of the development of the globe. The geologists were the first to give close attention to petrefactions, and hence palæontology has made its way hitherto wholly in aid of geology.

Now, the value of fossils to the geologist lies chiefly in the fact that they tell him the relative ages of the strata that have been deposited from the water, and are now lying one upon the other. The zoologist, on the other hand, recognises in petrefactions the remains of dead and gone forefathers and relations of the animals now living. He has to aim at building up from the regular historic succession in which these occur, a correct ancestral history, the history of the ceaseless transformation of species. Hence, *e.g.*, is it that the different mammalian fossils have the deepest interest for zoologists, the least for geologists. On the other hand, the many fossil species of Gasteropoda and Lamellibranchiata that have for the geologist the highest significance, as guides in the study of the formation of mountains, are of only secondary importance in the phylogeny of animals.

No mistake in the treatment of zoology has, up to the present time, led to such evil consequences as this unnatural separation of the two branches of the study of development. It was impossible for man to understand the essential nature of organic evolution so long as ontogeny and phylogeny, the development of the individual and that of the species, had no concern one with the other. For, in truth, these two halves of the science of development stand in the most intimate causal connexion. The series of forms that the organic individual runs through, in its short, swift development from the egg, repeats for us in broad, general outlines the series of forms that its ancestors have run through since the beginning of organic existence in the long, slow course of their ancestral history, or transformation of species. Or, in other words, the history of the individual, or ontogeny, is a brief, rapid repetition, under laws of heredity and adaptation, of the history of the race, or phylogeny.

The clear recognition of this most important relation is of greatest moment, not alone for the estimation of the science of development, but for the whole of zoology. But the fact that this was first clearly understood but recently will enable us to grasp how very backward even now is our science. The natural genealogical classification which regards the natural system of organic species as their genealogical tree can, as we have seen, only develop unfettered as a consequence of this recognition.

The branches of zoology that have been mentioned so far, anatomy and classification, development of the individual and development of the race, all belong to that wide domain of our science that is named the study of forms, or morphology. Side by side with this, as a second part of zoology, stands physiology, the study of the life-phænomena of animals. As morphology is divided into the two chief branches of anatomy and development, so physiology is divided into the physiology of labor and the physiology of relation. The former investigates the intrinsic functions of the organism, the latter its life-relations to the outer world. Further, these two orders of study have taken origin from departments of natural science quite different and widely separated.

That which has to do with the environment, the physiology of relation, or the study of the relationship between the animal organism and the outer world, is again divided into two parts, œcology and chorology. By œcology we mean the study of the œconomy, the house-keeping of animal organisms. This has to do with the totality of the relations of the animal, both to its inorganic and its organic surroundings, and, above all, the amicable and inimical relations to those animals and plants with which it comes into direct or indirect contact: in a word, all those complex mutual relationships that Darwin has shown are the conditions of the struggle for existence. This œcology (often incorrectly called biology in its limited sense) constituted, until the present time, the chief part of so-called "natural history" in the ordinary sense of the word. It grew, as the many popular natural histories of former and of recent times show, in very close connexion with ordinary classification. Uncritically as this economy of animals was treated on the whole, it at all events had the merit of keeping alive an interest in zoology in many minds.

Much less interest was for a long time taken in the other branch of the physiology of relation, viz., chorology, *i.e.*, the study of the geographical and topographical distribution, of the horizontal and vertical limits of animal species, or the geography of animals in the widest sense of the word. Until the present time this was a waste chaos of different facts, heaped together and not understood, in which even an Alexander Humboldt and a Carl Ritter could only now and again create any deep interest. Of late, thanks to

Darwin's new fundamental idea, the theory of descent, it has become possible to understand the geographical and topographical distribution of organic species in relation to their mechanical causes, and to explain them as in their real nature active natural processes, essentially conditioned by the migrations of varieties and their transformation in the struggle for existence. Although, therefore, only its first rudiments are grasped, yet chorology, like œcology, gives us a glimpse into the mass of interesting results that the future will bring forth.

Another main division of physiology that we noted previously as opposed to external physiology, or that of relation, was internal physiology, or that of conservation. This investigates the life of the organism in relation to itself, the functions of its organs, and especially those very important and very general life-phænomena, the functions of self-preservation, of growth, of nutrition, and reproduction. This second main division of physiology has, like anatomy, taken origin, quite independently of the first, from medicine. As soon as scientific medicine recognised that in order to a correct knowledge of the human body in disease, not only the knowledge of its organisation, but also of all its life-phænomena was an indispensable preliminary, it was forced to make human physiology the forerunner of pathology. But as the human organism was not available for many physiological inquiries, especially for the investigations and experiments connected with vivisection, the human physiologists very early turned to the Vertebrata most nearly allied to man, amongst which the faithful dog and the luckless frog have chiefly furnished the unfortunate subject-matter for experimental physiology. Of course this inquiry into certain life-phænomena in individual Vertebrata that arose from practical needs, was far from leading to a real comparative physiology. This even now exists only in conception and in outline, and the one-sidedness of the physiologists is not less blamable in this respect than the indifference of the systematic zoologists. This much, however, is already gained, that the metaphysical spectre of a so-called "vital force" is once and for ever banished, not only from the domain of human, but also from that of all animal physiology. In a true scientific investigation and explanation of life-phænomena, there can now be no more talk of this mystic product of the confusion of dualism which has done so much harm and made so much perplexity—now as an active life-principle, now as a final cause working towards a designed end, now as an organic creative force. We know to-day that all the life-phænomena of the lower animals, as of man, follow, under an absolute necessity, great mechanical natural laws ; that they are brought about by no final causes, but by mechanical or efficient causes ; that they are based in the last analysis upon physical and chemical processes, on, in fine, the delicate and complex motor-phænomena of the very small particles that make up living bodies. Here also in physiology, as in morphology, full light has been thrown, of late, on the natural and mechanical connexion of all phænomena by the descent-theory of Lamarck and Darwin. This shows us how, like the forms of cells and organs, their special life-movements also, their specific functions, have gradually, step by step, evolved along the lengthy, the toilsome, path of ever-advancing development and specialisation.

In no department of zoology will this knowledge bring about greater revolution than in that of animal psychology, to which we must, of necessity, in conclusion, give special attention for a moment. For, without doubt, the study of the animal soul has developed in more complete isolation, and is therefore more behindhand, than all other branches of zoology. Even human psychology, whence all the comparative psychology of the lower animals has ever sprung, has, as yet, labored wholly in the service of a speculative philosophy, that from the outset up to the present time has despised the indispensable fundamentals of empirical physiology.

What should we say to-day of a botanist who wished to separate the soul-life of plants from their other life-phænomena, and to relegate the study of the latter to empirical physiology, the study of the former to speculative philosophy ? And the soul-phænomena of many plants (as *e.g.* the sensitive Mimosa, the Venus' Flytrap and even our native berberry flowers) present a higher degree of perfection than those of many lower animals, as *e.g.* sponges, many corals and ascidians. But these last, the ascidians, among all the invertebrate animals, have the closest blood-relationship to the Vertebrata; and amongst them we find such an unbroken continuity in the graduated evolution of the soul-life that we can make out a connected, progressive series up to and through many Amphibia, whose spiritual development is far inferior to that of higher Vertebrata, and thence to many Mammalia that, in all probability, reach in mental development beyond the lowest conditions in man.

When once we, turning from this dark domain, ever more and more darkened by mystic speculation, follow those methods of inquiry that are our best guides in biology to the true end, the two methods of comparison and the study of development, we must, perforce, be led to the conclusion that the human soul-life, like other vital functions, has slowly evolved during man's history in the struggle for existence, step by step with the advancing perfection of the nervous system. Consequently, inquiry into this subject can fall to the lot of no other science than comparative physiology as a branch of zoology.

This is before all the point at which zoology comes into closest contact with speculative philosophy. But our care must be so to work that this contact may lead not to a hostile repulsion, but to a closer approximation. For zoology, to my thinking, can dispense with speculative philosophy as little as any other natural science. It is as little able to lead to lasting results without speculative philosophy, as the latter without the empirical basis of natural science. The highest aim and problem of sound natural science is the general and philosophical knowledge of nature. The deepest fundamentals and the very pillars of sound philosophy are the physiological laws of empirical origin. Only by the most complete mutual interpenetration and co-working can empirical natural science and speculative philosophy attain the end they have in common, the knowledge of the truths of nature.

Those scientists who, proud of their absolute empiricism, think they can advance science without philosophical thinking are guilty of the terrible confusion of ideas, and of judgment, and of the astounding blunders in natural logic, which we meet with generally in zoological and botanical literature, confusion and blunders which must draw from every philosopher a gesture of pity and of regret. The philosophers, on the other hand, who think they can arrive at the knowledge of general laws by pure speculation, without any empirical and scientific basis, are building castles in the air, that the first good empiric, with the help of actual experiments, can blow into the infinite.

Nothing demonstrates more clearly the necessity of the most complete mutual interworking between analytic empiricism and synthetic philosophy, in order to a true advance of science, and especially of zoology, than the great question which at present is engaging the thoughtful in all parts of the earth, the question as to man's place in nature. Even this question, however, we regard as already decided in the sense of the theory of descent. In conformity with that theory we admit a graduated evolution of the human race from a series of lower vertebrate forms. We base our idea upon the consensus of opinion of the greatest scientific men now living. Of these we will name only the great Englishmen, Darwin, Lyell, Huxley, Hooker, Spencer, Lewes. In their name we bid the German men of science nearer home be silent.

In opposition to those able and thoughtful men who, ranking among the many foes of this theory, are of an opinion opposed to mine, I cannot but lay especial stress on the fact that this question of questions is in the strictest sense of the word a purely zoological one, and that the battle-field on which it must be decided is the domain of scientific zoology alone, *i.e.*, the empirical and philosophical study of animals. For the zoologist alone, who has certain morphological and physiological knowledge, and who knows how to make use thoughtfully thereof in Catholic fashion, can rightly estimate the immense value of the proofs that the theory of descent in its application to man has been already established beyond all possibility of contradiction. When, therefore, speculative philosophers, without the indispensable knowledge of anatomy, embryology, and physiology, wish to deal with this question, their contributions to its solution are as worthless as those of the rude empirics who, from want of philosophic grasp, are unable to combine and estimate the exact value of a series of facts. Although now, unfortunately, the majority of the many treatises that aim at deciding once for all man's place in nature belong to one or to the other of these two categories, still on the other hand its definite determination is, by the efforts of true empirical and philosophical zoology, advanced so far that in a short time the prophecy of Lyell ought to come true: "It will come to pass in this question as ever when a new and surprising scientific truth is discovered, that men will say first, it is not true; second, it is antagonistic to religion; lastly, it has been known these many years."

As I close my explanation of the ends and the significance of scientific zoology with this hint as to its highest problem, I dare to hope that I have given an approximate idea of the extraordinary capabilities of development, the momentous future of our young science. Whilst the study of animals existed for a century and a half as an entirely isolated science, whilst it has lived the greater part of this time in child-like unconsciousness, ignorant of the forces slumbering within it, and without a dream of its own lofty aims, it has since the commencement of our century begun to gird itself up for higher stages of development, and to gather to itself its own integral parts that have been evolving unconnected with each other in the service of other, stranger sciences. Since, ten years ago, Charles Darwin fashioned that unifying bond which unites all these orders of thought, once so widely asunder, into one majestic whole, since in doing thus he breathed into the giant form of zoology, born again, a new, a forceful life, the range of view, the ends and aims of our science have grown beyond measure. From all sides it is drawing to itself keen workers, athirst for knowledge. In all directions there is promise of the richest harvests. And if we think but little of all other acquisitions of zoology, its indissoluble connexion with empirical and philosophical anthropology alone would give it a meaning of the very deepest. The monistic philosophy of the future will be unable to dispense with the comparative study of animals on this one ground alone. From the small, despised seed grain of zoology a tree of knowledge shall evolve, that will in the coming years gather all other sciences beneath its shade, and from whose roots all shall draw something at least of sustenance.

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PLAN OF THE CHIEF DIVISIONS OF SCIENTIFIC ZOOLOGY.

ANIMAL MORPHOLOGY, OR THE STUDY OF FORMS.	I. ANATOMY. Study of body-structure. (Comparative anatomy.)	1. Tectology, or study of structure. (Histology, Organology, Blastology, Cosmology.)
		2. Promorphology, or study of types. (Geometric ideals, types and actual structure.)
	II. ZOOGENY. Development of animals.	3. Ontogeny. History of embryo. (Embryology, metamorphosis, life-history.)
		4. Phylogeny. History of race. (Palæontology, genealogy, classification.)
ANIMAL PHYSIOLOGY, OR THE STUDY OF FUNCTIONS.	III. ERGOLOGY. Physiology of internal work.	5. Physiology of vegetative functions. (Digestion, nutrition, circulation, respiration, reproduction.)
		6. Physiology of animal functions. (Sensation, motion, will, imagination, soul-life.)
	IV. PERILOGY. Physiology of relation.	7. Œcology. Study of the household. (Œconomy, habitat, relation to other organisms, parasites.)
		8. Chorology. Study of distribution. (Geography and topography of animals—their diffusion.)

VII.—THE DEVELOPMENT OF LIFE-PARTICLES;

And THE PERIGENESIS OF THE PLASTIDULE.

THE DEVELOPMENT OF LIFE-PARTICLES;

AND THE PERIGENESIS OF THE PLASTIDULE.

FOR the last ten years a philosophic movement in natural science has gone on with steadily increasing force, whose waves have reached ever wider and wider circles, and have produced in the realm of philosophy a corresponding movement of a scientific order. With the increase in the number of new discoveries that the unwearied energy of many observers is making in all parts of the domain of natural science, the more powerfully are all thoughtful scientific men feeling the necessity of a unified philosophic standpoint for their understanding of these discoveries, of rising from the knowledge of facts to that of causes. On the other hand, the less the ability of those many systems of metaphysical speculation that are in deadly hostility to empiricism to hold together the remnants of their quondam following, the more is the conviction forced on the far-seeing philosophers, that on the secure basis of experimentally acquired facts can an enduring system of knowledge be built, and that hence the knowledge of facts must precede the knowledge of their causes.

Of all the many things that this remarkable approximation of philosophy and natural science has led to and has favored, without doubt the most important is the origination of the study of development, to which Charles Darwin gave its first impulse by his work on the "Origin of Species." Although this great scientific observer, with his usual care, abstained from giving to his theory of Natural Selection and the theory of descent as modified by the former the name of a philosophic system, and from drawing thence all the consequences interwoven with his theory ; yet no careful observer can any longer doubt that the vastest consequences of Darwin's writings lie, not in the immense wealth of the experimental facts he has gathered together, but in the intelligent explanation and co-ordination of those facts by means of the common bond of the theory of Evolution. But this unifying explanation of the different orders of phænomena is a philosophical fact.

I tried ten years ago, in my "Generelle Morphologie der Organismen," to make systematically the first comprehensive attempt to lay down the philosophical bases of thought for the new theory of Evolution, and especially to construct the mechanical foundations of the science of organic forms in the light of the theory of descent. Though this attempt failed and was in many respects premature, yet many statements that were then made for the first time have since proved in accordance with fact and productive of results. In especial does this hold true in respect to my enunciation of the two main branches of the study of organic Evolution and of the causal connexion between them.

As long as we understood by the study of development, after our blundering fashion, only that of individual organic forms, the so-called embryology and metamorphology (embryonic and post-embryonic development), both these were included under the term ontogeny, or the history of the germ. But this same ontogeny is but a main division of biogeny, or the comprehensive "history of development of organisms."

As a second division, opposed, in a sense, to the former, we have the palæontological development of species and phyla, the series of forms that have evolved in an unbroken succession of numberless generations, from the first appearance of organic life on our planet up to the present time. This history of the successions of generations, including palæontology and genealogy, is best named in brief as ancestral history or phylogeny.

Ontogeny and phylogeny, the history of the individual and the history of the race, are, as I hold, two sciences standing in the closest and most immediate causal connexion. But these two subjects evolved to such different extents, that the older of them only, ontogeny, was at first held as the "true development;" whilst the younger, phylogeny, only ten years ago became an independent branch of knowledge, and even at the present day is but little known—all this results, first, from the different experimental methods; second from the dissimilar theoretical claims of the two studies. For the individual development of organisms, ontogeny, is a swift process of upbuilding that is run through in a very short time under our very eyes, whose external appearances we can follow directly from beginning to end, generally within a few weeks or months, rarely within a longer period of time. Step by step, stage by stage, we are able, by continuous observation, to trace out the changing series of forms through which every individual animal, every individual plant, passes from the ovum to the adult condition. On the other hand, the palæontological development of organisms, their ancestral evolution or phylogenesis, a slower process of upbuilding, occupies an enormous time, whose individual stages are to be measured by thousands of years, whose perceptible advances, corresponding with geological formations, must be measured by hundreds of thousands and by millions of years. The difference between a seconds clock, whose hand completes its circle in a minute, and a year clock, whose hand completes its circle in 365 days, is not so great as the difference between the advance as with a breathless speed of embryonic history, and the movement hardly perceptible in its slowness of race history. But what weighs still more heavily on us is the deficient empirical basis of the latter. The palæontological account of first creations, which ought to show us directly, in the successive series of fossils, the picture-galleries of the dead ancestors of the organisms of to-day, is, on well-known grounds, in the highest degree imperfect and deficient. Even as regards its very important fragmentary remains this branch of knowledge could scarcely be intelligible to us unless we were in possession of two others, of highest value as supplements and completions to palæontology—comparative anatomy and ontogeny. The lofty significance that in especial belongs to comparative anatomy in this connexion Carl Gegenbauer has shown, more than other men, in his excellent works. It is possible for us by a thorough knowledge, a thoughtful comparison, a critical use of these three most weighty branches of science, comparative anatomy, ontogeny, phylogeny, to understand the outlines of phylogeny, or the history of the race.

The intimate causal nexus between ontogeny and phylogeny is therefore most important of all. This causal connexion, full of meaning, that the older thinkers had foretold for half a century, and on which Fritz Müller more than all others, except Darwin, has laid stress, may be formulated as follows. The series of forms through which the individual organism passes during its development from the egg to the complete adult condition is a brief, condensed repetition of the long series of forms that its animal ancestors, or the parent forms of its species, have passed through from the earliest ages of what is called organic creation to the present time. (Cf. my "Generelle Morphologie," vol. ii., pp. 295—300; "Zeitschrift für Naturwissenschaft (Jena), vol., viii., p. 5; vol. ix., p. 409; vol. x. Supplement, p. 77.)

The development of the embryo is an epitome of that of the race; an epitome the more complete, the more the epitomised development, or palingenesis, is retained under heredity; the less complete, the more the development that is not due to heredity, or cenogenesis, is introduced by adaptation.

That this biogenetic fundamental law is the true thread of Ariadne that will lead us through the involved labyrinth of ancestral history, I think I have demonstrated for the whole animal kingdom, by the example of the Gastrula in my Gastræa theory. In my monograph on the calcareous sponges, I have proved the law as regards the whole of the allied forms of this little group of animals, working it out in details in individuals. In my "Anthropogenie" I have tried to prove it by the special example of the history of the human embryo.

Every advance in embryonic life is of either a palingenetic or cenogenetic nature.

As soon as heredity was proved to be the active cause of palingenesis, adaptation to be that of cenogenesis, and these two, working together, the essential factors of ontogenesis, the next aim appeared to be to work out more thoroughly heredity and adaptation as physiological functions of organisms.

In my "Generelle Morphologie," I had brought heredity into direct physiological connexion with reproduction, adaptation with nutrition, and thus I had shown the possibility of a mechanical conception, and a physical and chemical explanation of these two vastly important constructive functions of organisms. For if the physiology of to-day most righteously closes its doors against vitalism and teleology, if it rejects every mystical and supernatural action of the nature of a "life-force," and only allows within its domain physical and chemical, or in one word mechanical forces, it must seek the like mechanical explanation for the two most momentous of the life-functions that have to do with the upbuilding of the body, heredity and adaptation. And if our great critical philosopher, Immanuel Kant, rightly demands of natural science that it substitute at all points mechanical causes (*causæ efficientes*) for intelligent causes (*causæ finales*): if Kant, moreover, considers that mechanics alone provides a real explanation of phænomena, and that "in general there can be no natural science outside the principles of mechanics," we shall recognise this monistic basis as the only possible one for our history of development if it is to be a genuine natural science; we shall seek mechanical causes, and mechanical causes alone, for the physical facts of organic Evolution.

But modern physiology, to which alone this duty falls, has not, up to the present, ventured on the attempt really to grapple with heredity and adaptation in this sense, and to seek out the elemental changes involved in the two physiological functions. An attempt of this kind has as yet been made by Charles Darwin alone, when he enunciated, in 1868, his provisional hypothesis of pangenesis. This is to be found in the second volume of his valuable work on "The Variations of Animals and Plants under Domestication" (chap. 27). In the second edition of this work that has recently appeared (1875), Darwin has stated his hypothesis of pangenesis more fully, and with some modifications. I give now, in the first place, the gist of the theory in the words of its founder (vol. ii., p. 369) :—

"It is almost universally admitted that cells, or the units of the body, propagate themselves by self-division or proliferation, retaining the same nature, and ultimately becoming converted into the various tissues and substances of the body. But besides this means of increase I assume that cells, before their conversion into completely passive or 'formed material,' throw off minute granules or atoms, which circulate freely throughout the system, and when supplied with proper nutriment multiply by self-division, subsequently becoming developed into cells like those from which they were derived. These granules, for the sake of distinctness, may be called cell-gemmules, or, as the cellular theory is not fully established, simply gemmules. They are supposed to be transmitted from the parents to the offspring, and are generally developed in the generation which immediately succeeds, but are often transmitted in a dormant state during many generations and are then developed. Their development is supposed to depend on their union with other partially developed cells or gemmules which precede them in the regular course of growth. Why I use the term union will be seen when we discuss the direct action of pollen on the tissues of the mother-plant. Gemmules are supposed to be thrown off by every cell or unit, not only during the adult state, but during all the stages of development. Lastly, I assume that the gemmules in their dormant state, have a mutual affinity for each other, leading to their aggregation either into buds or into the sexual elements. Hence, speaking strictly, it is not the reproductive elements, nor the buds, which generate new organisms, but the cells themselves throughout the body."

This is in brief the hypothesis of pangenesis of Charles Darwin. Its detailed explanation and the proofs in its favor, its application to the various phænomena of organic development, and especially its use in explaining the phænomena of heredity and adaptation, may be seen in the original work, a work which by its unwearied accumulation and critical investigation of a mass of observations unequalled in extent, and by the grasp and clear presentment of those facts, shows us the great English naturalist "in his habit as he lives."

Charles Darwin has himself from the outset called his hypothesis of pangenesis a provisional one, a first attempt at tracing back the totality of the processes of organic development to primary causes, at explaining them on one unifying causal basis. This pangenesis hypothesis has, like his Natural Selection theory, awakened the liveliest interest. It has met with as complete assent on the one hand as flat contradiction on the other. For my own part I have thus far not dealt with it in my works, and in my "Natürliche Schöpfungs-geschichte" and "Anthropogenie," as in my other essays upon the study of Evolution, I have purposely as yet passed over the idea of pangenesis in silence. I am anxious to add that neither want of interest nor want of esteem for its keen-sensed author has led me to this silence. The real truth lies in this. From the outset, and now after I have been acquainted with pangenesis for eight years, I have found myself in complete mental antagonism to it, an antagonism the stronger and the more invincible the more I try to become acquainted with the hypothesis by continued reflexion on it, and try to grasp its usefulness in application to the various phænomena of development. Only I was always, and am now, possessed of far too high a veneration of Charles Darwin, of far too sincere an admiration for his suggestive thought, to oppose a hypothesis so comprehensive and in large measure so well founded, or to attempt its refutation unless I were able to place something else in its stead. If to-day I venture on this attempt, I do so because certain germs laid down ten years ago in the "Generelle Morphologie," have in the interim developed into a definite hypothesis, that seems to me to have more intrinsic probability of truth than pangenesis, a hypothesis of which I dare to hope that it may rise to the height of a genetic molecular theory. I call this hypothesis "the perigenesis of the plastidule," or making the attempt at a modern name that shall correspond as nearly as possible with the more classical one, "the wave-motions of living particles."

To prevent misunderstanding, and to obviate the false view taken in connexion with my carbon theory and others of my theoretical speculations, that I wanted to introduce a new "dogma" into science, I state in advance that I also regard this perigenesis of the plastidule as only a provisional hypothesis, although I entertain the hope that the germ lies within it of a wide theory by which, it may be, in the future the whole of the phænomena of organic development will be explained in a rigidly mechanical fashion on physical and chemical elementary principles. At the same time I would explain, with reference to my esteemed friend and master, Charles Darwin, that my opposition is solely limited to his pangenesis. His other theoretical ideas, especially that most special work of his, the theory of Selection and all its consequences, I regard as perfect, and work for with all my powers. This explanation is assuredly unnecessary in regard to Darwin himself. For the great English scientist, who introduced into biology a new epoch, fruitful beyond all calculation, to whom I myself owe my chief stimulus to work, is much too firmly convinced of my sincere gratitude and real sense of inferiority to him to be at all astonished at my combating pangenesis and preferring perigenesis. This explanation, however, seems necessary on account of the tactics of many foes of the Descent theory, who hail any differences of opinion that appear in the camp of its adherents with delight as signs of its inaccuracy. Once again, therefore, I state explicitly that Darwin's theory of Selection and the new theory of Descent based upon it in my opinion are unshaken, and will not be in the slightest degree menaced by the speculative discussions that follow. Here we are simply concerned with a hypothesis as to the mechanical explanation of the most elementary conditions of Evolution. Whether pangenesis or perigenesis is right, or even if both are inaccurate, the Descent theory of Lamarck and the Selection theory of Darwin are not affected in the least.

