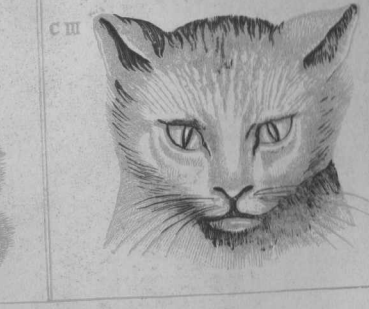
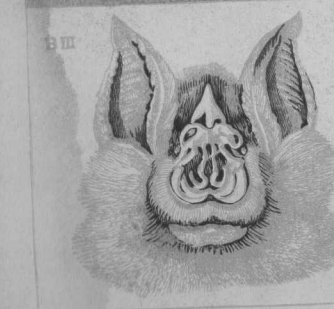
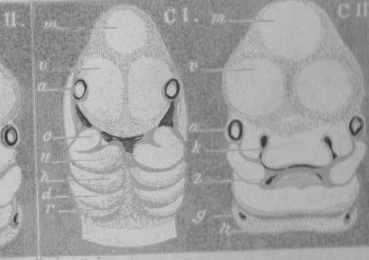
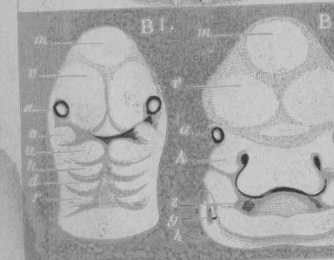
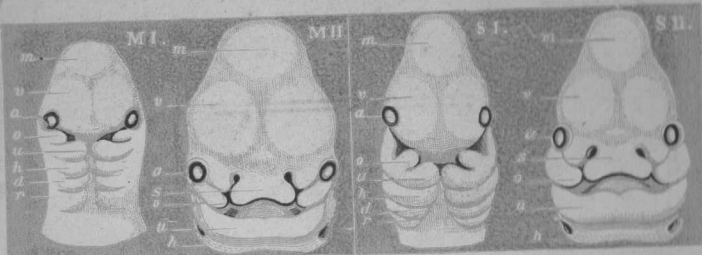


DEVELOPMENT OF THE FACE (THIRD STAGE).

EXPLANATION OF CHAP. XXI.



M. Man.

B. Bat.

S. Sheep.

C. Cat.

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THE EVOLUTION OF MAN

A POPULAR EXPOSITION

OF THE

Principal Points of Human Ontogeny and Phylogeny

FROM THE GERMAN OF ERNST HAECKEL, PROFESSOR IN THE UNIVERSITY OF JENA, AUTHOR OF "THE HISTORY OF CREATION," ETC.

IN TWO VOLUMES

VOL. I.

The Werner Company, Book Manufacturers, Akron, Ohio

Dost fondly fancy I shall hate my life,  
And hie me to the waste, because not all  
My blossom-dreams bear fruit ?

Here sit I forming manhood in my image,  
A race resembling me,  
To sorrow, and to weep,  
To taste, to hold, to enjoy,  
And not take heed of thee,  
As I!

GOETHE.

## FAUST.

Earth's narrow circle is well known to me ;  
What is above the eye can never see.  
Fool, who peers thither with his vision dim,  
And feigns a crowd of beings like to him !

Let him look round him, standing without fear,  
This world speaks plain for who has to hear,  
He need not stray within the vast to be  
But clasp what he can feel and see.

So let him wander all his earthly days,  
Though ghosts should walk, still let him go his way,  
In every progress woe and joy betide,  
Though every moment be unsatisfied.

Yes, in this thought, I fix unswerving ;  
Wisdom gives thus her judgment form ;  
Those are of Freedom, Life deserving,  
Who daily take them both by storm.

GOETHE.

## THE EVOLUTION OF MAN.

## CHAPTER I.

## THE FUNDAMENTAL LAW OF THE EVOLUTION OF ORGANISMS.

*General Significance of the History of the Evolution of Man.—Ignorance of it among the so-called Educated Classes.—The Two Branches of the History of Evolution.—Ontogeny, or the History of Germs (Embryos), and Phylogeny, or the History of Descent (or of the Tribes).—Causal Connection between the Two Series of Evolution.—The Evolution of the Tribe determines the Evolution of the Germ.—Ontogeny as an Epitome or Recapitulation of Phylogeny. The Incompleteness of this Epitome.—The Fundamental Law of Biogeny.—Heredity and Adaptation are the two Formative Functions, or the two Mechanical Causes, of Evolution.—Absence of Purposive Causes.—Validity of Mechanical Causes only.—Substitution of the Monistic or Unitary for the Dualistic, or Binary Cosmology.—Radical Importance of the Facts of Embryology to Monistic Philosophy.—Palingenesis, or Derived History, and Kenogenesis, or Vitiating History.—History of the Evolution of Forms and Functions.—Necessary Connection between Physiogeny and Morphogeny.—The History of Evolution as yet almost entirely the Product of Morphology, and not of Physiology.—The History of the Evolution of the Central Nervous System (Brain and Spinal Marrow) is involved in that of the Psychic Activities, or the Mind.*

*"The History of the Evolution of Organisms consists of two kindred and closely connected parts: Ontogeny, which is the history of the evolution of individual organisms, and Phylogeny, which is the history of the evolution of organic tribes. Ontogeny is a brief and rapid recapitulation of Phylogeny, dependent on the physiological functions of Heredity (reproduc-*

tion) and Adaptation (nutrition). The individual organism reproduces in the rapid and short course of its own evolution the most important of the changes in form through which its ancestors, according to laws of Heredity and Adaptation, have passed in the slow and long course of their palaeontological evolution."—HAECKEL'S *Generelle Morphologie* (1866).