For the foundation of our perigenesis, we turn to those ideas of the organic world that are based upon the nature of visible elemental parts, and that find widest expression in the magnificent cell-theory. Since the cell-theory was established for the plant-kingdom, by the genial botanist Schleiden, in Jena, in 1838, and was extended to the animal kingdom by Schwann in the following year, it has held its ground in botany as in zoology, in the morphology as in the physiology of organisms, as the firm basis and immovable starting-point for every elementary inquiry. Greatly as the conception of the cell has changed in the thirty-eight years that have elapsed since that time, grand as has been the building up within, the extension without, of the cell-theory, its fundamental conception has remained unchanged, and has ever risen to a higher value. This fundamental conception is, that we have to look upon the microscopic cells as independent living beings, as organisms that are physiologically and anatomically autonomous. Brücke has, therefore, called them very aptly, elementary organisms; Virchow, life-armies; Darwin, living units. Referring to the successive steps of the organic individuality (organ, person, stock), I have, in my "Generelle Morphologie," placed them as "individuals of the first order," at the foot of the anatomical study of individuality. Rudolf Virchow, more than all other scientific men, has the further merit of having extended the study of cells in this sense in all directions, and given, by his "cellular pathology," a firm histological basis to recent medicine. If I myself have been able to contribute something to the earlier upbuilding of the study of development, I owe it in great measure to the ideas in cellular biology that the teaching of Virchow at Würzburg gave me twenty years ago. In pursuance of his ideas, I looked upon every higher organism as an organised social unity, as a state whose citizens are the individual cells. As in every civilised state the individual citizens are independent to a certain extent, but at the same time are connected in the division of their labor one with another, and are subject to general laws; so in the body of every higher plant and of every higher animal the innumerable microscopic cells enjoy, to a certain extent, their individual independence, but are, as result of specialisation, differently constructed and dependent one on another; in like manner, also, they are governed to a greater or less degree by the laws of the centralised whole. This political comparison, as complete as it is frequent in its application, is no strained picture of the imagination. It expresses a real fact. The cells are in reality citizens. The simile can be extended yet further, in that we may regard the extended and yet centralised animal body as a cell-monarchy, the plant-organism with its lesser centralisation as a cell-republic. Just as the different state-crafts, in the various governments existing at the present time among men, present us with a long series of advancing perfection from the rude hordes of savages to the most highly developed civilised states, so does the comparative anatomy of plants and animals reveal to us a long series of gradations of increasing perfection in the cell-states. At the lowest step in the association of cells and the formation of a community, we encounter the lower algæ and fungi, the sponges and corals, who have in their limited specialisation and centralisation not risen above the level of the wild savage tribes. At the other extreme we find, high up in evolution, the mighty cell-republic of the tree, the wondrous cell-monarchy of the Vertebrata, in which the manifold improvement and specialisation of the constituent cells have given rise to the origin of the most diverse organs, and in which the co-ordination and subordination of classes, the co-operation for the welfare of the whole, the centralisation of government, in a word, organisation, have reached a marvellous height. As a rule, the blunder is made, that this great complex organism, with its judicious contrivances, can only have been called into being as result of a carefully thought-out plan of creation. Nevertheless, this organised cell-state, with all its "plans," has evolved without any preconceived aim as necessarily from the co-operation and the co-ordination of its constituent cells in the course of time, as the civilised state of man in the course of a few thousand years evolves step by step as result of the transformations and advancing specialisation of its citizens. The history of human civilisation is the explanation of the history of the organisation of the multicellular organisms.

This political conception of the cell-theory, on which the whole understanding of biology hangs, is strengthened by embryology. Every organism, higher as well as lower, is developed primarily from a single cell, the ovum. As we are able to observe this unicellular origin for every individual, we ought, without a doubt, to assume it for every organic stem, for every group of related species. The unicellular embryo-form that has been verified by experiment is, according to our fundamental biogenetic law, the replica of a like, dead and gone, and now unknown ancestral form. The nature of such a unicellular ancestor is again exemplified to us in the clearest manner by the many unicellular organisms still living at the present day—the Amœbæ, Flagellata, Diatoms, etc. These are savage hermits, that retain their free independent life as single cells, and are unable to band themselves together in associations and in the forming of a state.

Holding firmly to this cellular-political fundamental idea, which forms the real fulcrum for the understanding of the cell-theory, we must touch briefly upon the most important modifications thatthe latter has undergone in recent times. The protoplasm theory, as the idea most weighty in consequences, must be mentioned first. This was enunciated by Ferdinand Cohn in 1850, was further extended by Max Schulze in 1861, and was formulated in like manner by Lionel Beale in England the year after. Starting from the resemblance that the structure of ordinary plant-tissues in section under the microscope exhibits to a honeycomb, the cells of the former, independent but closely packed, were compared with the honey-cells of the latter, and hence took their name. In the one place as in the other the cell appears to be a closed sac or vesicle containing fluid. But soon it is evident that in very many cells an external, firm, investing envelope, a true cell-membrane, is altogether wanting, and that the cell consists essentially of the colorless semi-fluid cell-contents, or more accurately, of the cell-substance alone. This cell-substance is made up, sometimes exclusively, sometimes to a very great extent, of albuminoid matter, first recognised by Hugo Mohl, and called by him protoplasm, or first formative matter. Protoplasm, or the true cell-substance, is always a nitrogenous carbon compound of very complex chemical composition. It exists in the living cell always as a white semi-fluid aggregate ; but, most important of all, it seems to be the veritable possessor of the life-functions. It is the active factor in the cell-life. Protoplasm performs the functions of nutrition and reproduction, of sensation and motion. Protoplasm is the true life-matter, or as Huxley has it, "the physical basis of life."

Whilst protoplasm, or the living cell-substance, was thus brought to the front in the cell-theory, all other tissue elements met with in the completed organism, especially cell-membranes and intercellular substance, were, in view of this primary, active, living matter, relegated to the background as secondary accessory parts, as passive products of protoplasm. One part alone was an important exception to this, the cell-nucleus or cytoblast, on which Schwann and Schleiden had already laid stress. This is a smaller body, surrounded by protoplasm, to which it is very closely allied in chemical and physical properties, but from which it is still different morphologically. Regarded at first as a non-essential, and often absent, part of the cell, the nucleus was found more and more generally distributed and of higher and higher import. At last it was evident that every true cell, either throughout its life or at least in the earliest period of that life, has a nucleus, and that this latter has, in reference to certain life-processes, especially to cell-division, an importance as great as, or even greater than, protoplasm. On these points the celebrated and painstaking researches of Edward Strasburger, Oscar Hertwig, Leopold Auerbach, Otto Bütschli, and others, have yielded us the most valuable results. Although the function of the cell-nucleus is not thoroughly determined in all details, this much is certain, that the nucleus stands with and stands near protoplasm in the vanguard of cell-life as a most important part of the living cell. I was, therefore, right when in my "Generelle Morphologie" I spoke of nucleus and protoplasm as the two essential parts indispensable to the conception of the cell, and contrasted them as active constituents of the cell with the passive plasm products.

A further advance in our knowledge of elementary organs was made by the discovery of the Monera. In the year 1864, I observed, in the Mediterranean, near Nice, for the first time a very simple organism, whose whole body, not only during its development, but also in its perfectly developed and free-moving condition, consisted of a homogeneous, structureless piece of protoplasm without a nucleus, without any different parts. This Protogenes primordialis for the first time gave us proof that there were organisms even more simple than the unicellular living beings whose bodies had not reached even the status of a single cell, but seemed as homogeneous as a crystal. In the following year (1865) two similar organisms were discovered by Cienkowski in fresh water, and were described as Vampyrella and Monas (better, Protomonas). I placed therefore in my "Generelle Morphologie" (vol. i., p. 133: vol. ii., p. 22) under the head Monera, these very low living beings in which the living organism "meets us, not only in the simplest form actually observed, but also in the simplest form conceivable;" and I called attention to the lofty significance that they had as compared with all other organisms. All other living things, all plants and animals, and all the Protista that are neither plant nor animal, are made up of differentiated parts. Even the simplest of these, the unicellular forms, consist of at least two different parts, the protoplasm and the enclosed nucleus. The Monera alone dispense entirely with such a composition. Their protoplasmic body, a very simple living globule of jelly, has not gone even as far as the formation of a nucleus. They are, in truth, organisms without organs. All life-functions, nutrition, reproduction, sensation, movement, are performed by these Monera, without any different parts being told off for particular functions. Every fragment can do everything that the whole can do. Consequently, here, as in a crystal, every smallest particle is of homogeneous chemical composition, every molecule is in its physiological or its chemical and physical nature like all the rest of the body. Hence the Monera stand on the boundary-line between the organic and inorganic, between the living and the dead. Hence are they, and they alone, able to give us a picture of the primordial origin of the former from the latter, they alone are able to solve for us the vast problem of the origin of life. The Monera alone could have been able, by intrinsic reproduction or ontogeny, to arise out of inorganic materials ("Gen. Morph.," chap. v.)

The extraordinarily high morphological and physiological significance that attached to the Monera, on which I laid stress in my "Generelle Morphologie," in 1866, I worked out further in my monograph of the Monera, and in the essays on the plastid theory added to that work (1868). I was in an especial manner led to this work by further observations on certain new Monera, that I had the opportunity of studying in 1867 on the coast of one of the Canary Islands, Lancerotta, and in the Straits of Gibraltar. Certain fresh water Monera also, living near Jena, and observed later by Von Kleinenberg among others, furnished yet further contributions to the natural history of these exceedingly simple organisms. Most wonderful, most important of all, was the mass of Monera belonging to the deep sea-beds that Huxley described in 1868, under the name Bathybius. This Von Bessels observed recently again (1874), on the bed of the North Polar Sea in living condition, and examined with especial reference to its rhizopodic movements. In the Monera that were first observed, the homogeneous, formless protoplasm mass of the body seems generally individualised to this extent, that the single pieces reach a certain size by growth, and then, when this is surpassed, separate by division into two or more pieces. In Bathybius, not even this commencement of individualisation is observable. Its colorless, shapeless protoplasm-body, covering in enormous masses the deepest abysses of the sea, has apparently no individualisation at all. The separate pieces do not seem to attain any definite size. They multiply according to the circumstances in which they are placed ; that is, they fall into fragments according to no definite law or plan, when their growth has reached the limit of adaptation to the surrounding circumstances for the time being (Cf. "Kosmos," vol. i., 1877, "Bathybius and the Monera").

I have already pointed out in the "Generelle Morphologie," that the Monera (and also the so-called non-nucleated cells, that are met with under other circumstances, and to which we shall return presently), no longer come within the limits of the cell-theory held up to the time of their discovery, and that this theory must, of necessity, have a corresponding extension. For if we take away from the idea of the cell, in its strictest sense, all accessory and secondary things, all non-essential accidental accompaniments, there still remains the idea of its composition of two parts of different morphological and physiological value, the outer cell-substance, the inner cell-nucleus. But the Monera do not present this differentiation, this earliest separation of parts in the elementary organism. Their bodies are neither really true protoplasm nor true nucleus. They are rather homogeneous masses of albuminoid matter having the nature of both. It is at once cell-substance and cell-nucleus. It is, therefore, with wisdom called living-matter or formative matter, plasm or bioplasm. But all so-called non-nucleated cells, all elementary organisms whose active bodies consist, as in Monera, of plasm alone, must be separated from the nucleated cells, and placed apart from these under the name of cytods.

Similar cytods appear in the circle of development of other organisms. Edouard van Beneden, especially, was the first to show that the embryo of the unicellular Gregarina is at first only a simple cytod. The embryonic globule of the Gregarina consists of homogeneous plasm. Later on, as a secondary phænomenon, the separation or differentiation takes place, as result of which the inner cell-nucleus is marked off from the outer cell-substance. The formative plasm differentiates into protoplasm and cytoblast. But of yet more importance and interest is the significant fact, that every higher organism at the beginning of its individual development is found to pass through a cytod-stage. Either before impregnation, or immediately after, the female ovum-cell loses its nucleus. The act of impregnation itself consists in the fusion of these non-nucleated cells with the spermatozoa of the male. The nucleus of the latter altogether, or in great part, vanishes in the fusion with the ovum. The product of this fusion is at first not a cell, but a cytod. As this non-nucleated cytod, with which, in reality, the organism that is the result of the act of reproduction begins its individual existence, as this cytod is according to our biogenetic law, a repetition conditioned by heredity of the original Moneron parent form, I have called this embryonic form, Monerula. Afterwards, the plasm of this Monerula differentiates into two different substances. A part of the internal molecules form the nucleus, and separate from the surrounding protoplasm. Thus arises from the first cytod, the first cell. It is evident that both the life-phænomena of these independent Monera, and these earliest histological differentiations in the individual development of the higher organisms, are of fundamental meaning. Physiology and morphology, phylogeny and ontogeny, can draw thence the weightiest conclusions. For they show us, first, that commencing life has first to do with a formless, structureless mass, as homogeneous as a crystal. They show us, next, how such a cytod, despite the want of all organs, is able to perform all life-functions, nutrition and reproduction, sensation and movement. They give us, again, clear proof that life is, in its strictest sense, linked on, not to a body of special form, morphologically differentiated, made up of different organs, but to a formless substance with determinate physical qualities, of determinate chemical composition. They teach us, lastly, how such a cytod, made up of plasm alone, can pass by differentiation of nucleus and protoplasm into the true cell.

As regards the cell-theory, the momentous conclusion follows from all this, that the cell is not, as was generally held, the simplest, oldest, lowest elementary organism; but that the true, nucleated cell must arise from the lower, non-nucleated cytod. Cytods and cells are the two chief forms of the elementary organisms or life-units. Organic life on our globe began with the cytod, a simple piece of plasm. Thence, later on, the protoplasm and nucleus differentiated and the cell arose. The cytod is the first and lower, the cell the second and higher form of the life-unit. I have given to the two together the name of plastids : for they only are, in truth, the plastic artificers that have the power to build up all the wondrous structures of organic life. All organic forms owe their existence to the constructive faculty of microscopic plastids. Thus the cell-theory widens out into the plastid-theory (Cf. my biological "Studies on Monera and other Protista," 1870).

As now the broader conception of the plastidule has taken the place of the narrower conception of the cell, as, by consequence, the whole mysterious problem of life carries us back to the elementary chemical properties of plasm, our next task is to obtain, as far as possible, an exhaustive knowledge of the nature of this most important life-matter, of this the true physical foundation of life. In the first place, we ought to demand of Chemistry that it give us details as to the quantitative composition and the qualitative properties of plasm. But, unhappily, our chemical knowledge of plasm is in inverse relation to its extraordinary importance. Not that there have not been many painstaking attempts to unravel the enigma of the chemical constitution of the numerous modifications of plasm, protoplasm, and nucleus. But the difficulties in the way of these attempts are altogether abnormal and, in part, insurmountable. First, it is altogether impossible to isolate and investigate any perceptible quantity of plasm in a chemically pure state, because the simple plasm of the cytods and the protoplasm and nucleus of the cells are so intimately mixed with other substances that have been formed out of them, and are in small quantities interspersed amongst, interwoven with other tissue elements, as cell-membranes and intercellular substance. But further, all modifications of plasm are decomposable and changeable in a far greater degree than other allied albuminoid bodies. Above all, it must be kept in mind that although the modifications and varieties of plasm bodies are endless in number and in variety, these are as nothing in comparison with the variations in quantitative composition. The coarse, rude methods of our chemistry of to-day are far enough from the solution of a problem of such delicacy and difficulty. But that very variability beyond limit, that very readiness of decomposition and mobility of the atoms in the plasm-molecules, are of deepest significance in the study of Evolution. For they explain to us how, under those physical and chemical influences of the environment, endless in number and in variety, that occur in the nutrition of the plasm, this latter undergoes slight alterations, endless in number and variety, and thus can evolve into the most diverse organic forms.

From the physiological and chemical side, therefore, it is possible to regard all plasm-bodies as a single great group of allied compounds, and to class them together as the plasm-group. In this group we may perhaps mark off : 1. the archiplasm as the oldest life-substance, arising originally directly as the result of ontogeny ; 2. the monoplasm, as the body-material of the cytods living at the present time ; this probably varied more or less from the archiplasm ; 3. protoplasm, or the true cell-substance ; 4. nuclein or coccoplasm, the substance of the nucleus, as the whole, chemically different, nitrogenous basis of the cell-nucleus may be called. Although protoplasm and coccoplasm are very nearly allied and most intimately related, they appear to be essentially different, possessing characteristic and, to some extent, opposed qualities, that are not distinctly marked off one from another in archiplasm and monoplasm.

Everything that is essential of that which we know as to the plasm-group may be summed up as follows. The plasm-group is a part of the larger group of albuminoids or proteids. Like the rest of the albumin-compounds, the plasm bodies are distinguished by an extraordinarily complex composition of their atoms. In every molecule at least five elements are present, and on an average the percentage composition is 52-55 carbon, 6-7 hydrogen, 15-17 nitrogen, 21-23 oxygen, 1-2 sulphur. The way in which the atoms of these elements are united in each plasm-molecule to form a chemical unity is, without doubt, a very complex and special question, and stands in direct causal connexion with the vital properties of these wonderful compounds. For the sum of those physical and chemical properties that we name with the word "life" is clearly, in the ultimate analysis, conditioned by the molecular structure of the plasm, and this again is, on my carbon-theory, referable to the peculiar and very marvellous property of carbon, by virtue of which it enters into the most complex and most unstable compounds with the other elements I have named. With great wisdom has recent chemistry called the collective study of the so-called organic bodies, or, what was in earlier times called organic chemistry, the chemistry of the carbon compounds. But with equal justice I have regarded the chemical and physical nature of carbon as the ultimate cause of the peculiarities that distinguish the organic from the inorganic, in a word, as the ultimate basis of life. If this carbon-theory is rejected as an arbitrary and phantastic dogma, denial is made of the causal connexion between the chemical composition of plasm and the physical phænomena that I call in a word life functions.

Amongst the physical properties of plasm the most noticeable is its marked power of imbibition, the faculty of absorbing water in variable, and often in very considerable, quantities, and of placing it between its molecules. Hence results that peculiar soft yet dense condition of all living tissues, which we call a condition of semi-fluid aggregation. It seems to be a necessary pre-condition of all the complex molecular movements whose totality we call life. The readiness with which plasm under varying external conditions absorbs or gives out water and watery solutions is, therefore, of special significance, not less than the extraordinary inclination of most kinds of plasm to commingle with other carbon compounds (fats, for example) and with salts. These and many other peculiarities of the plasm-group prove that we have here to do with carbon-compounds, whose molecules differ from all others in an unwonted mobility and changeableness, instability and many-sided affinity. These plasm-molecules, at every farther investigation of elementary conditions, are eternally forcing themselves to the front. With them we have to do in our perigenesis as the really active elemental factors.

The plasm-molecules or plastidules, as we will call them in brief, after Elsberg, possess, in the first place, all the properties which Physics usually ascribes to hypothetic molecules or "compounded atoms." Therefore every plastidule is not further decomposable into smaller plastidules, but can only be broken up into its constituent atoms, and, of course, only into atoms each of which contains the five elements already named. The plastidules are probably always surrounded by water-envelopes, and the greater or less thickness of these, which at once separate and connect adjacent plastidules, determines the softer or firmer plasm into whose composition they enter. Probably the plastidules are so small, that the smallest piece of plasm which we are able to see by aid of our best microscopes, contains an enormous number of plastidules. That which holds of the original, simple plasm or archiplasm, naturally holds in general as to protoplasm and coccoplasm that arise by differentiation of the former. The protoplasm molecules may be named, for short, plasmodules, the nucleus-molecules, coccodules. The same physical properties and physiological functions exhibited by the homogeneous plastidules, in the homogeneous plasm of the cytods, are found to be common to the plasmodules and coccodules in the cells. The plasmodules and coccodules have arisen, later on, by differentiation from the plastidules.

Besides these general physical properties, which Physics and Chemistry ascribe to-day to the molecules of matter in general, the plastidules have special attributes, exclusively theirs, that are, in common parlance, vital properties. By these the living is in a general way separated from the dead, the organic from the inorganic, using these words in the ordinary fashion. Every more exact, and more detailed comparison of organisms with inorganic things, based on the broad experimental basis of newly discovered facts, and most of all the unprejudiced comparison of the Monera and crystals are teaching us, now-a-days, that the gap between these two main groups of natural bodies is much narrower than is commonly thought. I can refer in this connexion to the detailed comparison of organisms and inorganic things that I have given in the fifth chapter of my "Generelle Morphologie," (vol. i., pp. 111—166). Many properties that our superficial ideas of nature have hitherto ascribed to organisms alone, belong also to the inorganic, and are, in fact, the common property of natural bodies, or to speak more exactly, the common property of all atoms of all the smallest, separate particles of bodies which modern chemistry unanimously regards as the ultimate parts of all bodies.

As the views of chemists and physicists, as to the nature of atoms, and of the æther existent between the masses of atoms are in accord, so also certain elementary ideas as to their essential nature, have now obtained general acceptance. We must hold that atoms are the smallest separate particles of masses, having an unalterable nature, separated one from another by hypothetical æther. Every atom has an inherent sum of force, and is in this sense gifted with a soul. Without the acceptance of an atom-soul, the commonest, the most general phænomena of chemistry are inexplicable. Pleasure and displeasure, desire and loathing, attraction and repulsion, must be common to all masses of atoms; for the movements of atoms which must occur in the formation and decomposition of every chemical compound, are only explicable if we impute to them sensation and will. On what ground does the generally accepted chemical teaching of "affinity" in bodies rest except on the unconscious supposition, that in fact the attracting and repelling atoms are possessed with definite inclinations, and that they follow these sensations or impulses, have also the will and the ability to move to or from each other. The whole truth is embodied in that which Goethe has said in his "Wahlverwandtschaften," as to these relations, when he traces them up from the elementary soul-life of atoms to the very complex soul-life of man; and when in that classic romance affinity is laid down as the sole spring of human actions, and of the history of the world which is the sum of these, the mechanical nature of the most complex organic processes is thus denoted in unmistakable manner by the great thinker and poet.

And if the will of man and higher animals seems to be free as opposed to the fixed will of atoms, herein lies an illusion due to the very complex movements of the will in the one case, and the exceeding simplicity of them in the other. The atom everywhere, and at all times, wills in the same fashion, because its disposition with regard to the atom of every other element is a constant, is unalterably fixed: every one of its movements, therefore, is determined by this. On the other hand, the disposition and arbitrary movement of the higher organisms appear to be free and unconditioned, because in the incessant change of material, the atoms are continually altering their relative positions and modes of combination, and as a consequence the total result of the innumerable will movements of the constituent atoms is of the greatest complexity, and is changeable without end. Hence we are "a sport for every breath of wind."

Whilst from the mechanical standpoint of Monism we regard all matter as possessing a soul, every mass of atoms as provided with a constant and eternal atom-soul, we are not afraid of having the reproach of materialism hurled at us. For this our monistic position is as far from a one-sided materialism as from the emptiness of spiritualism. In it alone are we able to find the reconciliation of the crude atomic and the empty dynamic conceptions of the universe, which have up to the present time been in such violent contention, and which in their limited view are each dualistic. As the mass of the atom is indestructible and unchangeable, so the soul of the atom indissolubly bound up therewith is eternal, is immortal. Transitory are the numberless and eternally changing combinations of the atoms, the unending manifold modifications in which atoms unite to build up molecules, molecules to build up crystals or plastids, plastids to build up organisms. This monistic conception of the atom alone is in harmony with the great law of the conservation of energy and the conservation of matter —that law which the natural philosophy of the present age rightly regards as its inalienable fundamental.

If, therefore, we regard all matter as in possession of a soul, every atom as gifted with sensation and will, we can no longer look upon these two properties, as men generally look upon them, as exclusively the prerogative of organisms. We have to look for other qualities that may separate the organic from the inorganic, the plastidules from other molecules, and that may constitute the essence of life in its narrower sense. The most important of these qualities seems to us the faculty of reproduction, or of memory, that is at work in every event of development, and especially in the reproduction of organisms. All plastidules have memory. This faculty is wanting in all other molecules.

In a notable treatise, as carefully thought out as clearly written, on "Memory as a general function of organised matter," Ewald Hering in 1870 has discussed this momentous question so thoroughly that we need not enter in this place into any detailed proof. We need but refer to his treatise. We are in truth convinced by the profound thought that if we ignore the idea of an unconscious memory as a property of living matter, the most important life-functions are, as a rule, inexplicable. The faculties of ideation, of thinking, of consciousness, of use and habit, of nutrition and reproduction glide into the function of unconscious memory, whose action is of far more general importance than is that of conscious memory. Hering says rightly enough "that it is to memory we owe almost all we have and are."

On one point alone we must join issue with the statements of Hering, or rather we must limit them a little more definitely. We look upon memory not so much as a general function of all organised matter, but only as a function of the really living, the plasm. All plasm-products, everything formed of protoplasm and nucleus, all the inactive organised parts of the organism, are destitute of memory, even as is inorganic matter. Strictly speaking, on our plastid theory only the group of plasm-bodies is gifted with memory; the plastidules alone are reproductive, and this unconscious memory of the plastidules conditions the characteristic movements of the molecules of the plastidules.

The difference which memory, or the power of reproduction in the plastidules, determines between the organic and inorganic, shows itself first in the different method of their growth, and this is clearly determined by their different condition of aggregation. The inorganic grows by apposition, or by the external addition of molecules. The organic grows by intussusception, or the internal deposition of molecules. The most perfect inorganic individual, the crystal, grows by particles on particles, depositing externally on the solid crystalline body already in existence, The least perfect organic individual, the Moneron, grows by particles, penetrating from without into the interior, and becoming assimilated by the semi-fluid plasm-bodies. This assimilation is of such a nature that new plastidules are being formed from the nutritive fluid, that is, absorbed, and are being deposited between pre-existing plastidules. The semi-fluid condition of the organic matter is the pre-condition of this peculiar growth, and the molecular structure of the carbon compounds its true cause. This growth by intussusception, occurring in all organisms, wanting in all organic bodies, is the explanation both of that nutrition and that transformation of matter which distinguish the former from the latter. Finally, this growth by intussusception is the chief circumstance that conditions that life-phænomenon, which stands out prominently as the most important factor in organic evolution, and of which we must, therefore, treat next : reproduction and its companion, heredity.

It is beyond dispute that reproduction, more than any other function, marks off the organic from the inorganic. For through reproduction alone, through heredity, which we regard as an essential and integral part of reproduction, is the preservation of the organic species and phyla possible, those species and phyla that continue to exist in the linked chain of generation on generation, despite the continual vicissitudes of individuals. Since no inorganic body is capable of reproduction, inorganic nature has nothing of the ancestral history, the phylogeny which characterises the organic world. The study of reproduction or gonology is, therefore, the essential starting-point for the due understanding of phylogeny.

What is reproduction? To give a correct answer to this question we must first of all divest ourselves of the ordinary idea that the union of the two sexes is the most important and most necessary event in reproduction. This idea, based upon the general method of reproduction of individuals in man and in the higher animals and plants, is seen at once to be incorrect, as soon as we think of the asexual processes of reproduction, endless in their extent, that everywhere and at all times are taking place in the multiplication of the plastids. On the whole, sexual or amphigonic reproduction, with its special peculiarities, appears to be only a special case among the multitude of events which we group together as reproduction or procreation; events which in by far the greatest number of cases are asexual in their nature. All the countless myriads of cells that make up the body of every higher animal, of every higher plant, arise not by sexual, but by asexual reproduction, by division. All, or at least the majority, of the many unicellular beings that stand on the limit of the animal and vegetable kingdoms, and that we class together as Protista, increase in number not by sexual but by asexual reproduction. But even many higher animals and plants, that have sexual reproduction, multiply in addition in asexual ways, by division, by gemmation, by spore formation. If we reflect how everywhere and at all times masses of plastids are perishing, and are restored by division and by budding, it is evident that asexual reproduction is the general rule, and sexual a relatively rare exception to that rule. Certainly we should be making an estimate too low rather than too high, if we say that, on an average, for every simple sexual act of reproduction in nature more than a thousand, probably more than a million, asexual ones occur.

But now it is evident that the simplest forms of asexual or monogonic reproduction, first fission, next gemmation, give us the clearest explanation as to the nature of reproduction, and are our guides to the far more difficult and more complex sexual methods. Turning to those simplest forms of monogony we find as simplest answer to our question. Reproduction is the growth of the individual beyond its individual mass. If a very simple plastid, or homogeneous Moneron has grown up to a certain bulk, the structureless plasm-body splits as its growth continues into two similar halves, inasmuch as the cohesion of the plastidule no longer is sufficient to hold the whole mass in one.

In like manner, every ordinary cell-division depends essentially upon a growth continued beyond the individual mass of the particular cell. The remarkable details of the process by which two similar daughter cells arise from one mother cell, have been worked out by Auerbach, Bütschli, Hertwig and Strasburger. That in these cases, the two daughter cells resembling one the other, have inherited the nature of their common mother cell seems easily understandable, for they are like halves thereof, and the molecular movements of the plastidules must be the same in the former as in the latter. Heredity here appears as a simple, necessary consequence of division. In like manner, it gives us here the deepest law of its nature. Heredity is the transmission of the motion of the plastidules, a reproduction of the individual motion of the plastidules, of the mother-plastid in the daughter-plastid.

But the conditions under which the two similar halves pursue their individual lives are always more or less diverse. In especial, the complex relationships that in the struggle for existence condition the plastids as well as the multicellular organisms, are ever peculiar for each individual. Whilst these diverse conditions of existence are influencing the elementary organism, they affect its primary nutrition, and bring about a partial alteration in the primary motion of the plastidules. This alteration or variation we name adaptation. Adaptation is alteration of the motion of the plastidules, in consequence of which the plastid acquires new properties. If, later on, the two daughter-plastids that have arisen from division of one plastid again increase in size, and after passing the limits of their individual growth again split, by fission, into two, these four grandchildren will no longer be so alike as were their two mother-plastids. It is true that they will have inherited from these the greater part of the properties which the two received from the original grandmother. But also a part of those peculiarities will be noticeable which each of the two mothers acquired during its individual life, and finally each of the four grandchildren will itself acquire new peculiarities in the course of its individual existence. Small, and without significance as these new acquisitions may seem in each single case, yet it is clear that finally, in the lengthy chain of many generations, they may accumulate, and sum up to very notable deviations from the movements of the plastidules in the original parent form.

The inheritance of variations, on which the whole evolution of the phylum depends, has full play in the life of the plastids, and produces an endless number of different individual motions of the plastidules. Every later movement of plastidules—or in other words, the life of every plastid later on, be it cytod or cell—consists, therefore, on the one hand of the vastly preponderating set of old motions that have been maintained from generation to generation by heredity, on the other hand of a smaller part consisting of new motions acquired by adaptation. All these variations of the plastidules are naturally conditioned by the intussusception of atoms ; and in the endless complexity and variety of the atomic composition of the plastidules, in their extraordinary instability and tendency to decompose, an unlimited field for the production of new forms is offered to adaptation.

In transferring the teaching of Lamarck as to the inheritance of variations—the most important pre-supposition in the Darwinian theory—from the large multicellular animals and plants in whom it is seen palpably, before our very eyes, to the plastids (cytods and cells), and from these again to the plastidules that make up the plastids, for these last the same consequences, of course, hold that the selection-theory grants to the former. That the struggle for existence obtains amongst the molecules was first made clear by Pfaundler in 1870—that it obtains in the strictest sense, and most of all, among the active plastidules. Those plastidules which best adapt themselves to the external conditions of existence, *i.e.*, those which most easily take up the fluid nutritive matter penetrating from without, and thus accomplish most readily the consequent intussusception of atoms will, of course, have best assimilation, and thus by reproduction of plastids acquire superiority.

The next consequence of Natural Selection in the struggle for existence, is the increasing differentiation of forms, which Darwin has called "divergence of character." Its best known form is the division of labor or polymorphism of persons. It is well known that in human life division of labor affords the best measure of the degree of civilisation attained. The same principle holds in regard to the wonderful civilised states of the ants, bees, termites, etc. Further, comparative anatomy shows us that the physiological perfection or the grade of evolution of every higher animal and of every higher plant, is conditioned by the specialisation of its organs. The complex machinery, *e.g.*, which constitutes the higher Vertebrate with its nerves and sense-organs, muscles and bones, alimentary canal and blood-vessels, glands and reproductive organs, is determined by the specialisation of all these organs, and of their separate parts, a specialisation now advanced to an extraordinary degree, but none the less acquired gradually and slowly in the struggle for existence during the past.

But specialisation or division of labor in organs, depends again upon that of plastids, of cytods and cells. The different tissues, that give to each origin its physiological peculiarities, are made up of different kinds of cells, those of nerve, muscle, bone, glands, alimentary canal, sexual organs, etc. The manner in which all these different kinds of cells have arisen by specialisation from one single, simple, original cell-form is shown us to-day by the individual development of the ovum of every higher animal. For the impregnated ovum-cell split up, at first, by repeated division into a great number of very simple, similar cells. From these morula-cells next arise the two primitive germinal layers of the gastrula, and this differentiation into two different cell-layers is the first commencement of histological specialisation. When the cells of the outer layer or of the ectoderm differentiate still further into cells of skin, nerve, muscle, etc., and when the cells of the inner layer or endoderm give rise by differentiation to cells of the alimentary canal and of glands, the formation of tissues, or histological differentiation, results on which the upbuilding of the various organs depends. But the ontogenetic specialisation of the cells as we are able to trace it out, step by step, under the microscope, is only on our fundamental law of biogeny the repetition of the slow phylogenetic histogeny, or tissue building that was originally conditioned by the active specialisation of the cells.

In what way is this specialisation of the plastids possible? Clearly only by the conditioning specialisation of the plastidules. For in exactly the same way, and according to exactly the same laws by, and according to which, the civilised state is conditioned by the division of labor of its citizens, is the high organisation of the human body by that of its organs, and these again by the division of labor among their constituent cells; this last also is effected in like manner by the division of labor among the plastidules, and arises according to the same laws from the interaction of heredity and adaptation in the struggle for existence. The morphological and physiological peculiarities by which every nerve-cell, every muscle-cell, every alimentary canal cell, as such, is characterised, are dependent simply and solely upon the fact that their constituent plastidules have differentiated to a greater or less extent, and thus have given rise to different kinds of plasm. Complex and heterogeneous as may be the molecular structure of the plasm, and its combination in the various kinds of cells with different sorts of plasm-products, none the less they all are proved to originate from the similar cells of the morula, just as these originated from the impregnated ovum-cell. The phylogenetic primary specialisation of the plastidules is, on the biogenetic fundamental law, still repeated at the present day in the ontogenetic differentiation of the plastid-molecules.

One particular form of this histological specialisation deserves in this place our closer attention, that is, the sexual differentiation. As we have already remarked, sexual reproduction does not possess nearly the great general significance that is ascribed to it at the present time by the majority of people. It is the more necessary to insist upon this because in the first place this function is veiled with the mystic cloak, as if it were a supernatural or very mysterious function, and in the second place so many prominent scientific men over-estimate out of all proportion the meaning of this phænomenon as regards the study of development. In the first place, then, it must be laid down clearly that a large number of the lowest organisms, *e.g.*, the chaotic division of the Protista, many Protophyta and Protozoa know, as a rule, nothing of sexual reproduction, but reproduce themselves solely by asexual methods (most generally by simple fission, but in addition by bud-and-spore formation). Secondly, it should be stated that no sharp line of demarcation exists between sexual and asexual reproduction (amphigony and monogony). To this the interchanging conjugation and copulation that occur in many of the lowest organisms bear witness. In the third place, the wide distribution of parthenogenesis among very different groups of higher animals and plants is very instructive. It is evident that these have arisen from ancestors that were sexually different. Yet in the course of time the males have become unnecessary and have disappeared. No less instructive, in the fourth place, is the frequent connexion of sexual and asexual reproduction in the alternations of generations in one and the same species. Finally, in the fifth place, the essential part of sexual reproduction loses all wonder and mystery when we abstract from it all non-essential and secondary accidents, and fix our attention firmly and only on the histological essential of the process. For then sexual reproduction is no other than the conjunction of two plastids that have developed in very different directions, as result of an extraordinary specialisation of their plastidules.

Thus, in fact, the dark mystery of sexual reproduction is cleared up in the simplest manner, and the "wondrous riddle" of love that moves the world solved in soberest fashion. Of course we must eliminate all those manifold and remarkable sex-arrangements that have been slowly and gradually acquired by the higher plants and animals, in part under the general influence of Natural Selection, in part by the special working of Sexual Selection. Originally we meet with nothing more than two different kinds of cells; the female egg-cells, the male sperm-cells. These frequently do not even appear in special organs, but lie separately dispersed in different tissues, the egg-cells between the epithelial cells of the alimentary canal, the sperm-cells between the epidermal cells of the skin. This is seen in the Gastrœada, Spongida, many Hydrozoa, etc. All that occurs in the way of sexual union in these cases is that these two kinds of cells, set free from their connexion with the multicellular organism, and meeting, haphazard, in the water, apply themselves each to each, and blend one with the other into a single plastid. The internal attraction, conditioned by the chemical affinity of the two living cells, draws them inevitably together. The new cell thence arising is the child of the mother germ-cell and the father sperm-cell: it consists of the conjoined bodies of both. If we trace out this very important but very simple fundamental process of amphigony yet further, we find that from it a complete and intimate commingling of the plastidules results, a thorough blending of the different molecular movements in the two plastids. Generally a partial or complete vanishing of the nuclei seems to precede, or in some cases to follow, the blending of the two sexual cells. Hence the newly produced individual is at first no cell but a cytod, and turns into a cell later by the re-formation of its nucleus. We have called this cytod, monerula, and the first cell, cytula. It is evident that the individual plastidule motions that are inherent in this first plastid, and condition all its further development, are the resultant of the two different plastidule motions of the female egg-plastid and the male sperm-plastid. If we look upon these latter as the two sides in the parallelogram of forces, the plastidule motion of the monerula and of the cytula resulting thence is the diagonal of that parallelogram. In this way there is a simple explanation of the fact, well known in amphigonic heredity, that the child inherits many properties of both parents. The primary life-movements of the child are the diagonal between those of the mother and of the father.

Considered from the purely morphological side, that blending of the two kinds of sexual cells that is the sole essential in sexual reproduction, is from beginning to end no peculiar process. It falls, rather, under the broader idea of the concrescence or growing together of plastidules, a histological process, that we have already seen very general under many and various modifications, *e.g.*, in the formation of the plasmodia of the Monera and Myxomycetes, in the formation of the reticulate tissues, the blending of the stellate cells of muscle, of nerve, of connective tissue, etc. But of especial value in this connexion is the so-called conjugation of two apparently similar cells, that precedes in many Protista (Protophyta and Protozoa) the asexual multiplication by division (Gregarinida, Infusoria, Diatomaceæ, Desmidiaceæ, etc.). We ought to look upon this conjugation of two similar plastids as the first shadowing forth of sexual differentiation, or as the transition from asexual to sexual reproduction. As, according to the well-known experiments of interbreeding, a certain degree of difference between the two sexual individuals is of distinct advantage to the result of their union and the fertility of their progeny, Natural Selection will favor dissimilarity between the two conjugating plastids, and will, by gradual accumulation and identification of their individual peculiarities, lead them on by degrees to the notable condition that we see in the different composition of the large amœboid ovum-cells and the small flagellate sperm-cells in the majority of animals. This also is but a special and strongly marked form of division of labor.

If again we call to mind, that considered as a whole, reproduction is nothing else than a growth of the individual beyond its individual mass, we shall regard every conjunction of two similar cells which is known as conjugation, and has taken the first phylogenetic step towards sexual differentiation, as only a special form of growth. Whilst in the ordinary simple process of asexual reproduction, the preceding and determinal growth (general in fission, partial in gemmation) proceeds slowly and gradually, in conjugation this takes place swiftly, suddenly. Once again the mystery of sexual reproduction is traceable back to a special form of growth and of division of labor.

The idea of sexual reproduction here given seems, as far as regards the lower, simpler forms, so evident, that it requires no further proof. But it gives us also the key to the understanding of the higher, more complex forms, which do not at first sight seem so thoroughly explained by it. To this end it is necessary that we, first, understand the physiological individuality of the plastid-life, and the active significance of the plastidules on which that depends, and that we, secondly, give to the idea of alternation of generations a far wider extension, and more general application than has been hitherto given. This alternation of generations, that we name briefly, after Owen, metagenesis, depends on the regular, periodic alternation of two or more different generations, whereof one produces its offspring asexually, the other sexually. With this periodic alteration in the method of reproduction is bound up a more or less complete specialisation of persons (or in plants of the shoots) that is often evident in a very striking difference in form and organisation. Thus we see, *e.g.*, that from the spores of the fern no fern arises, but a prothallium, a new form of plant without stem or leaves, resembling in all essentials a liverwort. This prothallium is sexual. It forms ova and sperm-cells, and from these arises a new cell, the cytula. As the cytula undergoes repeated division a little plant is formed, that develops, by differentiation of stem and leaves, into a fern. On the under side of the leaves of this fern are formed later on the brown masses of spores. We see a like alternation of generations in very many of the lower animals. Thus, from the fertilised eggs of most Medusæ, no Medusa develops, but a stationary hydroid-polyp, of quite another structure. This in its turn gives rise (by asexual gemmation) to the free swimming Medusæ, that are sexual. The Aphides and many small Crustacea (*e.g.*, the Daphnidæ) reproduce themselves during the summer asexually, by parthenogenesis, through the medium of unimpregnated egg-cells or spores. Later on, in the autumn, appears a generation, sexually differentiated, with males and females, and from the fertilised eggs of this generation arises the first asexual generation in the spring.

But if we now classify our plastids as autonomous "elementary-organisms," possessing morphological and physiological independence, and if we consider the individual process of development from the histological standpoint of the plastid-theory, we shall, on a survey of the above-quoted facts, be led to the idea that alternation of generations or metagenesis is in reality a very widely spread phænomenon. For in the individual development of every multicellular animal, of every multicellular plant, appears, first, a generation of sexual plastids represented by the female ovum-cell, and the male sperm-cell. As result of their union arises a cell, the cytula, and this produces, in asexual fashion, by repeated division, the generation of similar cells that form at length the morula, and the blastula that arises from it. For the first time division of labor makes its appearance among the similar cells of the blastula generation. They separate into two kinds of cells, those of the inner or vegetative, those of the outer or animal layer of the blastoderm. Each of these, again, by repeated division gives rise to many generations, and in these the specialisation of the cells is the more marked, the more complete the organisation of the fully developed individual. All the innumerable generations of dissimilar cells that make up tissues and organs multiply asexually by division. Two only of these polymorphic cell generations differentiate sexually, the ova and the sperm-cells. When these, later on, in the sexual act of reproduction come again into union, we have re-reached the beginning of the reproductive circle at which we started. The reversion or atavism of the plastids has led us back once more to the cytula. Essentially, the individual development of every multicellular animal or plant, that is reproduced by hypogenesis, *i.e.*, without any alternation of generations of the persons by a sexual act of reproduction, consists in reality of a very complex alternation of its constituent cells. The difference lies only in this, that the latter remain in close contact one with the other in the multicellular organism, whilst the persons, as representatives of the different generations in true metagenesis are widely separated one from another and are free. To emphasise this difference, I have called the alternation of reproduction in the plastids, strophogenesis ("Gen. Morph." ii., 106). The word metagenesis is left for the alternation of reproduction in persons, limited to individuals wholly independent and physiologically free. How non-essential, for the rest, this distinction is, the Siphonophora show. In these the same persons, widely differentiated by division of labor, remain united on one stock that in other Hydro-medusæ lead separate and independent lives. The specialisation of persons that we meet with in these animals as in the civilised states of the ants, bees, termites and men, is, considered in itself, only on a large scale the same as the specialisation of the plastids in the course of strophogenesis is on a small scale. The latter is, in essentials, no other process than that specialisation of the plastidule that we have already considered. This is the elementary factor of advancing organic evolution, the ever increasing improvement and variation of organic forms. Here, as ever, the microcosm is the image of the macrocosm.

If we try to find a unifying general point of view on a Monistic basis, for the manifold and wondrous events of organic reproduction and development thus lightly touched on here, this can, at all events, only be sought in the domain of the study of motion, or of mechanics in its more rigid sense. For all the processes of the universe that are known to us in all their limitless expanse, the evolution of the solar system and the planets after Kant, the organic evolution of this globe after

Lyell, its organic evolution after Darwin, are one and all, of necessity, conditioned by fixed, unalterable mechanical laws. And like the whole of the evolution of organic nature on our earth, like the ancestral history of the plant and animal kingdoms, the history of the evolution of mankind, and of each individual man, is governed by the same fixed laws of dynamics. The sole difference lies in this, that the process of evolution in organic nature is as a whole and in details infinitely more complex, and therefore more difficult to grasp, than is the same process in the organic world. But the one, as the other, depends essentially only on molar motion, and molar motion is entirely referable to attraction and repulsion of molecules, of the atoms which make up these, and of the æther that envelopes atoms.

The biogenetic process, as we may name in brief the totality of the organic movements of development on our planet, is far too complex in its details, the number, variety and complication of all the particulars that compose it are far too vast, for it to be possible, with our imperfect knowledge of them all, to follow step by step its rigidly mechanical course. None the less we may hold that we have already gained a Monistic insight, not unsatisfactory, into its true nature. The preliminary to this is the recognition of that biogenetic fundamental law, which by its proof of the causal nexus between ontogeny and phylogeny, alone seems capable of dissipating the clouds that beleaguer all branches of biogeny. The formulation of that intimate causal connexion between the history of the embryo and the history of the race, is only possible to him that is unblinded by prejudice, is acquainted with the facts of organic evolution, and is capable of a philosophical judgment on their meaning.

But if we desire to inquire still more closely into the mechanics of the biogenetic process, we must descend into the dark depths of the plastid life, and seek for the true and effective cause thereof in the motion of the plastidule. Here, also, finally, the question must be asked whether we are in a position to form a preliminary hypothesis, satisfactory in its nature as to the peculiar nature of this molecular motion of the plastidules, hidden from our actual observation, by means of the study of analogous motor phænomena. Our hypothesis of perigenesis aims at an approximate answer to this question.

If, in the first place, we survey from the highest and most comprehensive point of view the totality of the phænomena of development already known, the most general result is a conviction that the biogenetic process runs its course as a periodic movement. We find its clearest analogy in the similitude of a complex undulatory movement. Confining ourselves at first only to the facts most directly within our ken and most incontrovertible, we are able to trace this truth in our own ancestry. It is the same if we limit ourselves to the so-called historic period, in which man is, beyond a doubt, followed by man ; or if we trace out our ancestral series further and further down through the sub-kingdom of the Vertebrata to Amphioxus, through the Invertebrata down to Gastræa, and at last to Amœba and to Moneron. To us, proceeding thus, the movement of development in our ancestral series is representable under the simple similitude of a series of undulations, in which the individual life of each person corresponds with a single wave.

But if we cease to confine our attention to the series of our direct ancestors, and extending it, take into view all our blood-relations, we can, without doubt, picture their connexion in the simple form of a genealogical tree. As regards the undulatory movement of connected evolution, we may represent the movement of development of each individual person on this tree by a wave. Thus the genealogical tree, as a whole, presents the picture of a complex wave-motion, a ramified undulation. Whatever ancestral form we may take to be the parent of any whole group on the genealogical tree, whose members are connected by descent, or as the parent of any part of such a group, it will always be as the point of origin of a connected undulatory movement that, as the branches and twigs of the genealogical tree, ramifies in all directions.

We find the same picture of a ramified undulation, that is furnished us in little by the history of the evolution of every human family, by the genealogy of every dynasty on a larger scale, when we study the natural system of organisms in the light of the theory of descent. For in every considerable group of related plants and animals, as in every human family, "all forms are alike: yet none resembles its fellow." The "secret law," the "holy riddle," to which this choir of forms points, as Goethe has it, is that transmitted motion of development on which affinity depends. Hence the natural system is none other than the true genealogical tree of related species, and its every branch and twig represents a smaller or larger group of descendants from one common ancestral form. This unity of origin connects all the forms of a class, of an order, etc. When every class is divisible into different orders, every order into several families, every family into genera, every genus into species and varieties, the wave-movements grow more complex that are communicated from the common parent-form to the whole group of its descendants; and every ripple makes its individual impression in special manner on its different descendants.

Now, our biogenetic law teaches us that this large process of development in the stem history is reflected in miniature in the embryonic history of every individual. Here it is the life histories of the constituent plastids that correspond to the single waves. The cytula, or the first product of the fertilised ovum, whence the multicellular organism is developed, bears the same relation to the different cell-generations that arise from it by fission, and later on form the various tissues by specialisation, as the parent form of a class or order to the many families, genera, and species that arise from it, and develop in varying wise under adaptation to varying life-conditions. The ontogenetic cell-ancestor of the former has exactly the same form as the phylogenetic species-ancestor of the latter. The transmitted motion of development that in one case passes from the parent-species of the whole group of species, in the other case from the parent-cell of the whole group of cells, assumes in each instance the form of a complex wave-motion. He who understands the great biogenetic law will regard it as but natural that the microcosm of the ontogenetic genealogical tree of the cell represents the diminished and partially distorted image of the macrocosm of the phylogenetic genealogical tree of the species.

As we are only able to understand and explain every compound and complex phænomenon by breaking it up into its individual parts, and by making a most close and searching analysis of these, it is essential that we work out our mechanical theory of Evolution to its final and elementary details. Now, the whole biogenetic process is the very complex resultant of the developmental components from all organised species, These again are made up of the development processes of persons, as these are of those of the constituent plastids. But the development of each individual plastid again is but the product of the active movements of its constituent plastidules. Now it has been seen that the development movement of phyla and classes, of orders and families, of genera and species, of persons and plastids, has at all times and places the characteristic fundamental form of the complex undulatory movement. Therefore the molecular motion of the plastidule, lying at the root of all these events, can actually possess no other form. We are bound to conclude that this primal cause of life-processes, this invisible motion of the plastidule also is a complex undulatory movement. We name this true, this efficient cause of the biogenetic process by the name Perigenesis, the rhythmical wave-propagation of the living particles or plastidules. In truth, this mechanical hypothesis is well fitted to explain clearly this process to us.

Whilst then we regard an unbroken, complex wave-motion of the plastidules as the working cause of the biogenetic process, we see the possibility of tracing back the ceaseless and complex phænomena presented in the latter, to the mechanical motion of masses of atoms. These would be as much conditioned by chemical and physical laws as in all the phænomena of inorganic nature. If we name this complex wave-motion of the plastidules, as perigenesis or wave-propagation, we shall thus indicate the characteristic peculiarity which distinguishes this as a complex form of motion from all kindred rhythmical processes. This peculiarity depends on the power of reproduction of the plastidules, and this, in its turn, is conditioned by their peculiar atomic composition. That power of reproduction which alone makes possible the reproduction of the plastids, is but the equivalent of the memory of the plastidules. And here, once again, we come back to the well-founded idea of Ewald Hering, adopted already in this essay, that unconscious memory is the most important characteristic of organised material, or more accurately of the organising plastidules. Memory is a large factor in the biogenetic process. Through the memory of the plastidules, the plasm is able to transmit in continuous rhythmical movements its characteristic properties from generation to generation by heredity, and to implant in these the new experiences which the plastidules have acquired by adaptation in the course of their evolution.

I have already proved, in detail, in the "Generelle Morphologie," that the changes of organic forms that we include under the idea of adaptation in its widest sense, are conditioned by changed relations in the nutrition of the plastids. But these latter are referable to chemical changes in the atomic composition, and consequently, in the molecular motion of the plastidules. These are, by the extraordinary mobility and complex arrangement of their constituent atoms, at once affected by the changing influence of the surrounding external world, or by the external conditions of existence. The plastidules do not forget these experiences. They transmit them to their descendants as modifications of the original plastidular motion. Thus heredity is explained, as essentially that transmission of individual plastidular motions which is essentially bound up with every process of reproduction.

In the "Generelle Morphologie" (vol. i., p. 154; vol. ii., p. 297), and in my "Natürliche Schöpfungs-geschichte (6th edition, p. 226, 300), I had already derived every separate organic form as an essential product of two mechanical factors, that may be named after the fashion of our older biology, constructive forces, or stimuli. The internal force, the formative force within (named by Goethe the centripetal stimulus or that of specification) is heredity. The external force (named by Goethe the centrifugal or metamorphic stimulus), is the power of adaptation or variability. The latter is conditioned by that which Baer called the "degree of perfection"—the latter by that which he named "the type of formation." Keeping in view our idea of perigenesis, we can now mark off with greater precision the opposition between these two fundamental forces that determine the structure of organisms, by saying that heredity is the memory of the plastidules, variability their power of comprehension. The former brings about the stability, the latter the variety of organic forms. In very simple and very stable forms the plastidules have, in a sense, learnt nothing and forgotten nothing. In very complex and variable forms the plastidules have learnt much and forgotten much. As an example of the former, I quote the embryology of Amphioxus, of the last, that of man ("Anthropogenie," viii. and xiv. lectures).

The differences between my hypothesis of perigenesis and Darwin's of pangenesis are evident. Just as Darwin's gemmules or living particles differ essentially from plastidules or living molecules, the molecular motions that our two hypotheses postulate are entirely different. The gemmules of pangenesis are groups of molecules that "are able to grow, nourish themselves, and multiply by fission, like cells." The plastidules of perigenesis, on the other hand are single molecules, and as such, do not possess all the properties just enumerated. They are only capable of transmitting their individual plastidular motion to neighboring plastidules, and of forming by assimilation in immediate contact with themselves new plastidules of like nature to their own, after the fashion of a crystal growing in its mother liquid. Further, they are capable of changing with great readiness their atomic constitution under external influences, and of changing *pari passu* with that atomic constitution, their plastidular motion. Darwin holds that every cell gives off particles to all regions of the body, and that all reproductive cells, both the egg and sperm-cells, that are concerned in sexual reproduction, and the indifferent cells that have to do with asexual reproduction, receive gemmules that have been given off from all the cells of the organism ; and not only of this organism, but of all its ancestors. I am unable to see how these could arrange themselves in the reproductive cells and form the new organism. Indeed, a theory of development on this basis seems to me incompatible with the cell-theory, the plastid theory, and with our knowledge as to the successive differentiation and specialisation of cells in the course of ontogeny. The specialisation and definite succession seen in cell-life, on which I lay the greatest stress, and the regular periodicity of the movements of the plastidules which from time to time repeat this acquired process of specialisation, and render it yet more complex by further acquisitions, these have no place in the theory of pangenesis.

On the other hand, my hypothesis of the perigenesis of the plastidule is based on the mechanical principle of transmitted motion, that which Aristotle looked upon as the most important cause of individual development. This great thinker held that in sexual reproduction the initiation of the stimulus, or the excitation to the movements of development, originate from the male cells and pass thence to the female cells. Further, he combats expressly the idea involved in pangenesis that the reproductive cells come from all parts of the body. Our plastidules are the constituent molecules of the plasm, which the plastid-theory, an extension of the protoplasm-theory, regards as the sole active factors of plastidular life, whilst only a passive rôle is assigned to the other tissue-molecules by this same theory. When the oscillatory molecular motion of these plastidules (the plastidular motion) is transmitted in the multiplication of plastids to the new-formed plastids as heredity, it becomes a complex undulatory movement. When in the different descendants the varying conditions of existence exert direct influence upon the different branches, new forms arise by adaptation. Through the inheritance of these adaptations arises in the later descendants the divergent specialisation of the plastids, that we regard as the chief cause of further evolution. Hence are the wave-circles of this ramifying undulation ever more numerous, more varying in nature, more complex, the further we trace the advancing perigenesis of the plastidules.