THE natural phenomena of the evolutionary history of man claim an entirely peculiar place in the wide range of the scientific study of nature. There is surely no subject of scientific investigation touching man more closely, or in the knowledge of which he is more deeply concerned, than the human organism itself; and of all the various branches of the science of man, or anthropology, the history of his natural evolution should excite his highest interest. For it affords a key for the solution of the greatest of those problems at which human science is striving. The greatest problems with which human science is occupied—the inquiry into the true nature of man, or, as it is called, the question of "Man's Place in Nature," which deals with the past and primitive history, the present condition, and future of Man—are all most directly and intimately linked to this branch of scientific research, which is called The History of the Evolution of Man, or briefly, "Anthropogeny."<sup>1</sup> It is, however, a most astonishing but incontestable fact, that the history of the evolution of man as yet constitutes no part of general education. Indeed, our so-called "educated classes" are to this day in total ignorance of the most important circumstances and the most remarkable phenomena which Anthropogeny has brought to light.

In corroboration of this most astounding fact, I will only mention that most "educated people" do not even know that each human individual is developed from an egg, and that this egg is a simple cell, like that of any

animal or plant. They are also ignorant of the fact that, in the development of this egg, an organism is first formed which is entirely different from the fully developed human body, to which it bears no trace of resemblance. The majority of "educated people" have never seen such a human germ, or embryo, in the early stages of development,<sup>2</sup> nor are they aware that it is not at all different from those of other animals. They do not know that, at a certain period, this embryo has essentially the anatomical structure of a Lancelet, later of a Fish, and in subsequent stages those of Amphibian and Mammal forms; and that in the further evolution of these mammal forms those first appear which stand lowest in the series, namely, forms allied to the Beaked Animals (*Ornithorhynchus*); then those allied to Pouched Animals (*Marsupialia*), which are followed by forms most resembling Apes; till at last the peculiar human form is produced as the final result. These significant facts are so little known that, when incidentally mentioned, they are commonly doubted, or are even regarded as unfounded inventions. Every one knows that the butterfly proceeds from a pupa, the pupa from a caterpillar, to which it bears no resemblance, and again the caterpillar from the egg of the butterfly. But few, except those of the medical profession, are aware that man, in the course of his individual evolution, passes through a series of transformations no less astonishing and remarkable than the well-known metamorphoses of the butterfly. The mere tracing of this wonderful series of forms, through which the human embryo passes in the course of its development, is, of course, of great general interest. But our understanding will be satisfied in a far higher degree, if we refer these remarkable facts to their final causes, and recognize



that these natural phenomena are of the utmost importance to the entire range of human knowledge. They are of special importance to the "History of Creation," and, in connection with this, to philosophy in general,—as we shall presently see. Further, as the general results of all human striving after knowledge are summed up in philosophy, it follows that every branch of scientific research comes more or less in contact with, and is influenced by, the History of the Evolution of Man.

In undertaking to describe the most important characteristics of these significant phenomena, and to trace them back to their final causes, I shall assign a much greater scope and aim to the History of the Evolution of Man than is usual. The lectures given on this subject in German universities during the past fifty years have been exclusively designed for medical students. It is true that the physician is most deeply interested in becoming acquainted with the development of the bodily organization of man, with which he deals, practically, from day to day, in his profession. I shall not here attempt to give a special account of the course of the evolution of the individual, such as has usually been given in embryological lectures, because few of my readers have studied human anatomy, or are acquainted with the physical structure of the developed man. Hence, I shall have to confine myself in many points to general outlines, neglecting many of the remarkable details, which would have to be discussed in treating of the evolution of special human organs, but which from their complicated nature, and because they are not easy to describe, can only be completely understood by the aid of an intimate acquaintance with human anatomy. I shall strive, however,

to present this branch of the science in as popular a form as possible. A satisfactory general idea of the course of the evolution of the human embryo can, indeed, be given without going very deeply into anatomical details. As numerous successful attempts have recently been made to awaken the interest of larger classes of educated persons in other branches of Science, I also may hope to succeed in this department, though it is in many respects especially beset with difficulties.