All the manifold, complex, remarkable phænomena of the biogenetic process seem to me, in the light of perigenesis, capable of a simple mechanical explanation from a single point of view. On the other hand, I have tried in vain to build up a like simple mechanical explanation by aid of pangenesis, called by Darwin himself a very complex hypothesis. Moreover, all the chief phænomena of development, which he tried to explain by aid of the hypothesis of pangenesis—reproduction and heredity, nutrition and adaptation, reversion, alternation of generations, hybridism, regrowth of parts, seem to me to find in the pangenesis of the gemmules no mechanical explanation reconcilable with the facts of cell-life and of embryonic development. But such an explanation is given by the perigenesis of the plastidules. Darwin says explicitly: "that all forms of reproduction depend on the aggregation of gemmules, given off from all regions of the body." We say, on the other hand: "that all forms of reproduction depend on the transmission of plastidular motion, which is directly transmitted from the reproducing part of the body to the reproduced plastids, but further, may reproduce in whole or in part in the offspring the undulations of memory and of specialisation of the plastidules possessed by their forefathers.

That which I have here urged in objection to the ingenious pangenesis theory of Darwin, holds to some extent of that acute development theory, which, in 1874, Elsberg, of New York, put forward as the theory of the regeneration or the preservation of organic molecules (Proceedings of the American Association, Hartford, 1874). In this theory, however, in agreement with our plastid-hypothesis, plastidules take the place of gemmules. In his conception of the plastidules as real, active, plasm-molecules, and in his notion as to the fundamental importance of plasm itself, Elsberg is in essential agreement with myself. But he introduces the fundamental principle of pangenesis into his theory of regeneration. This last he formulates in the following words: "The germ of every reproduced living being contains plastidules from all its ancestors. I name this the regeneration hypothesis, because, according to it, the ancestors are born again in their offspring, to a certain extent bodily, and, indeed, in all other ways; or the hypothesis of the preservation of organic molecules, because it holds that certain plastidules are, for a long time at least, if not for ever, preserved and transmitted from generation to generation; or I could call it the hypothesis of the preservation of organic forces, which expresses the same meaning as the phrases already given."

As is evident in this passage and in other passages in Elsberg, he agrees on the most essential point with the pangenesis hypothesis of Darwin, in that the former thinker, as the latter, affirms the material transmission of actual molecules through the whole series of related generations, and with that the material composition of every germ out of the corporeal particles of all its ancestors. But our hypothesis of perigenesis is in direct opposition to this. For we affirm a direct transmission of corporeal molecules only from the individual that reproduces to that which is reproduced, but not from the older ancestors to that list. From the ancestors only the peculiar form of the periodic movement is transmitted or inherited, and this continuous wave-motion of the plastidules alone is it that can cause the properties of ancient ancestors to appear again in their later descendants like a memory. This is the very character of advancing undulation, that the kind of waves can reproduce themselves from the point of origin of the motion over wide areas and in numberless parts of the vibrating mass, although the moving molecules only move to and fro within very narrow limits, within a single wave-length, and the wave itself never shifts its place. In a very meaningful and significant manner, therefore, we call the undulatory motion a reproduction of waves. Adopting this form of speech, we may call the reproduction of organisms also a special undulatory motion.

Besides this point of difference, Elsberg seems to me to go too far also, in that he thinks the cell theory conquered by the histological researches of Beale and Heitzmann, and regards the reticulate arrangement of the series of plastidules in the plasm or formative matter as a general and essential property of all plastids. I regard this reticulate arrangement of the series of plastidules in the interplastidular substance as a secondary phænomenon, and hold that originally (*e.g.* in the simplest Monera) the plastidules alone, placed closely together, form the whole body of the plastid. Later, in consequence of their greater formative capacity, they separate, are intercalated among interplastidular-masses, and take on the reticulate arrangement that we see so general (though not universal by any means) in cytods and cells. None the less, Elsberg is in the right when he dwells upon the high importance of the plastidules, and looks upon them as the essentially active factors in the life-process.

The great group of facts on which we base our hypothesis of perigenesis, have, for the most part, long been known as empirical foundations of the evolution theory, and the theories based on them that we have connected together by the idea of perigenesis are at present accepted by the majority of biologists. We need waste no words in support of the cell-theory, with which we started. In like manner, of late, general acceptance has been given to the idea that the active, formative living matter of the cells, the material basis of life functions, is to be sought in protoplasm and the allied matter of the nucleus, and that all other parts of the tissues represent passive constituents formed out of these two. The Monera and the ontogenetic embryoform of the Monerula show us that protoplasm and nucleus have arisen later on by differentiation from simple plasm. Resting on these fundamentals, we venture to think that we have shown in our plastid-theory that all the numberless kinds of protoplasm and of nucleus are only modifications of a single, fundamental, formative matter, plasm itself, and that in consequence the plasm-molecules or plastidules must be regarded as the essential, molecular factors of the biogenetic process. The latter we are bound to describe as a peculiar molecular motion conditioned by their atomic constitution. It has been generally conceded that the biogenetic process as a whole, as well as in particular parts, may be represented as a complex undulatory motion. As we can find the effective cause of this very complex undulatory motion in the molecular motion of the plastidules alone, we are bound to speak of this latter motion also as an undulation.

If we wish to make out on rigidly mechanical grounds a claim on behalf of our hypothesis of perigenesis to the value of a theory of evolution, we should lay especial emphasis on the nature of the rhythmical molar-motion, the complex wave-movements that the biogenetic process incontestably presents. Then there only remains as a hypothetical element in the theory, the sum of the properties ascribed to the plastidules or plasm-molecules. We regard these particles of living matter as the true active factors of life processes, and attribute to them, in addition to those properties common to all molecules or little masses compounded of atoms, a peculiar property which distinguishes them as living molecules from others. This property, which alone really distinguishes the living organism from the non-living inorganic body, is the faculty of memory or reproduction. Without this hypothesis the manifold phænomena of reproduction and development seem absolutely incomprehensible. Ewald Hering, in the work already quoted more than once, has clearly shown on what good grounds the idea of such an unconscious memory of the plastidule is based. On the other hand, it has not been possible for me, after careful consideration, to find any tenable objection to this hypothesis. Therefore I consider memory, or the power of reproduction of the plastids, as a function of plasm, conditioned directly by the atomic composition of the plastidules themselves.

From this point of view we may, perhaps, call perigenesis a mechanical theory in a wider sense, or, at least, a hypothesis that may serve as the germ of such a theory. Another thing that speaks greatly in its favor, is its great simplicity. This is, as a rule, evidence of a theory in harmony with fact. How simple are the principles of Newton's theory of gravitation, Huyghen's undulatory theory, Myers' of temperature, Schleiden's cellular theory, that of descent of Lamarck, that of selection of Darwin. Yet by these simple principles the greatest and most extensive collections of different facts are connected into one, are explicable as due to a common cause. Just as simple is the principle of complex undulatory motion of the plastidules considered by us as the effective, mechanical cause of the biogenetic process.

The Monistic science of the present day rightly enough lays claim to explain all natural phænomena mechanically, and to trace them all back, teleology excepted, to efficient causes. This first duty is satisfied by our theory of perigenesis. For the principles of transmitted molar motion and the conservation of energy that lie at its base are purely mechanical. Purely mechanical also is the principle of autogony, that derives the first stimulus to this transmitted motion from those movements of atoms that occur in the formation of the first plastidules, and are effected by the peculiar motion of the plastidules. We have been able to refer heredity to the transmission of these plastidular motions, adaptation to their changes, and these are the two chief factors in the building up of organic forms. Thus the biogenetic process is in unconstrained harmony with the law-abiding march of all the processes in the universe. It is a special and very complex form of rhythmical molar motion. And its effective cause is the perigenesis of the plastidules.

VIII.—THE PROOFS OF EVOLUTION.

THE PROOFS OF EVOLUTION.

THE fertile influence exercised on the most different branches of science, and especially on natural history, during the last eighteen years by the new study of development has worked on none more swiftly, has brought forth rich fruit on none more than on the domain of organic morphology, the study of the forms of animals and of plants. In the first place, as a consequence of the new theory of descent, various important branches of inquiry, hitherto separated to a greater or less extent one from the other, are found to be closely allied, to be in the most intimate connexion and mutual relation. The consideration of internal and of external forms, comparative anatomy and classification, embryology and palæontology, are recognised in the clear light of the theory of descent as intimately connected sciences, moving by various routes to one and the same end, the knowledge of organic forms through that of their historic origin. As result of this a new science has evolved, whose immediate aim is the knowledge of this origin of allied animals and plants in genealogical connexion, and the discovery in the genealogical tree of these forms of a true natural system. This new science is ancestral history or phylogeny.

Every new science has to contend, at first, with the ill-favor and jealousy of its elder sisters, who fear from it injury to their older well-won rights. This fear is the greater the higher are the aims of the new comer, the wider the area of work it seeks to win. This is of value in that thus its young strength is tried in the hard struggle for existence, and like a young plant in a thickly populated field it has to wrestle with envious sisters for room, for light, for air. Thus the youngest of sciences and not the least hopeful, comparative philology, has to gain its own strength in the heated contest with other branches of philology. And phylogeny, whose aims and methods are closely allied to those of comparative philology, has not been spared that necessary struggle for existence.

When we made the first attempt, ten years ago, in the "Generelle Morphologie," to lay down the conception and ends of phylogeny, that attempt met almost everywhere with suspicion and derision, with scorn and hostility. How will this pretentious phylogeny reveal the secrets of organic creation? How will it prove the hypothetical genealogical tree of organisms? And what records are at its command in its inquiries into prehistoric things? Such doubts and the like as to the possibility, to say nothing of the consequences of phylogenetic inquiries, were loud and general, and whoever was not very intimate with the subject of organic morphology, and with the vast extent of its stores of knowledge yet uncoined in words, could not but look on our attempts from the first as hopeless, as courting defeat.

How lies the matter to-day, after a lapse of but ten years? We ought to be quite content with the results of this first decade in the history of phylogeny. Our foes ought not to grudge us our consciousness of decisive victory. Not only has phylogeny attained an independent value and a recognition in natural history, in biology, not only are phylogenetic ideas and principles forming already essential parts of our best treatises and handbooks. Many valuable special investigations into particular questions in phylogeny have already begun, and have, though as yet incomplete, brought to light results of the most startling description. Nay, at this hour we enjoy this much of triumph. Many of our opponents have made complete recantation, and are themselves treading the path first entered upon by us, and by them regarded as impassable. The ablest zoologists and botanists have accepted with one accord the phylogenetic method, and by use of it have already attained results that without it could never have been. The maligned genealogical trees, which phylogenetic investigation uses as the simplest, clearest, most condensed expression of its inventive hypotheses have received unexpectedly swift recognition, and are of general use in morphology. It is true that voices are not wanting to declare all these phylogenetic efforts as so much empty trifling. Only recently, we might hear from the mouths of recognised physiologists that our "genealogical trees were of the same value as are the pedigrees of the Homeric heroes in the eyes of the historical critic." But these utterances, and others as contemptuous, only prove that the physiologists concerned are wholly ignorant of the present condition of morphology, and have no idea of its range and significance. And further, one may read, not without sorrow, between the lines, that physiology in its one-sided fashion knows not how to make use of the study of descent, whilst morphology has obtained by the help of that study the greatest results. But just as ineffectual as the like ignorant prejudices were against comparative anatomy which has stood firm for seventy years, or against classification which has done the like for twice that time, and has employed thousands of busy workers, so will they be against phylogeny, at once youngest and most hopeful child of scientific morphology.

Further, the esteem in which phylogeny is held, is very different within the limited circle of those skilled in morphology and in the wider circle of cultured laymen. Especially is opinion divergent as to the worth possessed by the empirical records of phylogeny, and the stability of the hypotheses and genealogical trees based on these. Hence it seems wise, in this place, to cast a glance of inquiry over the records of phylogeny, and so ask how far in our building up of phylogenetic hypotheses we can rest on substantial facts. It is true that we have already made known our ideas on the value and significance of the different "evidences of creation" in our "Naturliche Schöpfungs-geschichte" (Edition vi., Lecture 15), and "Anthropogenie" (Edition iii., Lecture 15). But, nevertheless, as since then the ideas of other scientists on this question have differed greatly, it is not superfluous to bring back the over-estimation or under-estimation, on one side or the other, of these very important evidences to their true value.

I take the ground that in reality there exists no domain of natural history that does not yield us evidence of greater or less value in favor of phylogeny. Not only all branches of morphology, but also different branches of physiology, *e.g.* chorology, the study of the geographical and topographical distribution of organisms, give us facts that we can utilise directly or indirectly on behalf of phylogeny. But before all other branches of science three are most prominent as the most especially in evidence for phylogeny. These are comparative anatomy, ontogeny, palæontology.

Palæontology, or the study of fossils, furnishes at the present time in many ways the most reliable and most accessible kind of evidence as to the order of creation in the past. For the fossils or petrified remains of plants and animals that we meet with in the sedimentary strata of the earth's crust are, in truth, the fossil remains or impressions of those organisms, long dead, that hundreds of thousands or many millions of years before peopled our earth. Amongst these organisms also, in conformity with Evolution, must have been the veritable ancestors of the species of plants and animals in existence to-day, and the allies more or less closely related of those dead and gone ancestors. Hence many naturalists, especially those who wish to proceed as carefully and exactly as is possible, as well as those who would extend palæontology yet further, place in that science their greatest hope, and regard it as the sole reliable evidence in favor of phylogeny.

It is at the present time generally known that fossils are of very great significance and importance as actual medallions of creation. They alone are our immediate teachers as to the appearance and the historic changes of form in the various species of animals and plants in that long series of epochs in nature that are numbered in millions of years. They alone show us plainly what a wealth of differing species the individual groups of the animal and vegetable kingdoms present in the different sections of the earth's strata. They alone enable us to form a general picture of the characteristic physiognomy of the organic population in the different epochs through which our planet has passed. Finally, by the fossils alone are we taught how the special ancestral history of particular species and genera, the detailed ancestral tree of these last, may be traced out step by step, branch after branch. Thus we have lately, *e.g.*, been enabled by certain startling palæontological discoveries, to trace back, step by step, the pedigree of our modern horse to tapir-like forefathers. In like fashion we are able to trace out to a great extent, with varying degrees of certainty, the ancestral series of our cattle and of our swine. The genealogy of many Mollusca with calcareous shells, especially of the ammonites, is also known in detail with a degree of certainty that is encouraging.

But startling and palpable phylogenetic results such as these accruing from palæontology are, unfortunately, very rare exceptions, and in general it may be said that the value of palæontology as phylogenetic evidence has been greatly over-estimated. For valuable and incontrovertible as this most direct and most sure evidence is intrinsically on the one hand, on the other it loses value on account of its extraordinary uncertainty. This results in part from the nature of the organisms, in part from that of the rocks in which they have left their fossil remnants and impressions, in part from the nature of the process of fossilisation itself. The great majority of all organic forms are so soft and delicate, or live under such conditions, that rarely or never are they able to leave behind them a fossil of any value. Hence we obtain by aid of palæontology nothing, or almost nothing, of many classes of animals and plants, and of the soft embryos and earlier conditions of all organisms. But the hard and solid parts, which alone are capable of preservation as fossils, the skeletons, are in the different groups of animals of very varying value. Hence, *e.g.*, the fossil remains of Vertebrata, Mollusca, and Radiata are full of instruction, whilst the fossil remains and impressions of most insects, worms, and zoophytes (corals excepted), are of very limited significance.

In addition to this great deficiency in palæontological evidence, there is the difficulty that all the older sedimentary rocks, all the formations laid down before the Silurian and Cambrian age, have been, under the action of heated liquids from the interior of the earth, changed or metamorphosed in whole or in part, so that they contain only very few or absolutely no recognisable fossils. Hence of all the strata that belong to the Laurentian period, that stupendously long period in history, in which the organic world began to evolve and to advance towards the differentiation of the chief large groups of the animal and vegetable kingdoms, we must expect, as a rule, no evidence in the shape of fossils. And to this rule such Laurentian fossils as the much discussed Eozoon, so full of significance, are, alas, rare exceptions. Moreover, in many other formations, that contain many petrefactions, these occur in such bad condition and unrecognisable form, that they are of no value in phylogeny.

These and other circumstances, that are based upon the nature of organisms, of processes of fossilisation, and even on conditions of rock formation diminish to an extraordinary extent the significance of palæontological evidence, and compel us to conclude that of the vast majority of organic species that have lived on our globe, we shall never learn anything through the medium of their fossil remains. Of course, as yet, only the greater part of Europe and of North America has been carefully examined in regard to fossils. The rest of the regions of earth are, for the most part, still unexplored. We hope that palæontological investigation of them will make us acquainted with very many and very important fossil remains. But under no circumstances will these same be able to fill up all the gaps that exist, and to demonstrate beyond controversy the whole ancestral history of organisms by an unbroken series of fossils. Hence we are in need of other, more convincing evidence, and this we find partly in comparative anatomy, partly in ontogeny.

The comparative anatomy of animals and plants recognises certain characteristic relationships in the internal structure of those organisms, especially in the relative disposition and arrangement of the organs, that are common to all the members of a natural group or "type," despite the greatest diversity of external form. The number of these main groups or types in both the animal and vegetable kingdom is very small. In the latter we distinguish, as a rule, only three or four, in the former six to eight. Only within each type is a rigid, morphological comparison of all the bodily organs possible. Only within each type can we speak of true relationship of form. This internal and essential community of bodily structure, standing in remarkable contrast to the variety of external forms, was explained in the older comparative anatomy by the mystic idea of a "unity of design" or plan of creation. Since the reformation of the study of development, we explain it very simply and naturally as the result of the common origin from a parent form. This parent form transmitted all essential characteristics of its internal structure by heredity, with more or less completeness, to all its descendants, whilst these acquired by continued adaptation the most various differences in external structure and in non-essential particulars. Every type becomes thus a stem or phylum. The typical relationship of form becomes the real relationship through ancestry, conditioned by heredity. The aim of comparative anatomy is to distinguish and demonstrate the true kinship of the different as well as to explain the likeness of related form by aid of heredity from common ancestors, and adaptation to similar life-conditions. Comparative morphology is accordingly broken up into homology and analogy. Homologues are like organs that have originated from one and the same common ancestral form by adaptation to different functions. Analogues are like organs that have arisen from different ancestral forms by adaptation to similar functions. The pectoral fins of fishes, the wings of birds, the fore-limbs of quadrupeds, the arms of man, are homologues. The wings of birds and of insects, the fins of fishes, the swimmerets of the lobster, the "wings" of pteropods, the legs of quadrupeds, the legs of insects, are analogues.

It has long been known, that within every type or phylum (*e.g.*, within that of the Vertebrata) long series of forms occur, ranging from lower to higher, from the imperfect to the perfect, from the simple to the complex. Consider the long series of advancing development in all organs from the lowest vertebrate to the highest, from Amphioxus to man. But these series are not simple, ladder-like, but complex, tree-like, since starting from the original, simple, common forms, advancing improvement is carried out in different directions and in various wise. This tree-like arrangement of related forms, that the system of animal and vegetable classification acquires under the directing hand of comparative anatomy, expresses the facts of Evolution in a manner more actual than the genealogical tree. It is clear that this same pedigree, that represents the natural system of organisms, cannot be laid down with absolute certainty, but only approximately. But this is a necessary result of the nature of the question at issue, and in no sense lessens the value of the work that is done.

The ideas of different morphologists, nowadays, differ widely as to the value of comparative anatomy in the construction of a natural system, and as to how far we have the right to assume that such a natural system is a veritable genealogical tree. Some ascribe to it the highest, others the lowest significance, whilst yet others, holding a middle course, would mete out to it an average measure of importance. In reality, all this depends upon the different capabilities and power of comprehension of the morphologists concerned. Narrow minds, short-sighted observers, confining themselves always to the most evident and recognisable facts, are incapable of taking in at a glance large groups of related phænomena of form, after the fashion of comparative anatomy. Further, they are unable to distinguish between the essential and the non-essential, that which is important, and that which is accidental. Narrow, small minds of this order, although adapted by their very smallness and narrowness to become excellent specialists and species-mongers in science, can never estimate the value of comparative anatomy, and in large or small measure they reject its phylogenetic application. On the other hand, its value has been estimated to the full by philosophical thinkers, and by those large natures that are capable of taking in at a glance the whole of the vast domain of phænomena, and thus are able to distinguish the essential from the accidental. Such men as these will look upon comparative anatomy as the most important of all evidences in ancestral history, and will assign to it the first place in the building up of a natural system.

But this evidence as to the past, valuable as it undoubtedly is, has its weakness. And this is based, in the first place, upon the imperfection of its materials, and in the second place, upon the difficulty of distinguishing in all cases clearly between homology and analogy. A great number of connecting links between living forms in existence at the present day have perished long ago, and we are obliged to fill up the gaps that result by guesses. Many anatomical relations are so complex, that the phylogenetic explanation of them becomes, as a rule, exceedingly difficult. Just in proportion, therefore, as we estimate comparative anatomy at its true value as an important evidence in regard to descent, and as we are of opinion that it may become altogether over-looked, in the same degree must we warn ourselves, on the other hand, against an application of it that is too exclusive and one-sided. And when, of late, it was stated that in all phylogenetic questions the first and last word belonged to comparative anatomy, we were, and are, unable to share that opinion. We are rather of opinion that in many questions, and certainly in many of those that are most important, ontogeny, the third of our three chief witnesses, is of higher significance, of more decisive worth.

Ontogeny, or the history of the embryo, as we name in brief the history of the development of the individual, is at the present time very often undervalued in respect to its use as evidence in regard to the past, to the same extent as palæontology is over-estimated. We actually see the singular spectacle of many embryologists, specialists who have made the study of the development of the germ their chief occupation, denying to that study any phylogenetic value. Nevertheless, he who approaches this branch of knowledge with the understanding mind, who does not content himself with the mere observation, interesting as that is, of ontogenetic facts, but inquires into their phylogenetic causes, such a one will certainly have the conviction that ontogeny ranks among the most important and meaningful evidences as to the history of ancestral forms. Here, as in comparative anatomy, it is indispensable to carry on empirical investigations in a philosophical spirit, and to search amongst the infinite world of phænomena for those general facts which are common to the manifold forms that development assumes. In this study, as in that, it is especially necessary clearly and sharply to mark off the essential from the non-essential, that which is of moment from that which is an accidental accessory.

The phylogenetic importance of ontogeny—the value of the study of the embryo as an evidence in regard to pedigree—is, in the first place, based upon the fact that every organism, in its development from the egg, runs through a series of forms, through which, in like succession, its ancestors have passed in the long course of earth's history. The history of the embryo, therefore, is a picture in little an outline of that of the race. This conception forms the gist of our fundamental biogenetic law, which we are obliged to place at the head of the study of development, as the veritable fundamental law of organic development. We regard it as indispensable, as the chief principle that serves us in explanation of that organic development. Every advance in ancestral history that our forefathers made in their adaptation to new conditions of life, and that brought into being some new ancestral form, is repeated to-day by virtue of heredity in that history of the individual that corresponds with the history of the race. Just as at this hour every organic individual takes origin from a simple ovum-cell, so the common ancestors of all the species of any phylum was originally a simple cell.

Now, it is evident that only in rare cases, only in a few lower organisms, is this recapitulation of the ancestral history that we see with our own eyes in the embryonic history quite complete. In the great majority of cases the recapitulation is exceedingly abbreviated. Often, moreover, it is modified, and very frequently quite metamorphosed. This results from the fact that the young embryo, from the very outset of development, is subject to the transforming influence of external life-conditions, and adapts itself to them. As result of these "embryonic adaptations," entirely new formative elements enter into the individual course of development that, to a greater or less degree, alter the original process of development. In especial, a condensation of the original repetition of events occurs very frequently —the more frequently the higher the stage of evolution reached by the particular organism—whilst some or many stages in development disappear. At other times, on the contrary, quite new links are intercalated in the inherited chain of forms. We may denote all these later modifications of the original palingenetic process of development—in a word, all "bastard or spurious modifications"—as cenogenetic (κενος=unimportant).

Hence, all phænomena that we observe in the course of the development of the individual animal or plant, from the ovum-cell up to the complete formation of the adult body, fall into two great groups, the palingenetic facts or those of condensed history, and the cenogenetic facts or those that are spurious, and tell us nothing as to the history of the past. The ontogenetic facts of palingenesis alone are of direct value as evidence in respect to pedigree, and they alone have relation to corresponding precedent changes in phylogeny. On the other hand, the ontogenetic phænomena of cenogenesis have not only no kindred phylogenetic meaning, but are, on the contrary, will-o'-the-wisps. We must take heed that we are not misled by their false glimmer. The fundamental biogenetic law must therefore now be more rigidly formulated, as follows: "The history of the embryo is an epitome of that of the race; the more complete, the more the condensed development has been retained by virtue of heredity; the less complete, the more a spurious, non-historic development has supervened by virtue of adaptation." In my "Anthropogenie" I have tried to prove, by taking man as an example, how the fundamental law of organic development, thus formulated, finds its application, and how by aid of it we can, from the actually observed facts of embryology, draw the most important conclusions as to the hypothetical precurrent events that occurred in the history of the race.

If now, therefore, we regard ontogeny or embryology as the most important and essential of all the evidences as to phylogeny, we shall still, in doing thus, by no means lessen the great value that the other kinds of evidence, and especially comparative anatomy, possess. Without aid of this last we should not be in a position to understand the phænomena of embryology nearly so clearly, nor to estimate them with nearly so much accuracy, as we can, in fact, now understand and estimate them. Comparative anatomy and ontogeny are in the happiest fashion complementary one to the other, and in reciprocal manner each fills up the gaps of each. If, therefore, of late certain morphologists have regarded comparative anatomy exclusively, and others comparative embryology exclusively, as the only reliable witness on the points at issue, we are bound to look upon the points of view of both sets of thinkers as one-sided and deficient. We shall only be able to know the ancestral history of organisms by complete and conjoint investigation of both these two chief sets of evidence on the question. It is clear that it is of the first importance to this end that man should be intimately acquainted alike with the rich empirical treasures of both sciences, and that is certainly not the case with these lop-sided naturalists.

This much at the present time is certain beyond a doubt, that for the construction of a phylogenetic history an exceedingly rich storehouse of empirical evidence, of certain facts is at our disposal, that only needs to be taken possession of and understood in order to be recognised in all its full significance. It is not in this connexion a question of discovering new and unknown facts bearing upon the pedigree of organisms—and also on that of man—but of understanding and utilising the facts already to hand. Sources more rich, more full of meaning, than comparative anatomy and ontogeny will never be discovered. With their help alone we are already in a position to found the new science of phylogeny, even if we ignore altogether those less important sources of information accruing to us from palæontology, chorology, and other auxiliary sciences. But if many men—and among them even some scientists of repute—hold that the whole of phylogeny is a castle in the air, and genealogical trees are empty plays of phantasy, they only in speaking thus demonstrate their ignorance of that wealth of empirical sources of knowledge to which reference has been already made.

The aims and ways of phylogeny are the same as those of geology. Just as the hypothetical history of evolution of the earth is based upon a scientific foundation, as firm as it is beautiful, on the ground of experimental evidence, so is it also with its younger sister, the ancestral history of organisms. The one can, and will, rise to the position of a real "exact" science as little as the other. For the historical events of past time, whose connexion each of these branches of knowledge aims at demonstrating, occurred many millions of years ago, and are for ever removed from direct observation on our part. Hence geology and phylogeny alike are from the nature of things historical sciences. But the foundations of the hypotheses that belong to the latter, as of those that appertain to the former, repose upon a world of the securest proofs. And just as the value of the geological evidence is to-day generally recognised and utilised in the history of the evolution of the globe, so day by day grows the recognition of the incalculable worth that our morphological evidence has in regard to the ancestral history of organisms.

IX.—THE PRESENT POSITION OF EVOLUTION IN RELATION TO SCIENCE.

THE PRESENT POSITION OF EVOLUTION IN RELATION TO SCIENCE.

ON this festal day that gathers us together in this place at the opening of the fiftieth meeting of German scientific men, the relationship of science as a whole to our especial branches of enquiry has an importance greater than all other questions. Whilst cultured men of all classes trace out the astounding advances of natural science with keenest interest, they ought on such a day as this, with special emphasis, to ask what general results natural science has yielded in the domain of human cultivation. If, therefore, I, in obedience to the summons that you have given me—a summons that carries with it so much of honor—claim your close attention for a little space, I am thinking that I can choose no subject more worthy of our common consideration than the relation of knowledge as a whole to that branch of scientific enquiry that comes most home to me personally—the study of Evolution.

For more than ten years past no other study has taken so strong a hold on general attention, none other has entered so deeply into our most important convictions, as the new science of Evolution and that Monistic philosophy that is so intimately knit up therewith. For by it alone is the question of questions, the foundation question as to man's place in Nature, to be solved. As man is the measure of all things, it is evident that the ultimate questions and highest principles of all knowledge must depend upon the place that our ever-advancing knowledge of Nature assigns to man in Nature.

To Charles Darwin especially our science of Evolution to-day owes this—its lordly place in the front rank.[1] He it was who, eighteen years ago, first broke through the rigid icy barriers of the reigning prejudice, and brought into life a unity of development of the universe on the same fundamental principles as those which our greatest poets and thinkers, a century before, had initiated. At the head of these were Immanuel Kant and Wolfgang Goethe.[2] By the enunciation of his theory of Selection, of the idea of Natural Selection in the struggle for existence, Darwin was enabled to lay the firm foundation of the biological part, and that the most important part, of that general theory of Evolution that, in the beginning of our century, saw the light as the descent theory. Up to that time the older naturalists had fought in vain on behalf of this latter theory. Neither Lamarck[3] and Geoffroy St. Hilaire in France, nor Oken[4] and Schelling in Germany, were able to carry it to victory. It is now exactly fifty years since Lorenz Oken began here, in Munich, his academic lectures on the theory of development. Hence it seems good to us in this place, and at this hour to place upon the grave of this zoologist so far-seeing, this philosopher so gifted, a laurel-crown. For Oken it was, who in 1822, inaugurated at Jena the first gathering of German naturalists for scientific purposes. To him, therefore, the thanks of this, the fiftieth of such assemblies are especially due.

But the natural philosophy of that time was but able to sketch a general plan, a preliminary outline of the mighty edifice that we call to-day the theory of Evolution. The building stones of that edifice were gathered together by the assiduous labors of many men during the succeeding half-century. A voluminous literature, a marvellous improvement in the methods of scientific inquiry, bear very striking witness to the astounding advances made in science during that period. But it is certain that the measureless expansion of the field of empirical observation, and the specialisation that resulted thence, often led to a pernicious diffusion of energy. The higher aim, the knowledge of general laws, was almost forgotten in the interest in the observation of particular details which are of secondary moment.

Hence it could come to pass, that during the period of this rigidly empirical inquiry into Nature, from 1830—1859, nearly thirty years, the two chief divisions of natural history were working upon absolutely antagonistic bases. In the history of the development of the earth, since 1830, since the appearance of Lyell's "Principles of Geology," the general conviction that our planet had originated by a supernatural act of creation, or had arrived at its present condition through a series of complete revolutions of mystic origin, was dispelled. It was seen, on the other hand, that an all-powerful unbroken evolution had determined its natural formation, step by step. But in the history of the development of the living inhabitants of earth, the old unreasoning myth had held general sway, according to which the individual species of plants and animals, like man himself, appear independently one of the other, and a series of such created forms had succeeded one another without any genetic connexion.[5] The contradiction between the two orders of thought, between the natural theory of development of the geologists, and the supernatural creation-myth of the biologists was first decided by Darwin, in 1859, in favor of the former. Since that time, we know of a surety that the formation and the variations of form of the living earth-dwellers of our globe, follow the same vast, eternal laws of mechanical evolution as the globe itself and the whole universe.

To-day there is no necessity to state the grounds of proof on which the modern theory of development, associated with the name of Darwin, rests. That was done fourteen years ago at the Naturalists' Association at Stettin.[6] Since that time the recognition of its truth has made general way in very delightful fashion. In the particular branch of natural science, in which my own work lies, in the wide domain of the study of organic forms or morphology, it is already recognised by all as the most important basis of our work. Comparative anatomy and embryology, systematic zoology and botany, are no longer able to dispense with the study of the theory of descent. For, in the light of this alone is it possible to explain really the mysterious relationships of the innumerable organic forms to one another, *i.e.*, to trace them back to mechanical causes. Their likeness is a natural result of heredity from common ancestors; their dissimilarity is the necessary consequence of adaptation to different life-conditions. By the theory of descent alone the facts of palæontology, of chorology, of œcology,[7] are explained as simply as naturally. By it alone are we able to explain the existence of the remarkable rudimentary organs, eyes that see not, wings that are never used in flying, muscles that do not contract, utterly useless parts of the body that give the lie to the earlier teleology.[8] For they prove in the clearest manner, that adaptation to function in the structure of organic forms, is neither general nor complete. Such adaptation is not the outcome of a designed creative plan, but is brought about of necessity by the accidental coincidence of mechanical causes.

He who in the face of these overwhelming facts still asks for proofs of the theory of descent, only shows in thus asking his want of knowledge or want of judgment. It is preposterous to demand on its behalf direct, experimental proof. This enquiry, so often repeated, springs from the wide-spread misconception that all natural science must be exact. All the other branches of knowledge are often named in contradistinction to natural science, metaphysics. But in truth only the lesser part of natural or physical science is exact, that part, namely, which is based on mathematics: astronomy and higher mechanics generally, the majority of physics not included in the higher mechanics, most of chemistry, a great part of physiology, but only a very small part of morphology.[9] The phænomena in this last biological domain are too complex, too variable for us to make use, as a rule, of mathematical methods. And whilst the principle is established that we should aim at a foundation for all our knowledge as exact as possible, and where possible a mathematical foundation, yet as far as concerns the greater part of biological science, it is not possible to carry out that principle. In this department of thought the historical rather than the exact, mathematical and physical method obtains.

This holds especially of morphology. For we can only acquire a scientific knowledge of organic forms through the history of their development. The great advance of our age in this domain of knowledge consists in this, that we have a far wider conception of the end and aim of the study of development than was the case until the time of Darwin. For until that time we only understood by the phrase, that history of the development of the organic individual which we call to-day embryology or ontogeny. When the botanist traced out the growth of the plant from the seed, the zoologist the up-building of the animal from the egg, he held that with the completed observation of this history of the embryo he had solved his morphological problems. The greatest workers in the realm of embryology, Wolf, Baer, Remak, Schleiden, the whole of the school of embryologists founded by these, understood, in a word, by the study of development exclusively the embryology of the individual. To-day it is far otherwise, for the mysteries of the wonderland of embryology are no longer insoluble riddles to us. Their deep meaning is now clear. For on the laws of heredity the transition forms through which the germ passes under our very eyes in a very brief space of time are a condensed, an abbreviated repetition of corresponding transition forms through which the ancestors of the organism in question passed in the course of many millions of years. When to-day we place a hen's egg in the hatching-machine and see in twenty-one days a chick emerge thence, we no longer stand smitten dumb with wonder at the marvellous changes that lead us on from the simple ovum-cell to the Gastrula with its two layers, thence to the vermiform embryo, destitute of skull, and thence to the further stages that exhibit in essence the organisation of a fish, an amphibian, a reptile, and, finally, a bird. Rather is it that we deduce thence the corresponding succession of forms of those ancestors which have led up from the unicellular Amœba to the Gastræa, and onwards through the classes Vermes, Acrania, Pisces, Amphibia, Reptilia to the Aves. The succession of embryonic forms in the chick gives us a condensed picture of its actual ancestral series.

Our fundamental biogenetic law formulates the direct, causal connexion between the embryonic history of the organic individual and the ancestral history of its forefathers in this short sentence: the history of the embryo is an epitome of that of the race, conditioned by the laws of heredity.[10] And this palingenetic epitome only seems interfered with to any particular extent when, by adaptation to the conditions of embryonal life, cenogenetic alterations have taken place.[11]

This phylogenetic explanation of the ontogenetic phænomena is, up to the present time, the sole explanation in regard to the latter. But it receives from the results of comparative anatomy and palæontology, the weightiest confirmation and enlargement. It is evident that it does not admit of exact or experimental proof. For all these biological studies are of the nature of historical and philosophical science. Their common aim is the knowledge of historical events that occurred in the course of many millions of years, on the surface of our planet in its youth, long ere the appearance of the human race. Direct, exact knowledge on these matters lies quite beyond the domain of possibility.

An approximate knowledge is only possible as the result of a critical use of historical evidence, and of a speculation as careful as bold. Phylogeny uses these historical evidences in the same way, estimates them after the same method, as other historic studies. As the historian by aid of chronicles, biographies, letters, pictures to us a long past age; as the archæologist by the study of pictures, inscriptions, hieroglyphics, reveals to us the state of civilisation of peoples long perished; as the linguist by comparative investigation of all the living languages, and their older memorials in writing, that are related to each other, shows to us their origin and development from one common primal form; in just the same way the naturalist, to-day, by a critical use of phylogenetic evidence, of comparative anatomy, ontogeny, palæontology, has contributed to our ever increasing knowledge of those former changes which, in the course of measureless ages, befel the forms of organic life on our earth.[12]

Phylogeny, or the ancestral history of organisms, admits of as little exact or experimental proof as its older and more favored sister, geology. The high scientific value of the latter has been only quite recently generally recognised. The ignorant alone laugh incredulously, to-day, at the explanation that the huge alpine masses, whose snow-clad summits shine out upon us from afar, are none other than consolidated sea-mud. The structure of these stratified mountains, the nature of the fossils that they contain, admit of no other explanation. None the less, the fact does not admit of exact proof. In like manner, almost all geologists agree in recognising a definite systematic succession of rocky layers, corresponding to different periods of time. And yet this system of strata is nowhere on the earth complete from end to end. But our phylogenetic hypotheses are entitled to ask for recognition equal to that accorded to these generally accepted geological hypotheses. The only difference is, that the mighty theories of geology are far more complete, simpler, easier of comprehension than is that of the younger science, phylogeny.[13]

Thus, these historical natural sciences, geology and phylogeny, form the connecting band between the exact natural sciences on the one hand, and the historical metaphysical sciences on the other. Biology, as a whole, but especially systematic zoology and botany, is therefore raised to the rank of a true natural history, an honorable title, long sought by these departments of knowledge, but only of late deserved. The fact that these same branches of knowledge are still, at the present time, described in many places and even officially,[14] as "descriptive natural sciences," and are placed in antagonism to the "explanatory," only serves to show the false conception hitherto held as to their province. Since the natural system of organisms has been recognised as their genealogical tree, in the place of the dead, descriptive systematising, stands erect and living the ancestral history of classes and species.

Highly as we value this immense advance of morphology, it would still, not of itself, be sufficient to explain the extraordinary effect of the modern theory of Evolution upon knowledge as a whole. This depends rather, as will be admitted, upon one single special conclusion involved in the theory of descent, upon its application to man. The time-honored question as to the origin of our own race, is by this theory answered for the first time in a scientific manner. If the theory of Evolution is true as a general proposition, if it, as a whole, gives a natural history of the ancestry of living things, then is man the crown and summit of the creation, "the paragon of animals," sprung from the phylum of the Vertebrata, the class Mammalia, the subclass, Placentalia, the order Quadrumana. Since Linnæus, as early as 1735, in his fundamental system of nature, united man with the apes and bats in the order Primates, as all zoologists since then have been unable to separate him from the class of mammals, it follows that this systematic grouping of man that is now followed with one voice by all zoologists, can only find its phylogenetic explanation in the origin of man from that class.[15]

All attempts to do away with this consequence of the theory of Evolution, with all its fulness of meaning, are in vain. It is in vain that men try to preserve a special place for man, in vain that they construct for him a line of ancestors of his own alone, separately from the genealogical tree of the Vertebrata. The phylogenetic proofs of comparative anatomy, ontogeny, palæontology, speak out too clearly in favor of a uniform origin for all Vertebrata from one single common stem-form for us to be able any longer to be in doubt at the present day. Not one comparative philologist holds it as probable that languages so different as the German, Russian, Latin, Greek, Hindustani, have evolved from different primitive languages. On the contrary, all linguists, after critical comparison of the structure and development of these different languages, agree in the conclusion that they have all originated from one single Aryan or Indo-European primal speech.[16] In exactly the same way, to all morphologists the firm conviction has come that all the Vertebrata, from Amphioxus up to man, all Pisces, Amphibia, Reptilia, Aves, Mammalia, arose originally from a single vertebrate form. For it is unthinkable that all the different and highly complex conditions of existence that led through a long series of processes of Evolution to the formation of the vertebrate type, could have concurred more than once in the course of earth's history.

As for us to-day only the general conception of the vertebrate origin of man is of moment, we will not pause longer over the individual details of our ancestral tree.[17] We need only, in regard thereto, point out in passing that the chief stages in the series at least are already at the present time assured, thanks to the splendid labors of our most renowned morphologists, and in especial to those of Gegenbauer and Huxley.[18] Still it is often asserted to-day that by these labors only the origin of the human body, but not that of our minds, is explained. In answer to this important objection, we must keep ever in mind the physiological fact that our soul-life is indissolubly bound up with the organisation of our central nervous system. But the latter is composed and is developed in exactly the same manner as is that of all the higher Vertebrata. Further, according to the researches of Huxley, the differences between man and the higher apes in brain-structure are far less than the corresponding differences between the lower and the higher apes. As the function or work of every organ is unthinkable apart from that organ, as function is everywhere developed hand in hand with the organ, we are forced to the conclusion that our mental functions have slowly and with steady ascent evolved *pari passu* with the phylogenetic up-building of our brain.

Further, this question of soul, so full of significance, appears to us at the present moment in a light altogether other than was its wont twenty or even ten years ago. As man has gained a conception of the connexion between soul and body, spirit and matter, so the modern theory of Evolution goes with its clearer eyesight much further, and teaches us that all organic matter at least, if not matter as a whole, is, in a sense, gifted with a soul. In the first place, improved microscopic investigation has taught us that the structural elements of organisms, the cells, have, as a rule, an individual soul-life. Since Schleiden, forty years ago, established the cell-theory as far as the plant kingdom is concerned, and Schwann, in like manner, extended it to the animal kingdom, we ascribe to these microscopic living beings an individual, independent life. They are the true "individuals of the first rank," or "elemental organisms" of Brücke. The magnificent and fruitful application of the cell-theory made by Virchow, in his cellular pathology, to the domain of theoretical medicine rests on the fact that the cells are no longer to be regarded as dead, passive, building-stones in the organism, but as its living, workful citizens.

This conception is ultimately based upon the study of the Infusoria, Amœbæ, and other unicellular organisms. For here, in the solitary, isolated cells, we meet with the same outcome of soul-life, sensation and consciousness, volition, motion, as in the higher animals composed of many cells. But in these latter cell-societies, as in those former solitaries, the soul-life is linked on to, is bound up in, one and the same cell-substance of first importance, protoplasm. In the Monera and other very simple organisms, we see that single, detached particles of protoplasm have sensation and movement, as have complete cells. Further, we are compelled to conclude that the cell-soul,[19] the fundamental of empirical psychology, is in its turn complex, is, in short, the resultant of the psychic properties of the protoplasmic molecules that we name, in brief, plastidules. The soul of the plastidule[20] would, therefore, be the ultimate factor of the organic soul-life.

Has our modern theory of Evolution exhausted with this its psychological analysis ? By no means. The more recent organic chemistry, on the contrary, teaches us that it is the peculiar physical and chemical properties of one element—carbon—that, in complex union with other elements, condition the peculiar physiological properties of organic compounds, and especially of protoplasm. The Monera, consisting simply of protoplasm, bridge over the deep chasm between organic and inorganic nature. They show us how originally the simplest and most ancient organisms must have sprung from inorganic carbon compounds. If originally a definite number of carbon atoms united with a number of atoms of hydrogen, oxygen, nitrogen, sulphur, into a plastidule or protoplasmic molecule, we must regard the plastidular soul, *i.e.*, the sum of its life-functions, as the necessary product of the forces of those conjoined atoms. But the sum of the central atomic forces we may call, in the strict Monistic sense, an "atom-soul."[21] From the accidental collision and manifold combinations of the constant, unchanging atom-souls arise the manifold and highly variable plastidular souls, the molecular factors of organic life.

Related to this extremest psychological consequence of our Monistic theory of Evolution, is that old conception of the possession of a soul by all matter that finds varying expression in the philosophies of Democritus, Spinoza, Bruno, Leibnitz, Schopenhauer. For all soul-life admits, ultimately, of being reduced to the two elementary functions, sensation and movement, and to their reciprocal action in reflex movements. The simple sensations of pleasure and pain, the simple movements of attraction and repulsion, are the real elements out of which all soul-function is built up in its endless variety and complexity. The "loves and hates" of atoms, the attraction and repulsion of molecules, the movement and sensation of cells and of the organisms made up of cells, the thought and consciousness of man[22]—all are but different steps in the universal process of psychological evolution.

The unity of phænomena (or Monism) to which, therefore, the new theory of Evolution leads us, does away with the opposition hitherto existing between the two different dualistic systems of the universe. It avoids the one-sided policy of Materialism and of Spiritualism alike; it connects practical idealism with theoretical realism; it binds together physical and metaphysical science in one all-embracing, unified knowledge of things.

Whilst at the present time we see in the theory of Evolution a connecting bond between branches of knowledge the most diverse, this same theory is of first importance, not only for the purely theoretical, but also for the practical, applied disciplines. Neither practical medicine, an applied natural science, nor practical statecraft, jurisprudence, and theology, in so far as they are portions of applied philosophy, will be able to withdraw themselves from its influence. We are rather of conviction that in all these departments it will, as a rule, prove itself to be the most important instrument, both for advancing knowledge and for the better culture of man as a whole. For, as the most important means towards culture is the education of the young, the theory of Evolution must have the influence that is its due even in the school. Herein it is not to be on sufferance merely. It must receive its due proportion of attention—it will become our guide.

If, in conclusion, we are allowed in the fewest words possible to indicate the weightiest point in this relationship of Evolution to general knowledge, the great significance of the genetic method ought really to be dwelt on first. Teacher and learner, alike, will regard every subject of study with ever-growing interest and understanding, if they ask themselves these questions before all others. How has it arisen ? How has it evolved ? For in this question as to Evolution, the question as to the causes of facts is involved ; and it is always the knowledge of efficient causes, not the mere knowledge of the facts, that satisfies the constant desire in respect to causality that our reason has. The knowledge of general, simple primary causes for the most different, the most complex phænomena leads at once to simplification and to intensification of our knowledge. It is only by understanding of causes that our dead knowledge becomes living science. The true measure of our mental culture is not the quantity of our empirical knowledge, but the quality of our understanding as to causes.

How far the fundamentals of the general theory of Evolution have already made their way in our schools —in what order its chief branches, cosmogony, geology, the phylogeny of plants and of animals, anthropogeny, should be learned in the various classes—the determination of these points we must leave to the practical schoolmaster. But we believe that a great reform of study in this direction is inevitable, and that it will be followed by the happiest results. For example, how immeasurably will the important study of language gain in value when it is treated comparatively and genetically! How the interest in physical geography will grow when that branch of knowledge is linked on genetically with geology! What light and life will the systematic arrangement of organic species gain when once these are explained as the different branches of one common ancestral tree! And, above all, what a new understanding will be ours of our own organism when we no longer see it in the dim, magic mirror of mythology as the pretended image of an anthropomorphic creator, but behold it, in the clear daylight of phylogeny, as the most highly-developed form of the animal kingdom; as an organism that has gradually evolved in the course of many millions of years from the ancestral series of Vertebrata, and has far outstripped all its fellows in the struggle for existence.

When, therefore, the theory of Evolution, fertile, helpful, enters into all branches of study, it will awaken in teachers and scholars the consciousness of its unifying power. As a historical, natural science, it will pass as mediator, as reconciler, between the two opposed orders of thought that are to-day contending for mastery in the higher school-culture: on the one hand, the older classical, historical and philosophical learning; on the other, the newer, exact, mathematical and physical studies. We regard both kinds of study as alike necessary, alike indispensable. The mind of man will only reach its full, harmonious completion, when both are dealt with. But just as in earlier days classical lore was exclusively studied, so is it to-day only too frequently, with exact learning. The theory of Evolution leads both these excessive ideas back to the happy medium, whilst it acts as the connecting bond between exact and classical, physical and metaphysical science. It demonstrates everywhere the living stream of connected, unified, unbroken Evolution. Ever is it showing to the eager student new goals of science beyond those already gained, drawing "gently the striving heart nearer to the truth." The endless perspective of advancing improvement thus opened out before us by the theory of Evolution is withal the best protest against the fatal "ignorabimus," that we hear sounding on all sides of us to-day.[23] For none can say what "limits of natural knowledge" the mind of man shall transcend hereafter, in the widening scope of its astounding development.

By far the most important and weighty claim that practical philosophy makes upon the theory of Evolution would seem to be that it act as a new theory of conduct. Beyond a doubt, hereafter, as aforetime, the careful building up of the moral character, and of religious conviction, must remain as the highest aims of all education. Until the present hour the vast majority of men were firm in their conviction, that this most momentous end was possible only in relation to certain creeds of certain churches. But as these dogmas, especially in regard to the old creation myths, are directly contradicted by the facts of Evolution, it is the belief of many that by this last religion and morality are endangered.

We hold this fear as false. It arises from the perennial confusion between true, reasoning, natural religion, and the dogmatic, mythological religion of the churches. The comparative history of religion, an important branch of anthropology, teaches us to recognise the great variety of the external forms in which different peoples and different ages clothe, according to their individual characters and needs, their religious thought. It shows us that even the dogmatic teachings of the religions of the churches are linked together in one gradual, unbroken stream of Evolution. New churches and sects arise. Old ones pass away. Under the most favorable conditions, any particular order of thought holds its own but a poor two thousand years, a short, evanescent time in the succession of æons of geological time. Finally, the history of civilisation teaches us how little real morality is, in essence, connected with any particular form of ecclesiastical creed. Often hand in hand with the absolute lordship of an almighty church, go the grossest barbarity and lawlessness. Let us think only on the mediæval age! And on the other hand, we see men, who have cast themselves away from every belief of the churches attaining the loftiest heights of moral grandeur.

Dissevered from all church creeds, there lives in the breast of every man the germ of a true natural religion. It is indissolubly bound up with the noblest parts of man's being. Its highest commandment is love, the narrowing down of our natural egoism in favor of our fellows, for the good of that human brotherhood of which we are members. This natural law of morals is far older than all the religions of the churches. It has evolved out of the social instincts of animals.[24] Amongst animals lower than ourselves, we encounter the beginning of these instincts in very different classes, especially in mammals, birds and insects. Following the laws of association and of the division of labor, many persons, in these cases, band themselves together into the higher community of a state. The nature of that state is, of necessity, dependent upon the mutual interworking of its members, and on the sacrifices of egoism that each makes to the community as a whole. Consciousness of this necessity, the sense of duty, is none other than a social instinct. But instinct is in all cases a psychical habit, that, originally acquired by adaptation, has become hereditary in the course of generations, and at last appears to be "innate."

To convince ourselves as to the marvellous power of the sense of duty in the lower animals we have but to knock to pieces an ant-hill. Then we see at once in the midst of the catastrophe thousands of busy citizens not concerned with the salvation of their own dear lives, but with the protection of the community to which they belong. Brave warriors of the ant-state oppose themselves in forceful antagonism to our intrusive finger. The nurses of the young within rescue the so-called "ant-eggs," the beloved pupæ, upon whom the future of the state depends. Busy workers begin at once with indomitable courage the rebuilding of the wrecked home, the construction of new dwelling-places. But the marvellous civilisation of these ants, of the bees, and of other social animals, has originally evolved from the crudest of beginnings, even as has our own human civilisation.

Even those relationships of human life that our poets extol most highly are found foreshadowed even among the kingdoms of the lower animals. Have not the deep maternal love of the lioness, the touching love of the mate in the Java sparrows (the inseparables), the devotion and faith of the dog, become this long time proverbial? In these, as in man, the noblest affections of sympathy and of love that determine conduct are no other than bettered instincts. In consonance with this idea the ethics of Evolution have to seek out no new fundamentals. They have rather to lead the ancient, primary sense of duty to its natural and scientific basis. Long ere the origin of all church religions this natural sense of duty, of responsibility, ruled the law-abiding life of men, as of the lower social animals. And this immense fact the ecclesiastical religions will do well to utilise, in place of contending against it. For the future belongs not to that theology which wages a hopeless war against the victorious truth of Evolution, but to that which grasps, understands, and makes use of that truth.

Far from fearing as result of the influence of Evolution on our religious convictions, a destruction of all moral laws, and the terrible license of unbridled egoism, we hope rather, as consequence of Evolution, for a rational foundation of morals on the unimpregnable basis of fixed natural laws. For with the true understanding of our true place in nature, Anthropogeny opens up to us at the same time a glance into the necessities of our primary social responsibilities. Practical philosophy and pædagogy, like general theoretical knowledge, will henceforward derive its most important fundamentals, not from pretended revelations, but from the natural truths of Evolution. This conquest of dualism at the hands of Monism reveals to us a future full of hope, in which shall be an endless advance of our moral and of our intellectual development. In this sense we hail the modern truth of Evolution founded in these later days by Charles Darwin, as that which more than all others has carried forward all our knowledge, pure and applied.

NOTES.

(1) Page 278.—Charles Darwin in his chief work ("The Origin of Species through Natural Selection," 1859) has already stated and explained all the chief points in his own theory of Evolution, save in its application to man. This latter was first dealt with in 1871 in the work on "The Descent of Man and Sexual Selection." His other writings only contain further extensions and more definite and detailed proofs of the fundamental propositions laid down in those two main works.

(2) Page 278.—On the relation of Immanuel Kant to the theory of Evolution, see Fritz Schulze: "Kant and Darwin, a Contribution to the History of the Evolution Theory" (1875). On the bearing of the writings of Wolfgang Goethe upon Evolution generally, see my "Natürliche Schöpfungs-geschichte" (6th edition, p. 73).

(3) Page 278.—The zoological philosophy of Lamarck (published in 1809, and very soon translated into German by Arnold Lang) is the only work before Darwin's time (he was born in 1809) that attempted to deal with the domain of biological development in relation to and on the principles of mechanical phænomena; a very grand if premature attempt.

(4) Page 278.—Lorenz Oken's services to Evolution are generally so inaccurately gauged that most stress is laid on the phantastic excrescences of his writings on natural philosophy. On the contrary we ought to remember that he not only laid down the fundamental principle of the unity of development of the universe, but even anticipated the principles of the cell and protoplasm theories, and that he was the first in our century to undertake observations in embryology (Researches on the formation of the alimentary canal, 1806). See "Naturl. Schopf.," 6th edition, p. 86.

(5) Page 279.—It is amongst the most remarkable phænomena in the history of science that the supernatural theory of catastrophes laid down by Cuvier actually held its own until the last thirty years in biology, when that science was advancing so rapidly. And this, despite the fact that the antagonistic theory of uniformity had been stated by Lamarck as early as 1809, and had, since 1830, been shown by Lyell to be fully confirmed by geology. "Naturl. Schopf.," 6th edition, pp. 111, 115.

(6) Page 279.—When, fourteen years ago, at the thirty-eighth meeting of scientific men at Stetting, Sept. 12, 1863, I gave a lecture on the "Darwinian Theory" (see p. 3), and in doing thus gave open expression to his teaching for the first time in such an assembly, the recognition of that teaching was decisively refused by the great majority of my hearers. To-day such recognition is given willingly enough by all competent naturalists. See my preface to the fourth edition of "Naturl. Schöpf."

(7) Page 280.—Chorology, the study of the geographical and topographical distribution of organisms, and œcology, the study of the household, of the habits of life of organisms and their relations one to another, are physiological disciplines. They do not prove so directly as morphological studies the truth of the theory of descent. But their general phænomena can only be explained by the aid of that theory. See lecture xiv., "Naturl. Schopf."

(8) Page 280.—Dysteleology, or the study of the undesigned, is the name given to the study of the rudimentary organs, in that these organs in simpler and in clearer manner than all other phænomena, contradict that widely-spread teleology, or the study of design, that holds such sway in dualistic philosophy. "Gen. Morph.," vol. ii., p. 266.

(9) Page 280.—Crystallography and the promorphology of organisms may, *e.g.*, be called exact morphology. For both seek to refer the actual forms of bodies (in the one case the crystals, in the other the organic individuals), to ideal geometrical fundamental forms. But by far the greater part of morphology, and also a large part of physiology (*e.g.* chorology, œcology, psychology) are in large measure incapable of mathematical treatment, and are, therefore, not exact.

(10) Page 282.—The fundamental biogenetic law runs more accurately as follows: The development of the embryo (ontogeny) is a condensed and abbreviated repetition of the evolution of the race (phylogeny). This repetition is the more complete, the more the true original order of evolution (palingenesis) has been retained by continual heredity. On the other hand this repetition is the less complete, the more by varying adaptations the later spurious development (cenogenesis) has obtained. "Anthrop." 3rd. edition, p. 11.

(11) Page 282.—The cenogenetic disturbances that are brought about in the succession of palingenetic development by adaptation of embryos to the conditions of embryonal life, are in great part alterations of relations of place and of time in development (heterotopia, heterochronia), are in part new embryonic structures (*e.g.*, the formation of the egg shell, the amnion, etc.).

(12) Page 282.—The historical character of the morphological sciences (especially of comparative anatomy and ontogeny, as of palæontology), cannot be dwelt upon too much. To aim at the exact description of empirical facts, is here as natural as it is in history itself. But these sciences themselves can never be exact.

(13) Page 283.—Geology and phylogeny not only pursue kindred aims. They use the same methods. In both disciplines, the end is by thoughtful comparison of many separate facts, by critical examination into their historical meaning, by speculative filling up of the gaps left after all observation, to build up a connected account of the history of Evolution in the one case of the earth, in the other of its inhabitants. "Anthrop." 3rd edition, pp. 329, 382.

(14) Page 283.—The biological disciplines are to-day called officially (*e.g.*, in the Prussian examination regulations), descriptive sciences as opposed to physics and chemistry. This designation contains a *contradictio in abjecto*. For a true science can never be merely descriptive. Besides, in botany as in physics and chemistry, in morphology as in physiology, the empirical description of facts is only the beginning, their causal explanation is the philosophic end of science.

(15) Page 284.—The origin of man from other mammals, and most directly from the catarrhine apes, is a deductive law, that follows necessarily from the inductive law of the theory of descent. "Anthrop." 3rd edition, p. 392.

(16) Page 284.—August Schleicher on "The Darwinian Theory and the Science of Language," 1863.

(17) Page 285.—The ancestral series of man, which the xvi.—xix. lectures of my "Anthropogenie" sketch, is not less or more scientifically certain than all other phylogenetic and geological hypotheses, even if the different stages are not of equal certainty. When Du Bois-Reymond (Darwin versus Galiani), 1876, sneers that "ancestral trees of our race, sketched in the 'Schopfungs-geschichte,' are of about as much value as are the pedigrees of the Homeric heroes in the eyes of the historical critic," he but shows his astonishing ignorance of the morphological investigations on which these trees are based. If he calls phylogeny "a romance" he must give the same name to geology.

(18) Page 285.—For a knowledge of the vertebrate ancestors of man, the "Researches in the comparative anatomy of the Vertebrata" of Carl Gegenbauer, a work as thorough as it is critical, is of great value. See also his "Elements of Comparative anatomy."

(19) Page 286.—The cell-soul in the Monistic sense, is the totality of the responsive forces resident in the protoplasm.

The cell-soul is as indissolubly bound up with the protoplasmic body as is the human soul with the brain and spiral cord.

(20) Page 286. Plastidule-souls. The plastidules or protoplasmic molecules, the smallest, homogeneous parts of the protoplasm are, on our plastid theory, to be regarded as the active factors of all life-functions. The plastidular soul differs from the inorganic molecular soul in that it possesses memory. See my plastid-theory in the "Studies on Monera and other Protista," (1872), and also the previous lecture on the Perigenesis of the plastidule, or the wave-motion of living particles.

(21) Page 287.—Atom-souls. The recent contest as to the nature of atoms, which we must regard as in some form or other the ultimate factors in all physical and chemical processes, seems to be capable of easiest settlement by the conception that these very minute masses possess, as centres of force, a persistent soul, that every atom has sensation and the power of movement. See also Gustav Tschermark's "Unity of Development in Nature," Vienna, 1876. Zöllner on the "Nature of Comets," Leipsic, 1872.

(22) Page 287.—Consciousness, since the lecture of E. Du Bois-Reymond, in 1872, to the 45th meeting of German naturalists at Leipsic, has been very generally held as an impassable limit of natural knowledge and as, therefore, a second boundary altogether different in its nature from the first, or the connexion between matter and force. But beyond a doubt these two ideas are one and the same, although Du Bois-Reymond sneers that "we cannot, on this point, come to any decision, and must abandon all further inquiry thereon" (l. c. p. 33). Little as we are in a position, at the present time, to explain fully the nature of consciousness, yet the comparative and genetic observation of it clearly shows, that it is only a higher and more complex function of the nerve-cells.

(23) Page 290.—The "ignorabimus," which E. Du Bois-Reymond, in the lecture just cited (note 22), places in the way of the advance of our knowledge, is now on every opportunity quoted by the foes of Evolution as *testimonium paupertatis* of natural science. We, therefore, in this place, as already in the preface to these lectures, directly protest against it. For the study of the evolution of soul-life shows us that this has worked its way up from the lower stages of the simple cell-soul, through an astonishing series of gradual stages in evolution, up to the soul of man. No one, therefore, has the right to hold that in the future we shall not be able to pass beyond these limits of our knowledge that to-day seem impassable. Darwin, in the introduction to his "Descent of Man," says: "It is always those who know little, and not those who

know much, that positively affirm that this or that problem will never be solved by science."

(24) Page 291.—The social instincts of the lower animals have, of late, been regarded for various reasons as clearly the origin of morals, even of those of man. The laws of association and division of labor, in the one case as in the other, bring about the mutual inter-working of individuals in combination. This leads to the sense of duty, to responsibility. Therefore the history of civilisation in animals, a field of zoology as yet almost unworked, will have as its aim the tracing back of the civilisations of the ants, the bees, and other animals that live in communities to the lower, cruder historical conditions, just as in the history of the civilisation of man.

X.—THE ORIGIN AND THE DEVELOPMENT OF THE SENSE-ORGANS.

THE ORIGIN AND THE DEVELOPMENT OF THE SENSE-ORGANS.

THE knowledge of historical development is at the present time rightly regarded as the surest way to the true understanding of organic bodies. Especially is that knowledge of importance in regard to those organs, that through all their complex structure seem to be fashioned upon a determinate common plan. Nowhere does such a systematic, definite arrangement meet us so plainly as in our sense-organs. The exquisite structure of our eye, the marvellous labyrinth of our ear, have no equals in other organised bodies. Hence they have always been the especial favorites of anatomical and physiological investigation. Moreover this preference is intensified by the incomparable significance of these, the most important instruments of the mind. For the sense-organs are the sole sources of all knowledge, the only doors through which the external world makes entry into our inner mental life. Hence speculative philosophy has ever taken a special interest in this part of biology, for in this realm it comes into the most active relationship with empirical investigation.

Whilst at the present time the theory of Evolution, based on the firm foundations laid by Darwin, makes claim to explain the origin and formation of the sense-organs in the same way as it explains those of other organs, by the slow, gradual process of Evolution resulting from Natural Selection, it must be admitted that it is encompassed at the outset with the greatest difficulties. To conquer these nothing is of greater value than a brief glance at the history of the individual germ. For if we see that in any individual animal body these organs do not at first exist, but are developed slowly and gradually, then this important fact in the history of the germ is of use in giving us the key to the solution of the far more difficult, far more obscure question as to the evolution of these organs in the past.

To convince ourselves of this momentous truth, we need but place a hen's egg in a hatching machine, and follow out step by step in the brief space of three weeks the building up of a simple germ into the perfect bird. Thus we can settle by direct observation that eye, ear, even the lower sense-organs of smell and taste, are not present at the commencement of the development of the germ. They make their first appearance later on, and from a commencement undifferentiated, and of the greatest simplicity, pass gradually through a series of very wonderful changes to their later structure and form. Fifty years ago this fundamental fact was established by C. E. von Baer, the great embryologist, who raised the account of the incubated hen's egg to the position of one of our most important sources of knowledge. Next the able biologist, Emil Huschke, of Jena, a few years later (1830) worked out more fully, with extensive care, the wondrous details of these great changes. Many observers, startled by his brilliant discoveries, have more recently worked these out with a completeness that is astonishing. Finally, the general conclusion has been reached, that in man and in all other animals the sense-organs as a whole arise in essentially the same way, viz., as parts of the external integument or epidermis. The external integument is the original, general sense-organ. Gradually the higher sense-organs detach themselves from this their primal condition, whilst they withdraw more or less completely into the protecting interior of the body. Nevertheless in many animals, even at the present hour, they lie in the integument, as *e.g.* in the Vermes (Fig. 50).

But the activity of the sense-organs, as of all others, depends entirely upon that of the microscopic cells composing them. These small cells are, in fact, the true, independent "elemental organisms," whose functions in their continued totality condition the life of the whole multicellular organism. Hence the sense-organs, the sense-cells that give rise to the various sensory consciousnesses, are of greatest moment: the visual cells of the eye, the auditory of the ear, the olfactory of the nose, the gustatory of the tongue. If, then, as we now know, all the various sense-organs are actually only particular parts of the integument spe-

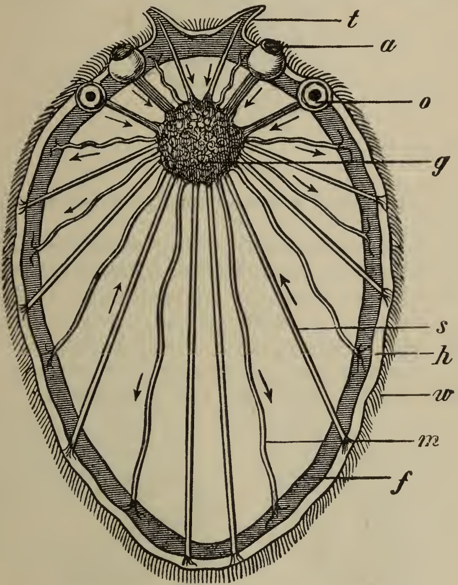

Fig. 50.

Nervous system and sense organs of the Turbellaria. Two kinds of nerves radiate from the simple nerve-ganglion or brain (*g*): the centripetal sensory nerves (*s*) pass to the skin (*h*), tentacles (*t*), auditory vesicles (*o*), eyes (*a*); the centrifugal motor-nerves (*m*) go to the flesh, the sub-muscular epidermal layer (*f*); *w* cilia of the epidermis.

cialised and modified, all the various sense-cells must have originally arisen from single epidermal cells. They are, in fact, as a whole transformed descendants, specialised in different ways, of the epidermal cells that are for the most part undifferentiated (Fig. 51).

This fundamental fact, whose significance cannot be valued too highly, is now established beyond a doubt. Every one who studies the incubated egg by the aid of

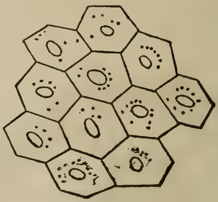

Fig. 51.

Epidermal cells of a human embryo of two months.

a good microscope, and the perfected methods of investigation now known, can convince himself that all sense-organs take origin from the integument. If we study, *e.g.*, the embryo of a chick on the third or fourth day of incubation (Figs. 52—56) we find that the earliest appearance of the nose (*n*), the eye (*l*, *sp*), the ear (*o*), is a simple depression of the integument. But this

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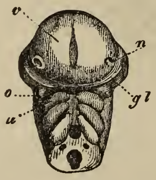

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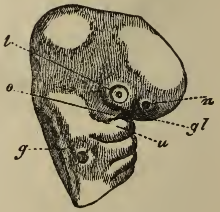


Fig. 52. Fig. 53.

Head of a chick-embryo (third day of incubation). 1. Anterior view. 2. From the right hand side. *n*. Rudimentary nose (olfactory depression). *l*. Rudimentary eye (ocular depression). *g*. Rudimentary ear (auditory depression). *v*. Fore-brain. *gl*. Eye-cleft. *o*. Superior maxillary process. *u*. Inferior maxillary process of the first gill-arch.

holds in regard to all the sense-organs of all other animals, and even of man. By this pregnant fact not only is the question as to the origin of the sense-organs greatly simplified. The key to the true understanding of them is also given. For by a fundamental biolo-

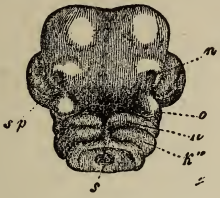
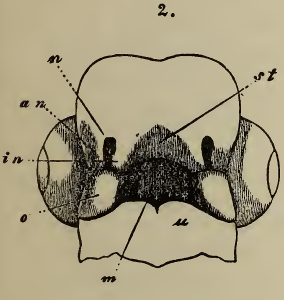


Fig. 54.

Head of a chick-embryo (fourth day), from below. *n*. Nasal groove. *o*. Superior maxillary process of the first gill-arch. *u*. Inferior maxillary process of the same. *k*. Second gill-arch. *sp*. Choroidal cleft of the eye. *s*. Œsophagus.



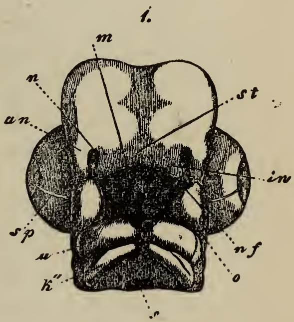


Fig. 55. Fig. 56.

Two heads of embryonic chicks. 1, at the end of the fourth; 2, at the beginning of the fifth day. Letters as in Fig. 54, and in addition *in* internal, *an* external nasal process. *nf*. Nasal furrow. *st*. Frontal process. *m*. Oral aperture.

gical law, the general law of organic evolution, every embryological fact is in direct, causal relation to a corresponding genealogical event that took place long previously, thousands, perhaps millions, of years ago, in the history of the ancestral series of the particular organism.

Originally such a change occurred in the ancestral history by adaptation of earlier forms. Then by heredity it was transmitted from these with greater or less completeness down the long line of descendants. If we see in the early stages of the chick in the incubated egg that the higher sense-organs are at first wanting, and that the first trace of them appears in the epidermis, we conclude that the earlier ancestors of the bird were lower animals, destitute of either eyes or ears, and that later on special regions of the epidermis in their descendants learned for the first time to distinguish light-waves and sound-waves. And if further we see that the delicate organs for the perception of the finer colors and sounds, the rods in the retina of the eye, the fibres of Corti in the cochlea of the ear, appear much later in the embryo of the bird, after the other parts of the eye and ear have been formed, we conclude that these most delicate and most perfect sense-instruments were acquired at a much later period in the earth's history by some more recent ancestor of the birds.

It must be remembered that this important conclusion as to the relationship between the observed history of the individual embryo and the hypothetical history of its forefathers is not applicable universally and without limitation. Everything that happens in the embryo does not allow of an explanation in relation to ancestral evolution. But where this is not admissible, when important gaps and breaks interrupt the chain of historical development, another science comes to our aid, that of comparative anatomy. This fascinating science compares the structure of the completed organs in the various classes and orders of animals. It proves that those organs are to be found side by side in the different animal groups in most varying stages of development. It gives a very instructive glance at the long series of historical evolution by which these organs have gradually, one after another, worked upwards from the simplest commencement to the highest complexity. Thus comparative anatomy, in quite another fashion than embryology, shows us that the wondrously complex structure of our human eye and ear is connected by a long, long series of intermediate forms, with the simpler and with the simplest organs of sight and hearing in the lower animals. Whilst the general arrangement of these organs is essentially the same in the higher Vertebrata, the Mammalia, Aves, Reptilia, as in man, we encounter simpler conditions in the Amphibia, and yet simpler in Pisces. But if we compare with these last the corresponding sensory structures in the lower animals, especially in Vermes, we are convinced that even the imperfect eyes and ears of Pisces are the later product of a long series of improvements and advancing perfection, through which these physical instruments have passed during many millions of years in the invertebrate ancestors of the fishes.

If, now, aided by these very important evidences as to descent, on the one hand by comparative anatomy, on the other by embryology, we try to make out the historical evolution of the sense-organs in man and in other animals we must first call to mind certain difficulties and certain precautionary measures, that must ever be kept in view in these difficult historic questions. For example, we can only decide as to the sensory impressions of other beings by the impressions that we ourselves receive through our own sense-organs. Hence we can have no conception of sense-functions that we cannot ourselves exercise. As the man born blind can have no idea of the nature of colors, as the man born deaf and dumb can have none of the nature of sounds, man can have no idea at all of these sense-functions in other animals that are wanting in man himself.

Five different sense-organs are generally distinguished in man. Of these the lowest is the integument, performing two different sensory functions, as the organ of touch and the organ for the perception of temperature. The tongue and the nose, as organs of taste and of smell, rise to an intermediate position, whilst ear and eye, the æsthetic organs of hearing and of sight, reach the highest condition of perfection. But comparative anatomy and physiology teach us, that with these six different kinds of human sense-functions the range of the sensations in the animal kingdom is by no means exhausted. On the other hand, we know in various animal classes organs of complex structure, with peculiar terminal organs of a nervous nature, that seem undoubtedly sense-organs, but do not seem to belong to any of the senses known to us. Such organs of a sixth or seventh sense, not known to us, are *e.g.*, the cup-shaped nerve-organs in the skin of many Vermes, the gelatinous tubes and mucous canals with peculiar nervous enlargements and cups in the skin of fishes (Fig. 57). It may be that such organs make pos-

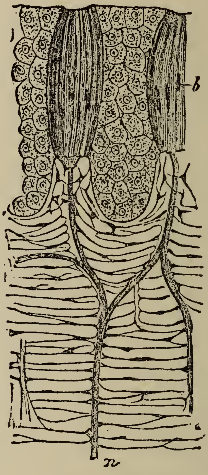


FIG. 57.

Two cup-shaped sense-organs (*b*) of unknown value in the skin of the tench (Tinca). *n*. Sensory nerves in the cuticle running into the longitudinally striated sensory cells of the cup (*b*). Between the latter are ordinary rounded epidermal cells.

sible to these water-dwellers the perception of certain conditions of the water of which we know nothing.

In other cases we ascribe the strange actions of certain animals, that do not appear due to senses known to us, to the presence of sense-organs of which we are ignorant. Were we to repeat Spallanzani's cruel experiment, and let bats whose eyes and noses were destroyed, whose ears were stopped with wadding, fly about a room across which many strings were stretched, the mutilated animals, despite their injuries, would fly dextrously in and out among the cords without touching them. In this case either there must be a special unknown sense-organ at work, or the sense of touch or of temperature is so exalted quantitatively, that it would seem to be a specialised and peculiar sense qualitatively. Further, the sense of locality in migratory birds and carrier-pigeons, as well as many so-called "enigmatical instincts" in the lower animals are most easily explicable on the supposition of a special sense-organ. There are, in all probability, many unknown qualities of natural bodies, of which we have absolutely no idea, inasmuch as the organs for perceiving them are wanting in us. The limits of our knowledge are bounded by those of our sensory perceptions.

In inquiries such as these, we must always bear in mind the fundamental fact that we do not perceive by our sensations the veritable properties of natural objects. All of which we are cognisant is only the occasional conditions of our sense-organs stimulated in special way by pressure, temperature, sound-waves, light-waves, etc. But the sensory nerve whose expansion in the sense-organ receives the stimulus from without, and transmits this stimulus to the central organ or brain, is in each separate sense-organ capable of only one special kind of perception. The optic nerve perceives light-waves alone, the auditory, sound-waves. In like manner the olfactory nerve deals only with olfactory sensations, the gustatory only with those of taste. The optic nerve can never perceive sounds, nor the auditory nerve colors. The skin cannot read a letter, nor the tongue listen to a symphony as the spiritualists, mesmerists and other rogues have asserted. On these facts the great biologist, Johannes Müller, based his celebrated theory of the peculiar functioning of individual sensory nerves, of their specific energy.

Full of meaning as is this theory of the specific energy of the sense-nerves, it is subject to an important limitation at the hands of our modern theory of development. For in view of the embryological truth, that all the different sense-organs have their specific nerves developed from the integument, it must be admitted that the specific functions of the individual nerves of sense were not a primary quality of these latter, but have arisen as result of adaptation. Optic and auditory nerves, no less than olfactory and gustatory, were originally simple epidermal nerves, as they are to-day in the lower animals, and in the youngest embryos of the higher. At first all nerves of perception could only perceive simple changes of pressure and of temperature. Then, by degrees, some of them learned to understand those influences that were brought to bear upon them by sapid and odorous bodies. Others entered upon a higher path, and passed on towards the recognition of sound-waves and light-waves. All the different sense-nerves have arisen originally by specialisation from simple epidermal nerves; and in like fashion we must regard all the different sense-organs, which are essentially nothing else than collections of expanded nerve-ends, as local specialisations or differentiations of one universal sense-organ, the integument. The simple tactile sensibility of this integument, its power of perceiving changes of pressure and of temperature, forms the starting-point for the specific energies of the higher nerves of sense. These last have evolved gradually, in the course of time, from the general sensibility of the outer layer of the body.

This idea, as to the descent of the higher sense-organs and functions, receives an important extension if we descend among the lower animals still further, to those lowest organised forms that are sometimes named primitive animals, Infusoria, Protozoa, and are sometimes placed, as a special neutral kingdom called Protista, between the plants and animals.

Among these remarkable Protista—of whom we shall only mention in this connexion the active Ciliata and Flagellata, the Rhizopoda, manifold in form, the important Amœbæ—we encounter sensory perception in various stages of development. The majority are sensitive, not only to variations of pressure and of temperature, but of light also. If a glass of water, in which many of these Protista are, is placed in the window, so that part of the vessel is in the light, part in the dark, most of the species present gather themselves together on the exposed side, but some are turned round towards the dark side. Already among these microscopic Protista are there some that love light, and some that love darkness rather than light. Many seem also to have smell and taste, as they select their food with great care.

Although such various kinds and degrees of sensory perception are easily and distinctly proved amongst these small creatures, none the less special sense-organs are wholly wanting—nay, nerves even are altogether absent in them. Here also we are met by the weighty fact, that sense-function is possible without sense-organ, without nerves. In place of these, sensitiveness is resident in that wondrous, structureless, albuminoid substance which, under the name of protoplasm or organic formative matter, is known as the general and essential basis of all life phænomena.

In most of these low forms of animals the whole body has throughout its life only the structure of a single, simple cell. It consists only of protoplasm enclosing a nucleus. Either the whole structureless mass of protoplasm, or the most superficial layer of the protoplasm, a layer often clearly marked off from the rest, performs in these unicellular Protista the functions of sensation, and takes the place of the sense-organs that are wanting. Already in many the separation of such sense-organs has begun, when the protoplasm gives off from its surface fine threads, setæ or cilia. These are naturally exposed in an especial degree to the changes of impression that occur in the surrounding water, and are therefore better adapted for sensation than the rest of the surface of the unicellular body (Fig. 58).

Whilst in these low animals or Protozoa, the simple cell can perform simultaneously all the life-functions, sensation, motion, digestion, reproduction, we find on the other hand that in all true animals (in all Metazoa) the body is of many cells, and its different functions are shared among several cell-groups. But in these beings also in every case the whole animal body consists at the beginning of its individual existence of a single cell only, the ovum. In many of the lower plant-like animals, *e.g.* the sponges, the ovum moves about independently, creeping like an Amœba, within

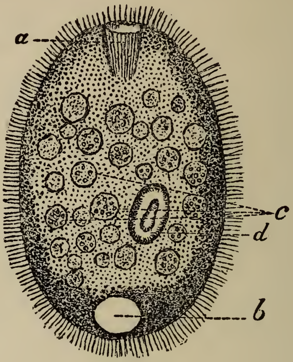


Fig. 58.

A unicellular Infusorium of the order Ciliata (Prorodon). *a.* Oral aperture of the cell with funnel-shaped œsophagus. *b.* Contractile vesicle. *c.* Food-vacuoles in the sarcode. *d.* Nucleus. The whole surface of the cell is studded with fine hairs or cilia, that serve at once for sensation and for spontaneous movement.

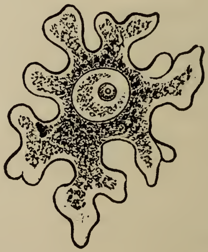


Fig. 59.

Ovum of a calcareous Sponge (Olynthus), that moves and feels like an Amœba.

the body of the parent, and shows at that time evident power of sensation, contracting under contact or irritation (Fig. 59).

But the original unicellular condition of the animal body after fertilisation of the ovum passes into a multicellular. At the very beginning of embryonic development, the ovum, by repeated division, breaks up into many cells. The globular cell-mass thus formed is transformed into a hollow sphere, whose wall consists of a single cellular layer, and by invagination this hollow sphere gives rise to that remarkable embryonic form that we denote by the name of Gastrula (Fig. 60).

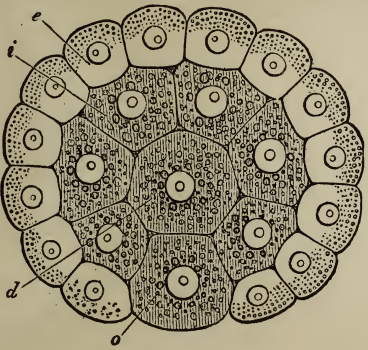


Fig. 60.

Gastrula of a mammal (rabbit). The whole body (shown in vertical section) consists of 96 cells, *i.e.*, 64 clearer, smaller cells of the epidermis (*e*), and 32 darker, larger cells of the mucous layer (*i*). The latter block up the gastric cavity (*d*) and oral opening (*o*) of the Gastrula.

In all true animals or Metazoa, in the course of the advancing development of the individual, appears an embryonic form that can be referred to such a Gastrula condition. This is, however, always wanting in the Protozoa.

The cup-shaped, ovoid Gastrula (Fig. 61) contains a simple, hollow cavity, the digestive or gastric (*g*), and this opens by a mouth that serves for the ingestion of food (*o*). The wall of this cavity is composed of two different cellular layers, the so-called primitive layers of the blastoderm. The inner, mucous layer, or endoderm (*i*) effects the nutrition and assimilation of the body, and from it are formed the organs of digestion. The outer serous layer or ectoderm, on the other hand, (*e*) is of special interest to us at present. For the sensory cells that compose it, have to do with the knowledge of the external world, and as the integument of the Gastrula represent a sense-organ in its simplest form.

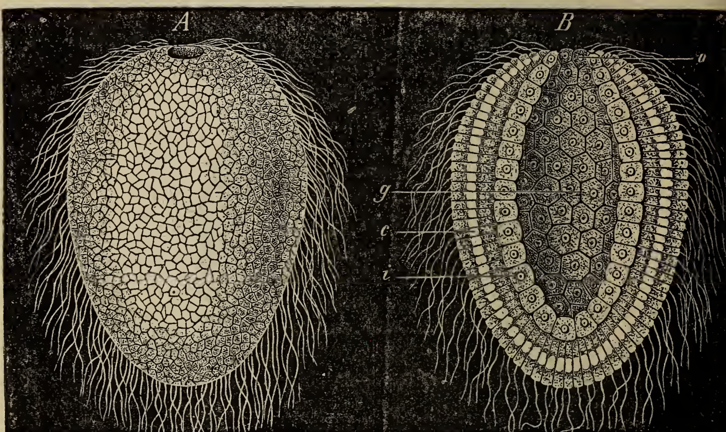


Fig. 61.

Gastrula of a calcareous sponge (Olynthus). A, seen from without. B, in longitudinal section. *e*. External embryonic layer (epidermal layer or ectoderm). *i*. Inner layer (mucous layer or endoderm). *g*. Primitive alimentary canal or gastric cavity. *o*. Oral aperture.

In all the Metazoa, not only do the cells that later on make up the skin, develop from this external layer, but the cells that form the nervous system and the rest of the sense-organs, have the same origin. Nerve-cells and sense-cells are alike, therefore, primarily derivatives of epidermal cells, and Remak was perfectly accurate when, thirty years ago, he spoke of the integumental covering of the embryo with its double wall as a sensory layer.

Whilst most of the lower animals pass very rapidly through the Gastrula-stage in their development; there are, at the present time, some lower animals that structurally are but little above this stage. Such permanent Gastrula-forms are met with in the Gastrœada (Physemaria), the lowest sponges and the hydraform polyps. Amongst the last, the common fresh-water polyp or Hydra is of special interest. For although this little cup-shaped animal is very sensitive to touch and irritation, to warmth and light, distinct sense-organs are as wanting in it as a nervous system. Individual cells of the ectoderm attend to these functions. Already, however, differences in sensitiveness of different ectodermal cells are evident. The delicate, tactile sensibility is especially localised in a circle of fine tentacles, surrounding the mouth and serving, at the same time, as prehensile organs for the seizing of the food.

Such feelers, or tentacles, are met with generally in the lower animals, very widely distributed, in great variety, and often in great numbers. In many invertebrate groups that are without eyes and ears, but are, nevertheless, sensitive to light and sound-waves, the epidermal cells of the tentacles seem to take the place of eyes and ears. Such are, *e.g.*, the corals, Polyzoa, many Vermes. Very frequently, delicate, hair-like or bristle-like processes are seen on particular cells of the epidermis of the tentacles, and these hair-carrying cells that are often developed in other regions of the body we must clearly regard as having a special claim to the title of sense-organs. For not only are there among the lower aquatic animals cells of this kind, whose protoplasm is extended into a delicate process, outstretched into the water and specially fitted to perceive alterations of pressure and changes of temperature, but these cells and processes appear well fitted to perceive distinct and regularly recurring oscillations of the water as sounds. It is, therefore, very probable that the widely distributed hair-carrying sensory cells, which we see in the epidermis of lower animals, have generally to do not only with sensations of touch and of temperature but with sound perceptions, that they are already incipient ears. And this idea is the more probable as the senses of touch and of hearing are generally very nearly allied, and as the first stages of development of true auditory organs are formed of like hair-carrying epidermal cells.

The great difficulty, that we meet at the outset, of distinguishing simple tactile organs from the earliest stages of veritable auditory organs, is of deep interest. For in this very fact is evident the close relationship of the various sensations, and hence we can understand how the different senses could have been evolved from the lower, general power of feeling resident in the integument. A like difficulty meets us in the comparative study of the other senses, and the same explanation tells in these cases also.

For example, in regard to the two chemical sense-organs of taste and smell, we are not in the position to make definite statements as to their characteristic nature, as to the line of demarcation between them and organs of touch.

We find, for example, on the proboscis of the fly, (Fig. 62) and on other parts of the mouth of insects, delicate sensory rods (*s*) projecting from the integument. These rods or setæ are in connexion with sensory cells (*g*) into which run branches of the sensory nerve (*n*). But we are unable to say with certainty whether these sensory rods are subservient to touch, taste, or smell, or whether, it may be, they have to do with blended sense-impressions. For taste and smell are very nearly allied to the simple touch, and only differ in essence from the latter in that the chemical influence of various bodies, perceived by the sense-cells of the particular organs in different manners, is translated into gustatory and odorous impressions. In the organ of taste the chemical changes are brought about by liquid substances that have been dissolved in water, in the organ of smell by gaseous matters, of infinite minuteness, borne by the air. At all events this is the case in the air-breathing Vertebrata, and we are accurately informed on this head in regard to these animals alone. It is, therefore, further, very doubtful if many organs that we look upon when they are met with in the lower aquatic animals, as the simplest organs of smell are not, in truth, rather organs of taste. It is as impossible to draw a sharp line of demarcation between taste and smell as between these two chemical senses and touch.

Hence the views of zoologists on the distribution of the two chemical senses in the lower animals differ very widely. Many hold that taste and smell are very

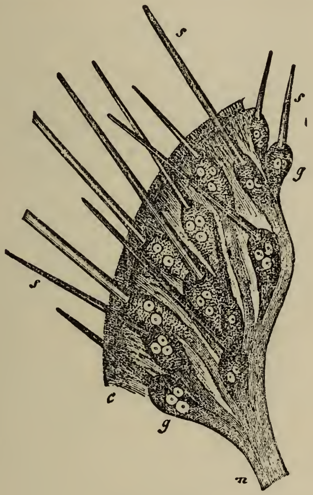


Fig. 62.

A small fragment of integument from the proboscis of a fly (Musca): vertical section. A sensory nerve (*n*) runs to the sensitive epidermis, whose cuticle is studded with fine hairs (*c*). The branches of the nerves run into groups of sensory cells (*g*) that end in projecting sensory rods (*s*).

general and only rarely are wanting. Others think they are absent in the majority of the lower animals. This much is certain, that a great number of lower animals choose their food with as much care as a gourmand; as to insects, we know that some of them have an extraordinarily delicate sense of smell, and scent out odorous bodies at great distances. Yet special organs for the perception of sapid and odorous substances are generally unknown with any approach to certainty. Wherever we do recognise these definitely they are only different parts of the integument whose cells have become adapted to chemical sense-perceptions : cup-shaped cells for taste, rod-like ones for smell. Frequently special depressions are seen in the neighborhood of the mouth, wherein such gustatory and olfactory cells are placed.

Even in the higher Vertebrata and in Man, in whom the organs of taste lie in the cavity of the mouth, the organs of smell in the cavity of the nose, the gustatory and olfactory cells are derivatives of the epidermal cells. The oral cavity, with the tongue and the palate, does not take origin along with the rest of the alimentary tract, but is derived from the epidermis, in

FIG. 63.

Gustatory cells from the tongue of a rabbit. *a*. Four separate cells connected inferiorly with very delicate terminal branches of the gustatory nerves. *b*. Two gustatory cells connected with an epithelial cell.

the same way as the nasal cavity. Both originate from involutions of the integument. The gustatory cells of the tongue, the olfactory cells of the nose, arise also actually from the cells of the external, not from those of the internal, layer of the blastoderm.

The gustatory or taste-cells (Fig. 63) are in man, as they are in other Mammalia, delicate, rod-like, or acicular cells, connected with the terminal fibres of the gustatory nerve, and invested by the broader epithelial cells (*b*) as a protective covering. They form numerous cup-shaped gustatory corpuscles (Fig. 64) or taste-bulbs scattered upon the surface of the tongue. In the centre of each corpuscle lies a bundle of gustatory cells, surrounded by investing epithelial cells. When food placed on the tongue comes into contact with the gustatory corpuscle, the sensation of taste results through the agency of the gustatory cells.

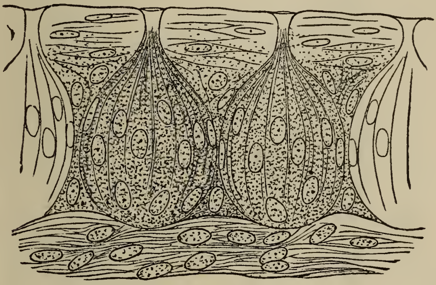
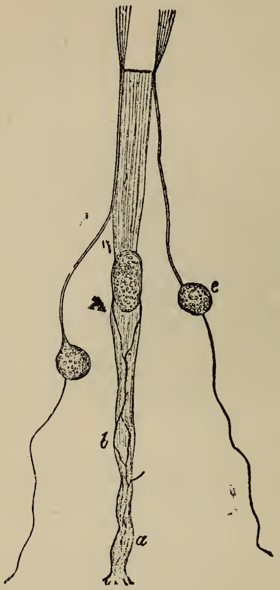


FIG. 64.

B. Four tactile corpuscles from the tongue of a rabbit. Only the two middle ones are complete. Vertical section through the surface of the tongue.

The olfactory cells in the mucous membrane of the nose are very like the gustatory cells of the tongue. They also are very delicate slender cells placed vertically in the epithelial surface, having their inner ends in direct connexion with very fine terminal fibrils of the olfactory nerve (Figs. 65, 66). As a rule, in the nasal mucous membrane of Vertebrata two kinds of olfactory cells are distinguishable, that in all probability have different offices in respect to the perception of odors. The more slender ones, often filiform acicular cells, are markedly swollen in the middle, where the nucleus lies (Fig. 65 *e*), and carry in the Amphibia a tuft of exceedingly fine and thin olfactory cilia at their free ends. The broader, rod-like, or cylindrical olfactory cells on the other hand (Fig. 65, *a*, *b*) carry no such cilia, and are regarded by many as simple epithelial cells. The nasal mucous membrane, in which these cells are placed, lines in the higher Vertebrata, as in Man, the internal wall of the nasal cavity. But it also is originally a part of the external integument. For



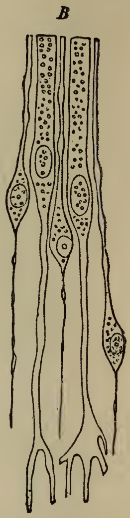


Fig. 65. Fig. 66.

Three olfactory cells from the nose of an Amphibian (Proteus). In the middle a larger cylindrical cell (*a*, *b*), without cilia; on each side of it a filiform olfactory cell, swollen in the middle into a globular shape, and bearing a tuft of very delicate olfactory cilia at the free extremity.

Five olfactory cells from Man, three more delicate, rod-like, and between these, two broader, cylindrical; all are connected below with terminal fibrils of the olfactory nerve.

the nose begins, even in these higher animals, in the same fashion that is persistent in Pisces, their lives through, as a pair of depressions of the integument.

Only in the course of embryological development these olfactory pits (Figs. 52—53 n) gradually retreat into the interior of the body, and in like manner in the course of evolution they have undergone the same change of place. The olfactory cells of the nose are, like the gustatory of the tongue, historical derivatives of the general tactile cells of the external integument.

If the ordinary distinction between the lower and higher sense-organs is maintained, the latter title only belongs in reality to those two noblest and most wonderful organs of the animal body that we call ear and eye. For the organ of hearing and the organ of sight alone reach that marvellous perfection of delicate structure, with its related complex division of labor, that makes them the most valuable instruments of our soul-life. These organs alone are the æsthetic sense-organs, the invaluable psychical instruments opening to us the portals to our highest blessings, Art and Science.

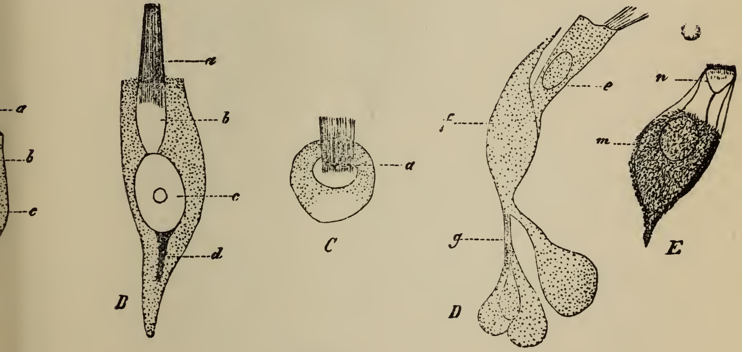


FIG. 67.

B. Auditory cells from the cochlea of the ear of a dove (Columba). A, B, C. Three separate ciliated cells. A and B seen in profile. C. The free end. *a* Bundle of auditory cilia. *b*. Clear cup-shaped space. *c*. Nucleus, with nucleolus *d*. Dark thread (probably continuous with a very delicate terminal nerve-fibre). D A ciliated cell (*e*) in connexion with a pointed cell (*f*) that has peculiar clavate appendages (*g*). E. A tegumental cell with dark internal part (*m*) and clear external part (*n*).

Whilst, then, the lower sense-organs that serve for the perception of pressure, temperature, taste, smell, exhibit generally throughout the animal kingdom simple uniform arrangements, in the higher sense-organs of hearing and sight, on the other hand, we meet with a number of complex and varying arrangements that awaken our deepest astonishment. Nevertheless, even here again, the real workers in perception are but highly developed cells. These æsthetic cells, the auditory of the ear, the visual of the eye, are in

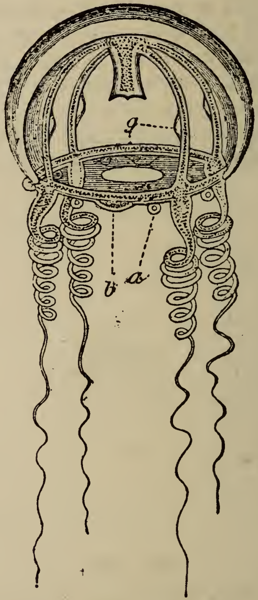


Fig. 68.

B. A Medusa (Eucope). From the middle of the bell-shaped body depends the gastric cavity, whence four digestive canals pass to the margin of the disk. The ova (*g*) lie in these canals. From the circumference of the disk (*b*) depend four prehensile tentacles, and between these are eight auditory vesicles (*a*).

their primal origin nothing but cells of the integument transformed and specialised.

The wonderful auditory cells of the ear are adapted to their special function, that of the perception of sound, in that they carry delicate bristle-like processes, the auditory cilia (Fig. 67, auditory cells from the ear of the dove).

Hence these also are called (not very conveniently), hair-cells. Sometimes each auditory or hair-cell carries only one delicate cilium, sometimes a whole bundle or tuft of them. The sound-waves brought to the animal *viâ* the water or the air, strike upon these auditory cells and cause their cilia to vibrate. In many other animals, *e.g.*, Polyps, Medusæ, Vermes, the like individual

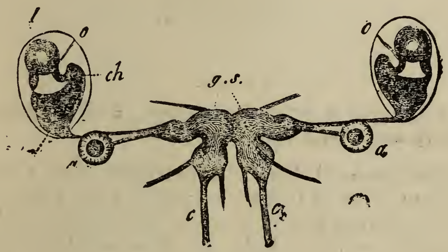


FIG. 69.

Soul-apparatus of a Pteropod (Firola or Pterotrachea. *a.* Auditory vesicles. *g.* Brain. *c.* Nerves (circumœsophageal). *o.* Eyes. *l.* Lens. *ch.* Pigment-membrane of the eye. *r.* Expansion of the optic nerve.

auditory cells are distributed throughout the integument irregularly or in special regions. But in the majority of the lower animals the auditory cells consist of two globular vesicles that lie usually in the vicinity of the nervous centres, sometimes deeply placed within, sometimes close to the surface of the skin. Many Medusæ have numerous auditory vesicles, lying quite freely in the margin of the disc: Eucope, *e.g.*, has eight (Fig. 68). These auditory vesicles (Fig. 69 *a*) are filled with liquid or gelatinous matter, and their wall is lined internally with a layer of cells, carrying in whole or part delicate cilia, and thus proving that they are auditory cells (Fig. 70 *e*).

From without an auditory nerve runs to the vesicle (Fig. 69), and gives off to the individual cells its finest fibrils. In the middle of the vesicle swims, as a rule, an otolith (Fig. 70, *o*) or nucleus of calcareous matter, or a concretion of many crystals of calcium carbonate. The delicate ends of the auditory hairs, or fine cilia of the auditory cells, seem for the most part to come into contact with the surface of the otolith.

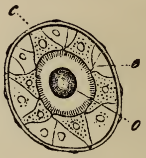


Fig. 70.

Auditory vesicle of a mussel (Cyclas). *c.* External capsule. *e.* Auditory cells, with cilia. *o.* Otolith.

The vibrations of the sound-waves that are transmitted from the exterior through the wall of the vesicle, pass through this wall to the fluid within, and to the otolith swimming in it. The auditory cilia receive the sound-waves collected here, and translate them into the perception of the noises, or of the note, that is now borne by the auditory nerve to the nerve-centre.

In a great number of Vermes, in the Ascidioida, Mussels, Snails, Brachiopoda, Crustacea, we meet with the auditory organs in this simple form, as globular, closed auditory vesicles, containing fluid and in the midst an otolith. But in the Crustacea are many animals, among others our ordinary crayfish and lobster, that have the auditory vesicles not enclosed, but connected by a short passage with the external skin, and directly communicating with the surrounding water. Instead of the usual calcareous otoliths that are formed by the animal itself, in these Crustacea there are little silicious or arenaceous particles that have been taken in from without. Nevertheless the sense of hearing is in these animals very well developed, and many delicate cilia, on the inner surface of the auditory organ, serve for the perception and distinction of the various sounds. If we give rise, by playing the violin, to notes of varying pitch, and at the same time observe the auditory organ under the microscope, we see that at each note only a particular auditory hair is set in vibration. There is present a suitable keyboard for notes, of such a nature that the number of undulations of every note corresponds with a cilium of definite length.

These facts are of the deepest interest in many ways, and especially in that they point us to the origin of the internal auditory vesicle from the integument. The auditory vesicles arise in the surface of the skin as shallow depressions, lined with ciliated cells. These depressions gradually deepen, fashion themselves into auditory organs, and, cutting themselves off entirely from the skin, become closed auditory vesicles. In the Medusæ also, as in the Crustacea, the phylogenetic origin of the auditory vesicle is established by the comparison of the stages of development that follow so closely one on the other, and it is completely settled by embryological investigations. In many Medusæ there are short tentacles that become transformed directly into auditory vesicles. They will coil up and lie as auditory bulbs within a vesicle. The auditory cilia within the latter, that are responsive to sound-waves, were earlier simple tactile hairs belonging to the epidermal cells, and then could only recognise alterations of pressure. They have gradually become adapted to the perception of the more rapid sonorous vibrations.

Here again we see how difficult is the distinction between auditory and tactile organs. For we cannot tell as we study the delicate auditory cilia under the microscope, whether they only respond to alterations of pressure or have already learned to perceive sonorous vibrations. But it is even more remarkable that in many lower animals, especially in the Articulata, that clearly have the sense of hearing, we are not able at present to distinguish special organs for that sense. But we find in these articulate animals sense-cells that carry hairs, and are connected with the nerves of the skin, widely distributed through the skin ; and, as their firm and elastic exoskeleton is excellently adapted for transmission of sound-waves, it is very probable that different parts of the external covering function as auditory organs. This conjecture is strengthened by the fact that perfect auditory organs are met with in the Articulata in very different parts of the body. Whilst in our common lobster and crayfish they lie in the head at the base of the internal feelers or antennules, in other crabs, on the contrary, as Mysis, we find them thrown backwards to the tail. The auditory organs in the musical Orthoptera lie at times at the side of the thorax, as in the well-known migratory crickets (Acridina), at times in the tibia of the front leg, as in the cricket and the green grasshoppers, in Gryllus and Locusta. It is beyond a doubt that these various organs of hearing in various places, having no relation one with another, have originated from the integument. For if they were inherited from some common ancestor, they would be situated in corresponding or homologous parts of the body.

The organ of hearing rises to a yet higher stage of development among the Vertebrata, although the arrangement of the parts follows in all essentials that met with in the lower forms. With the solitary exception of the lowest vertebrate, the well-known Lancelet or Amphioxus, we have in all Vertebrata, from the Pisces up to Man, a pair of conspicuous auditory vesicles located in the head. Each consists of two parts, an upper, the vestibule, and a lower, the utricle. In each part lies an otolith, or a collection of conjoined calcareous crystals, near which the auditory nerve spreads out on the inner wall of the vesicle, its finest fibrillæ coming into connexion with the auditory cilia placed thereon. From the upper—vestibule—pass off generally three annular or semicircular canals ; their cavities are in connexion with that of the vestibule, and, like it, are filled with fluid endolymph (Fig. 71).

From the lower—utricle—in the higher Vertebrata, is developed a peculiar organ that has been named the cochlea, on account of its outward resemblance to the shell of a snail. It would seem that this cochlea has to do with musical perception alone, whilst the vestibule and its derivatives are concerned in the perception of noises.

The delicate construction of this internal auditory organ is so extraordinarily complex in man and in the higher Vertebrata, that the name of labyrinth has rightly

Fig. 71.

Auditory vesicles (the so-called membranous labyrinth) of different Vertebrata. A, Man; B, Calf; C, Pike; D, Hawk; E, Frog. 1, 2, 3, the three semicircular canals (1, horizontal; 2, superior; 3, posterior). 4. Part common to the superior and posterior canals. 5. Ampullæ (enlargements). 6. Vestibule. 7. Utricle.

enough been given to it. Yet the astounding complexity of structure presented by this labyrinth, to the outlet from whose mazes the Ariadne-threads of embryology alone can be our guide, is primarily nothing more than a simple auditory vesicle, and, like the simple auditory vesicles of the lower animals, has been developed from the integument. This notable discovery was made in 1831 by Emil Huschke, in Jena. In order to convince ourselves as to its accuracy we have only to examine a fowl's egg that has lain for a day and a half in the hatching machine. In it we see on the side of the rudimentary head of the embryo chick a pair of shallow depressions lined by cells of the integument. By the third day of incubation these have become deep auditory cavities, that communicate with the exterior only by a narrow passage (Figs. 52, 53, *g*, p. 203). By the end of the third day they are cut off completely from the skin (Fig. 72, A, B). On the fourth day the isolated rounded auditory

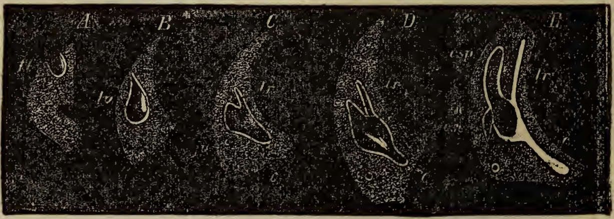


FIG. 72.

Development of the auditory vesicle or labyrinth of the ear in an incubated chick (in five successive stages. A—B). Vertical, transverse section of the rudimentary head. *fl.* Auditory depression. *lv.* Auditory vesicle. *h.* Appendage of the labyrinth. *c* Rudimentary cochlea. *csp.* Posterior semicircular canal. *cse.* External semicircular canal. *jv.* Jugular vein.

vesicle has already receded some distance into the head, and soon it becomes constricted in the middle, so as to mark off the vestibule above from the utricle below (Fig. 72, C, D).

Otoliths appear in both divisions. From the vestibule arise the three semi-circular canals, from the utricle, the cochlea (Fig. 72, E). Thus all the chief parts of the labyrinth are formed, and gradually acquire their delicate and perfect structure. But the most delicate auditory cells, that are developed later on in

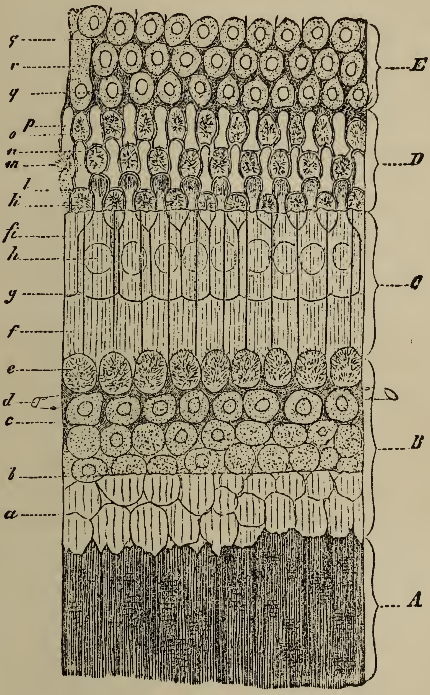


Fig. 73.

A piece of the organ of Corti or the lining membrane of the cochlea of a dog. A. Crista spiralis. B. Inner cell layer (epithelium of the sulcus spiralis). C. Pillar heads of the fibres of Corti. D. Lamina reticularis with outer ciliated cells. E. Outer cell layer (epithelium of the membrana basilaris). *a*. Cells of the sulcus spiralis. *b*. Outer boundary of the acoustic teeth. *c*, *q*. Meshwork between the lining cells. *d.* Vas spirali. *e.* Inner ciliated cells. *f.* Inner pillars (fibres of Corti). *g.* Limit between *f* and *h*. *h.* Outer pillars. *k*, *p*. Three rows of external ciliated cells. *n*. Supporting cells. (Highly magnified).

the cochlea, are still originally none other than descendants of ordinary epidermal cells. Here, again, the history of the embryo is a condensed epitome of that of the race. In the same way as in a few days the labyrinth of the ear of the chick is developed out of the integument, so in the course of many millions of years has the marvellous structure of our human auditory labyrinth been evolved out of the simple ear-vesicle of the lower animals.

The part of the labyrinth in man, and the other higher Vertebrata that surpasses all others in the wondrous delicacy and complexity of its structure, is the so-called organ of Corti, or the lining membrane of the cochlea (membrana tectoria cochleæ, Fig 73).

This wondrous organ is, when compared with the simple ear-vesicle of lower animals (Fig. 67), as a piano of the best makers with its keys in comparison with the simple vibrating cord or string that an Indian has strung upon his bow. In the canal of the cochlea we find a tunnel-like passage that is vaulted over by a series of delicate, bony arches, the fibres of Corti (C). Each fibre consists of an inner (*f*), and an outer pillar (*h*). On these fibres of Corti rest the most important acoustic constituents of the cochlea, the musical ciliated cells, set with very fine tufts, in which cells the very delicate end fibrils of the auditory nerves terminate. On the heads of the internal pillars (*f*) rests but a single row of ciliated cells (*e*) : on the heads of the outer pillars (*h*) 3—5 rows of external ciliated cells (*k*, *p*). It is probable that the number and arrangement of these ciliated cells condition the musical capabilities of the different Mammalia. The musically cultured man seems to have 4—5 rows, the rude savage 3—4, the ordinary mammal only 3 rows ; the Wagnerian musician of the future will probably have 6, or even a larger number. The very highly developed composition and arrangement of the cells in the organ of Corti, call to mind the like conditions in the retina of the eye. And as the latter has been gradually evolved in the course of many millions of years, from a simple layer of visual cells, so as the former from a simple layer of auditory cells. Visual and auditory cells alike have arisen from ordinary epidermal cells, and have gradually withdrawn themselves from the surface into the sheltered interior of the body.

But the totality of the acoustic apparatus in man, and in the higher Vertebrata, is by no means completed by the building up of this wonderful labyrinth. Other external parts become associated with this essential constituent of the auditory organ, parts that catch and conduct to the labyrinth sound-waves. These parts are wanting in Pisces. In these water-dwellers the sound-waves, in the water, strike directly on the skin and cranial bones, and through these reach the labyrinth lying within the skull. In many Pisces the perception of sound is aided by the labyrinth being in connexion with the swim-bladder that is filled with air. In the herring this is effected through the medium of special air-canals, in the carp and shad through a chain of auditory ossicles. The hydrostatic apparatus of the swim-bladder serves, therefore, as a resonator.

In the Amphibia (the salamanders and frogs), a special apparatus having to do with the conduction of sound is developed. To these animals, living alternately in water and on land, such an apparatus is of great service, as the air is not well-adapted for the conduction of sounds. A circular membrane like the head of a drum that lies in the skin covering the head, and receives the sound-waves in the air, is the boundary of a cavity filled with air and opening by a tube, the Eustachian tube, into the œsophagus. The labyrinth lies internally to this tympanic cavity, and receives the sound-waves partly through the medium of the air it encloses, partly through the columella, a rod-like bone that puts the membrane of the tympanum into direct connexion with the wall of the labyrinth. The whole of this conducting apparatus, which the Amphibia have transmitted onwards to the higher Vertebrata, has been evolved from the first gill-cleft, and the two gill-arches that bound it in the fish. This is proved by comparative anatomy, and also by embryology.

The external ear, which man has in common with the other Mammalia, is an evolution product of much later time.

This external ear consists of the pinna (Fig. 74 *a*), which catches the sound-waves of the air, and the external auditory canal (*b*) that conducts them to the

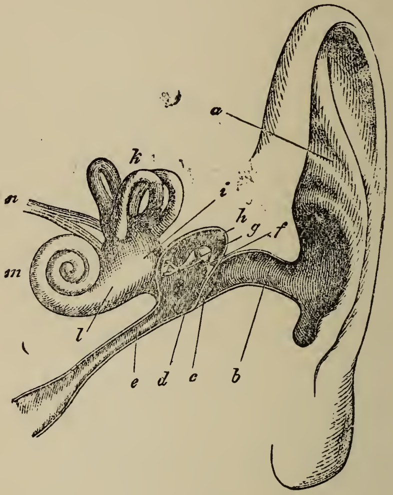


Fig. 74.

Human ear (left) seen from the front. *a*. Pinna. *b*. External auditory canal. *c*. Membrana tympani. *d*. Tympanic cavity. *e*. Eustachian tube. *f*, *g*, *h*. The three ossicles (*f*. Malleus, *g*. Incus, *h*. Stapes). *i*. Vestibule. *k*. The three semi-circular canals. *l*. Utricle. *m*. Cochlea. *n*. Auditory nerve.

drum or membrane of the tympanum (*c*). These are developed from an annular fold of the epidermis that forms the boundary of the external part of the first gill-cleft. In the Mammalia that have a very acute sense of hearing far surpassing that of man, the pinna is much more completely developed and has much freedom of movement. Its direction, as well as its shape, is altered by special muscles, so that the sound-waves coming in different directions may be caught in the best possible way. The external ears of the inhabitants of wildernesses, the jerboas, the foxes of the Sahara, are of remarkable size and mobility. For it is of importance to these to catch the slightest sound from afar in the dead silence of the vast plain. On the other hand, in man, who is far inferior to these animals in quickness and delicacy of hearing as of smelling, the pinna has lost its importance, and has sunk to the level of a useless or rudimentary organ. Men whose ears have been cut off hear as well as they did before. Moreover, in many domestic animals whose ears hang loosely, dogs, rabbits, goats, the disuse of the muscles of the ear resulting from the domestication of the animals has led to their degeneration, and in these cases also the pinna has gradually become superfluous and useless. That the human pinna is a rudimentary organ, is demonstrated by the extraordinary variations in its size and shape. In these it surpasses, probably, all other organs. In large gatherings, when we are not deeply interested with the matter in hand, there is no amusement more instructive than an investigation of the endless varieties of pinnæ to be seen.

The Australian negroes, Papuans and other savages, whose acuteness of hearing is far beyond that of civilised races can, as a rule, control the movements of the pinna very completely. Many favored individuals also among the civilised peoples are at the present time capable of these movements, and some celebrated physiologists, *e.g.*, Johannes Müller, have only by energetic and long continued efforts of the will, and by practice continued through many years, arrived at the power of moving their ears freely and quickly. Herein we have one of the most notable examples of the great force of use and habit, of the mighty power of adaptation. For in these cases ancient, long disused muscles are brought again into active service by repeated nervous activity, by the force of persistent willing.

In other connexions the development of our auditory organ gives us very instructive information as to the astonishing power of use and habit, of education and adaptation. What a world of difference is there between the rude perception of sounds of a savage, whose highest musical pleasure is in the rhythmical repetition of some noise, or at most of some simple sound of drum or of fife, and the musical perceptions of a cultured man, whose ear takes delight in the classic harmonies of an opera of Mozart, or a symphony of Beethoven! What a vaster world of difference between these last, and the hyper-cultured folk that revel in the Wagnerian music of the future, and find the true end and aim of æsthetic enjoyment of sound in complicated discords!

As every organic function evolves hand in hand with its organ, there is no doubt that with this historic advance in the power of perception of sound, is closely knit a like advance in the perfection of our auditory labyrinth. The minute structure of our cochlea is, to-day, different from that of our wild forefathers five thousand years ago. The labyrinth, moreover, of the wild savage of to-day in its minute structure, would probably present certain differences from that of the civilised man. It is no contradiction to this, that the former has a keener sense of hearing than the latter. For the acuteness of the ear in the savages, who hear sounds at a great distance, is altogether another thing than the delicacy of the musical ear of the cultured races. The ability of the one, stronger quantitatively, is very different from the ability of the other, which is higher in quality. This holds also in regard to the sense of smell and of sight. Whilst savages see much farther, and can recognise much more certainly weak odors than the civilised races, they, nevertheless, are far inferior to these in delicate discrimination of odors, and in the æsthetic perfection of the sense of color and of form, the result of thousands of years of civilised evolution.

We find in the organ of sight exactly the same relationships between its historic and its gradual perfection as in the ear. The eye, highest, most perfect of all the sense-organs, has not been suddenly called into being by the fiat of a designing creator, but, like all other organs, has slowly, gradually evolved by Natural Selection in the struggle for existence. As the eye and ear, the two noblest organs of the senses, the organs that perceive beauty, are very different, and yet comparable in their anatomical structure and their physiological function, so is it also with their evolution. As the sense of hearing of the ear has grown out of the tactile sensibility of the skin, so has the sense of light of the eye grown out of the thermal sensibility of the skin. Comparative anatomy and embryology show us in relation to the eye, as to the ear, a long chain of stages of evolution. Here also we must come to the conclusion that the marvellous organ of sight of man and of the higher animals is but the final result of a long series of advancing adaptations that have been gradually accumulated by heredity, and that lead us step by step from the lowest stages to the highest.

The first beginning of the organ of sight in the lower animals is no other than a simple dark spot in the clear integument, generally a black or red pigment-spot. Even in the unicellular Protista such dark specks of color-matter seem to serve for the perception of light. Single pigment-cells, or collections of such pigment-cells, constitute the beginning of a very simple eye in many Cœlenterata and Vermes. When pigment is deposited in the colorless integument of such animals, these dark spots must be more responsive to the changes of temperature in the surrounding water or air than the neighboring colorless regions of the integument. For it is well known that the light and heat rays are absorbed by dark bodies and reflected by colorless ones. A black stone becomes hot more rapidly than a white one when placed in the sunshine. Hence with the formation of dark specks in the integument there is the first beginning of an eye, but clearly only of a temperature, or a light-eye that can distinguish between warmth and cold, clearness and darkness, better than the rest of the skin around it. The ordinary nerves of the skin that pass to these dark pigment-cells of the integument have already trodden the first steps of that magnificent march, at whose end they have developed into the highest nerves of sense, the optic nerves.

But we expect more from a veritable eye than simple distinguishing between clearness and darkness. The true eye gives a picture of the conditions of the environing outer world; and the inner lining of the eye on which this picture is painted, as on the sensitive plate of a photographic apparatus or in a magic-lantern, is the expansion of the optic nerve, the retina. But a picture of this kind can only be formed on this sensitive nerve-layer when a refracting body, a lens, is present. This curved lens, like a burning-glass or a simple magnifying-glass, collects the rays of light coming from external objects, and throws on the retina a diminished image of those objects, that is felt by the optical cells and transmitted by the optic nerve to the brain. By the formation of a transparent refractive lens, the crystalline, the simple light-eye makes a great step onwards, and becomes a true picture-eye. This immensely important advance is accomplished in the lower animals, especially in Cœlenterata and Vermes, in very different ways. Sometimes a single epidermal cell, much expanded, globular or lenticular, curved, develops into the crystalline lens. Sometimes a group of conjoined cells, sometimes a hardened distinct part of the skin (as the chitinous lens of the Arthropoda), thus develops.

We have already all the materials for the building up of the very complex eye of the higher animals and of man, viz.: 1, a refracting lens, situated in the integument; 2, the optic nerve, spreading out on the inner surface of the lens as the retina; 3, a pigment layer, a layer of dark integumental cells, enveloping at once the retina and the lens. The crystalline lens refracts the rays of light and blends them into a picture; the pigment layer absorbs them, and the optical cells of the retina translate them into sensation, that is carried by the optic nerve to the central apparatus of the brain. All these essential parts of a simple eye are originally formed from the epidermis; a fact proved by comparative anatomy and embryology alike. Hence we draw this most weighty conclusion in regard to the ancestral history of animals that the slow gradual evolution of the organ of sight in the ages has, in the course of many millions of years, passed along the same way, and that in all cases the eye has been originally developed from the cells of the epidermis.

It is clear that it is a long journey from this simple eye of the lower animals with its three essential parts to the far more perfect eye of the higher animals, that may be composed of more than thirty different parts. Interesting as it would be to follow the long march of advancing evolution step by step, it is impossible in this place to enter more fully into the question, on account of the perplexing complexity of the minute anatomical and genetic relations of the parts. The wondrous structure of the eye in the various classes of animals is far more variable and more perfect than is that of the ear. And as the sense of sight is far higher than that of hearing, as the art of painting at its best is in advance of that of music, so also the structure and evolution of the eye are in like manner more fascinating, more wonderful than that of the ear, and, it must be confessed, more difficult. We must, therefore, content ourselves in this connexion with some brief statements as to the more general details of the evolution of the organ of sight.

In the first place, Natural Selection in the advancing structure of the eye improves the apparatus that refracts the light, substituting for one simple lens a very complex combination of variously refracting bodies, of which the most important are a hard laminated lens and a white semi-fluid vitreous body (Fig. 75, *l*, *h*). By this means the optical errors of the single lens are avoided. Next, in the place of a simple pigment layer, we meet with a differentiated vascular coat, the choroid, of many layers, with tapetum, fringes, etc. Lastly, and most important of all, the nervous apparatus of the eye is rendered more perfect to an astounding degree. In place of a simple nerve-expansion we find a very complex retinal structure, composed of many different layers.

The great group, Vermes, is in an especial degree instructive in the study of this evolution of the eye in time, for in that group we can follow out a complete series of gradations in the structure of that organ. In the lowest Vermes the eye is only made up of individual pigment-cells. In others, refractive cells are associated with these, and form a very simple lens. Behind these lens-cells optic-cells are developed, forming a single-layered retina of the simplest order, whilst they are in connexion with the very delicate terminal fibrils of the optic nerve. Finally, in the Alciopidæ very highly organised Annelidæ, that swim on the surface of the sea, adaptation to this mode of life has conditioned such perfection of the eye that this organ

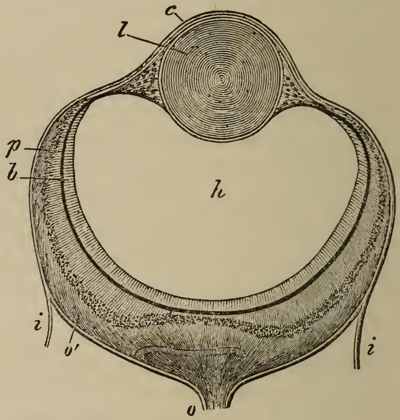


Fig. 75.

Eye of an Annelid (Alciope). *l.* Lens. *h.* Vitreous humor. *b.* Rod and cell layer. *p.* Pigment layer. *o.* Optic nerve. *o'.* Expansion of the last. *i.* Integument, forming a horny layer in front of the eye (cornea, *c*).

in these animals is in no way inferior to that of the lower Vertebrata (Fig. 75). In these beings we find a large globular eyeball enclosing externally a laminated globular lens (*l*), internally a vitreous body (*h*), of large circumference. Immediately investing these are the rods of the optical cells (*b*) sensitive to light, that are separated by a layer of pigment-cells (*p*) from the outer expansion of the optic nerve (*o*), the retina (*o′*). The external epidermis (*i*) invests the whole of the prominent eyeball, and forms in front of it a transparent horny layer, the cornea (*c*).

If we compare the highly developed eye of this worm with that of man (Fig. 76) or of any other of the higher Vertebrata, we find in all essential details a like arrangement of parts. Only in man the cornea (*b*) is more strongly convex, and the lens (*l*), by consequence, less

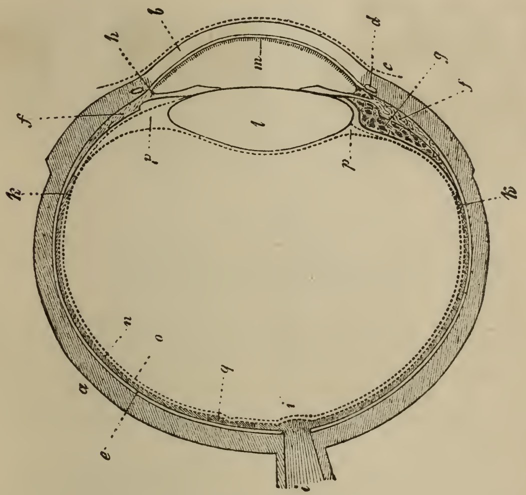


Fig. 76.

Human eye, cross section. *a.* Sclerotic. *b.* Cornea. *c.* Conjunctiva. *d.* Circular vein of the iris. *e.* Choroid. *f.* Ciliary muscle. *g.* Corona ciliaris. *h.* Iris. *i.* Optic nerve. *k.* Anterior limiting membrane of the retina. *l.* Crystalline lens. *m.* Membrana Descemetica. *n.* Pigment layer. *o.* Retina. *p.* Canal of Petit. *q.* Macula lutea.

globular and more flattened in shape. A very vascular choroid (*e*) lies internally to the strong outer sclerotic (*a*) and forms anteriorly the colored iris (*h*), which in its turn surrounds the pupil. Between the choroid (*e*) and retina (*o*) lies a simple layer of very regular hexagonal pigment-cells, filled with black pigment (Fig. 77, *a*).

This dark tapetum or pigment layer belongs both by origin and by its optical significance to the retina.

The most important and most remarkable part of the eye in man, as in other animals, is the retina, a very delicate thin membrane, formed essentially of optical cells. These cells are connected with the very fine

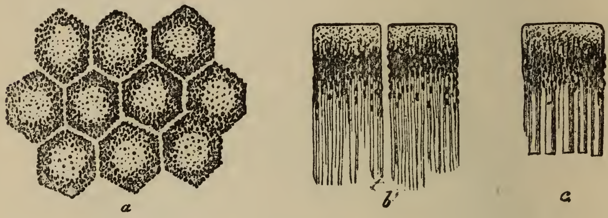


FIG. 77.

The pigment layer. *a*. Ten cells, surface view. *b*. Two cells, side view. *c*. One with rods attached to it.

end-fibrils of the optic nerve, and are, like most other sense-cells, slender and rod-shaped. In the lower animals these optical rod-cells are of simple and uniform nature. In the higher animals they are distinguished as two differently-shaped structures, called rods and cones (Fig. 78).

The rod-cells are longer and thinner, the cone-cells shorter and thicker. The former, which carry externally a delicate crystalline rod, seem to aid in the perception of the form, whilst the cone-cells, which carry a pointed conical process, seem to aid in the perception of the color of the retinal pictures. Hence the lower animals, whose optic nerve-fibres end wholly in rod-cells, see colorless pictures only, and know, probably, nothing of color. Only those higher animals that have cones intercalated with the rods seem able to distinguish colors. In bats and other nocturnal animals we find in the retina only a few cones, or even none at all. But the cones are more numerous and better developed in the lizards and the birds that love the sunlight and have clearly a highly developed sense of color.

In man, as in other higher Vertebrata, we can distinguish in the retina not less than ten distinct layers (Fig. 79).

Most externally lies the layer of black pigment-cells (pigmentosa, 10), and immediately beneath this is the

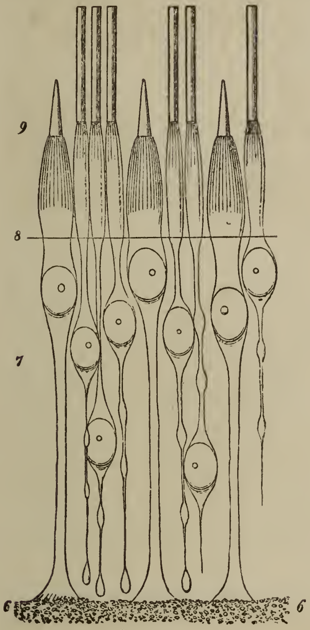


FIG. 78.

Nine optical cells from the posterior part of the human retina; three shorter thicker cone-cells lie between six longer thinner rod-cells.

layer of optic-cells with their rods and cones (7—9). This is separated from a thick layer of granular cells (5) by a thin granular layer (6), and the thick granular stratum is separated by another exceedingly broad granular layer (4) from a series of ganglion-cells (3) that are in direct connexion with the fibres of the optic

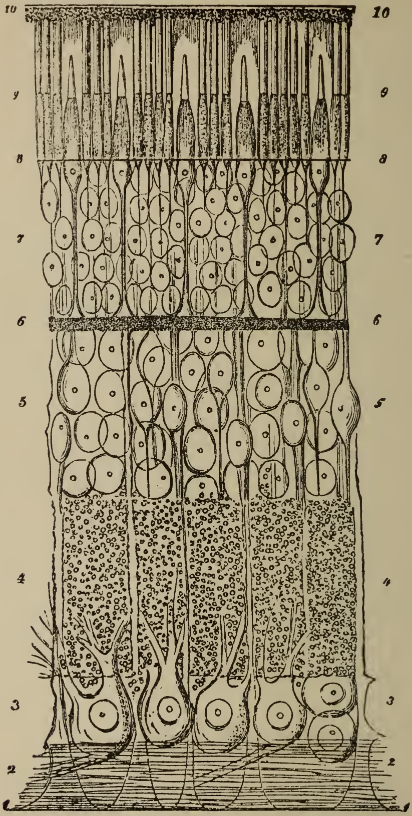


Fig. 79.

Vertical section through a piece of the human retina. 1. Membrana limitans interna. 2. Optic nerve-fibres. 3. Ganglion cells. 4. Internal granular layer. 5. Intergranular layer. 6. External granular layer. 7. Optic cells. 8. Membrana limitans externa. 9. Rods and cones. 10. Pigment layer. Very highly magnified.

nerve (2). The complication of structure and arrangement in the retinal elements corresponds with the stages of optical evolution reached by the eyes, so that the retina of the skilled painter will be more perfect than that of the rude savage.

With these the most important parts, optically considered, of the eye are associated in man, as in all the higher animals, many auxiliary structures, wanting in the older lower animals. Such are the intrinsic muscles of the eye that alter its form and adapt the lens to different distances; the extrinsic muscles of the eye that move the organs as a whole in different directions. Around the eyeball is placed a firm outer membrane, the sclerotic, in which in many cases (*e.g.* in birds) a circle of bony plates is present. In front the sclerotic passes into a transparent membrane, the cornea. The lachrymal apparatus, that keeps the external surface of the eyeball smooth and clean, is only developed in the three higher vertebrate classes; Reptilia, Aves, Mammalia. The eyelids, however, that act as protective curtains and keep out impurities from the outer surface of the organ, have already appeared in Pisces, and have been transmitted from these to the higher Vertebrata.

Not less interesting than these manifold advances that are evident in the structure of the eye in many classes of Animalia, are the retrogressions. Deeply placed within the head, covered by thick skin and muscles, true eyes, that cannot see, are found in certain animals that belong to various classes. Among the Vertebrata there are blind moles and fieldmice, blind snakes and lizards, blind Amphibia and Pisces. Amongst the Arthropoda we know many blind beetles and Crustacea. All these blind animals have grown accustomed to live in darkness. They shun the daylight, dwelling in holes or burrows under the ground. Thus they have lost the habit of seeing, and by the disuse of the organ the organ itself has become atrophied. All the animals known to us that live in this fashion were not originally blind, but have evolved from ancestors that lived in the light and had well-developed eyes. The atrophied eye beneath the opaque skin may be found in these blind beings in every stage of reversion. In the higher

Crustacea, whose eyes are placed on long freely mobile stalks, there are some blind dwellers in the earth (near allies of our river crayfish) in whom the eye itself has vanished, but the eye-stalk is still present. As Darwin puts it in his trenchant style, we have here the stand of the telescope left, but the telescope itself is lost.

Rudimentary eyes, such as these that see not, like the many other facts in the history of the evolution of the sense-organs, demonstrate in the clearest way that the most highly perfected sense-organs are not the artificial product of a thought-out plan of creation, but, like all other organs of the animal body, they are the necessary outcome of Natural Selection in the struggle for existence. On behalf of this mechanical or Monistic theory as to the origin of the senses the most convincing utterance is given by the fact that occasionally in different animals eyes are developed on parts of the body that never before bore such organs. Thus the higher Mollusca, the Sepia and the snail, have always only one pair of eyes in the head, as in the Vertebrata. But in some Gasteropoda, as Onchidium, in addition, eyes in large number are developed on the back, and, most remarkable of all, the structure of these dorsal eyes does not resemble that of the cephalic eyes of the Gasteropoda, but resembles that of the vertebrate eye. The true Lamellibranchiata have lost their head, and with it both their cephalic eyes. In lieu of these, many Lamellibranchs (*e.g.* Pecten) have numerous beautiful green eyes developed on the margin of the mantle, *i.e.* on the external border of a great dorsal fold of the integument, that invests the body like a mantle. In the higher Vermes we meet generally with a pair of eyes on the head. But individual Annelida (Fabricia) have in addition a pair of eyes placed posteriorly in the tail, and others (Polyophthalmus) have a pair of eyes on every limb. These and many similar facts prove most clearly that the eyes, like other organs of the body, have built themselves up by adaptation to external life-conditions.

The marvellous force that adaptation has constantly exerted on the advancing perfection of the highest organs of sense, can be followed out in detail during the short time of the history of human civilisation up to the present day. Especially does the higher color-sense seem to be incomparably more developed in us at the present day than in our ancestors, thousands of years before. Many observers have already come to the conclusion that the human race, two thousand years ago, only distinguished the lower colors of the spectrum, red, orange, yellow, whilst the higher tones, the green, blue, violet colors, were then unknown to man. Many strong evidences in favor of this idea are forthcoming in the works of art, and the classical writings of ancient time; but, on the other hand, it must be confessed that many facts tell against this view. The contest on this point in which the English statesman, Gladstone, the Breslau ophthalmist, Magnus, and also Dr. E. Krause, among others, have taken part, is still in full force to-day. When we consider how exceedingly variable is the development of the sense of color at the present hour among civilised races, and in different individuals, how widely prevalent in various classes of the community is color-blindness or Daltonism, we ought, at least, to regard it as certain that the highly developed sense of color of the present time, is a recent production of civilised Evolution. The recent development of landscape-painting speaks powerfully in support of this view. This branch of art has, of late, in our own century grown to a perfection undreamed of before. We perceive the more delicate beauties of natural coloring incomparably more clearly than our mediæval forefathers. The delicate cones of the retina that are concerned in this more cultured color-sense, have, therefore in all probability, gradually advanced in development during the last ten centuries. Even now-a-days we see in the surviving savage races a crudity as to this sense, and as to the sense of tone, that shocks our cultured sense of beauty. Our little ones also, like the savages, love collocations of glaring colors that grate upon us, and susceptibility to the harmony of delicate shades of color is the latest product of æsthetic education.

In the eye, also, as in the ear, it is education and improvement, use and habit, in a word adaptation, that have gradually raised the sense-organ and its æsthetic capabilities to such a height, and by heredity this magnificent heirloom is handed on from generation to generation. Seeing the astonishing advance already made by our senses of color and of tone in historic time, we may dare to hope that these will rise by yet further advances, and under careful training, to a far higher condition of perfection. And when we think that art, most noble, most regal of humanity's possessions, depends for its first principles upon the advance of these two æsthetic sense-organs, we may hope to make more and more perfect the arts of music and of painting in the coming years, through the ever-growing perfection of ear and eye. Thus the study of Evolution at this hour, in its application to the development of the sense-organs, gives us an insight, full of inspiration to happiness, into the more perfect world that is to be.

INDEX.

My thanks are due to my friend Captain Bingham for the preparation of the Index.—E. B. A.