The History of the Evolution of Man, as it has been usually treated in lectures for medical students at the universities, has only concerned itself with Embryology,<sup>3</sup> so-called, or more correctly with Ontogeny,<sup>4</sup> in other words, with the history of the evolution of individual human organisms. This, however, is only the first part of the task before us, only the first half of the History of the Evolution of Man in the wider sense which will here be attributed to the term. The second part, equal in importance and interest, is Phylogeny,<sup>5</sup> which is the history of the evolution of the descent of man, that is, of the evolution of the various animal forms through which, in the course of countless ages, mankind has gradually passed into its present form. All my readers know of the very important scientific movement which Charles Darwin caused fifteen years ago, by his book on the Origin of Species. The most important direct consequence of this work, which marks a fresh epoch, has been to cause new inquiries to be made into the origin of the human race, which have proved the natural evolution of man through lower animal forms. The Science which treats of the development of the human race from the animal kingdom is called Phylogeny, or the tribal



history of man. The most important source from which the science derives its material, is Ontogeny, or the history of germs, in other words, of the evolution of the individual. Palæontology, or the science of petrifications, and, in a yet greater degree, Comparative Anatomy, also afford most important aid to Phylogeny.

These two divisions of our science, Ontogeny, or the history of the germ, Phylogeny, or the history of the tribe, are most intimately connected, and the one cannot be understood without the other. The close intertwining of both branches, the increased proportions which germ-history and tribal history lend to each other, alone raise Biogeny<sup>6</sup> (or the history of organic evolution, in the widest sense) to the rank of a philosophic natural science. The connection between the two is not external and superficial, but deeply internal and causal. Our knowledge of this connection has been but very recently obtained; it is most clearly and accurately expressed in the comprehensive statement which I call "*the fundamental law of organic evolution*," or more briefly, "*the first principle of Biogeny*."<sup>7</sup>

This fundamental law, to which we shall recur again and again, and on the recognition of which depends the thorough understanding of the history of evolution, is briefly expressed in the proposition: that the History of the Germ is an epitome of the History of the Descent; or, in other words: that Ontogeny is a recapitulation of Phylogeny; or, somewhat more explicitly: that the series of forms through which the Individual Organism passes during its progress from the egg cell to its fully developed state, is a brief, compressed reproduction of the long series of forms through which the animal ancestors of that organism (or the ancestral forms

of its species) have passed from the earliest periods of so-called organic creation down to the present time.

The causal nature of the relation which connects the History of the Germ (Embryology, or Ontogeny) with that of the tribe (Phylogeny) is dependent on the phenomena of Heredity and Adaptation. When these are properly understood, and their fundamental importance in determining the forms of organisms recognized, we may go a step further, and say: Phylogenesis is the mechanical cause of Ontogenesis. The Evolution of the Tribe, which is dependent on the laws of Heredity and Adaptation, effects all the events which take place in the course of the Evolution of the Germ or Embryo.

The chain of different animal forms which, according to the Theory of Descent, constitutes the series of ancestors, or chain of forefathers of every higher organism, and hence also of man, always forms a connected whole. This unbroken succession of forms may be represented by the letters of the Alphabet A, B, C, D, E, etc., down to Z, in their alphabetical order. In apparent contradiction to this, the history of the individual evolution, or the Ontogeny of most organisms show us only a fragment of this series of forms, so that the interrupted chain of embryonic forms would be represented by something like: A, B, F, H, I, K, L, etc.; or, in other cases, thus: B, D, H, L, M, N, etc. Several evolutionary forms have, therefore, usually dropped out of the originally unbroken chain of forms. In many cases also (retaining the figure of the repeated alphabet) one or more letters, representing ancestral forms, are replaced in the corresponding places among the embryonic forms by equivalent letters of another alphabet. Thus, for example, in

place of the Latin B or D, a Greek B or Δ is often found. Here, therefore, the text of the biogenetic first principle is vitiated, while in the former case it was epitomized. This gives more importance to the fact that, notwithstanding this, the sequence remains the same, so that we are enabled to recognize its original order.

Indeed, there is always a complete parallelism between the two series of evolution. This is, however, vitiated by the fact that in most cases many forms which formerly existed and actually lived in the phylogenetic series are now wanting, and have been lost from the ontogenetic series of evolution. If the parallelism between the two series were perfect, and if this great fundamental law of the causal connection between Ontogeny and Phylogeny, in the strict sense of the word, had full and unconditional sway, we should only have to ascertain, with the aid of microscope and scalpel, the series of forms through which the fertilized human egg passes before it attains its complete development. Such an examination would at once give us a complete picture of the remarkable series of forms through which the animal ancestors of the human race have passed, from the beginning of organic creation to the first appearance of man. But this reproduction of the Phylogeny in the Ontogeny is complete only in rare instances, and seldom corresponds to the entire series of the letters of the alphabet. In fact, in most cases the epitome is very incomplete, and greatly altered and perverted by causes which we shall investigate hereafter. Hence we are seldom able to determine directly, by means of its Ontogeny, the different forms through which the ancestry of each organism has passed; on the contrary, we commonly find,—and not less so in the Phylogeny of man,—a number

of gaps. We are, however, able to bridge over the greater part of these gaps satisfactorily by the help of Comparative Anatomy, though not to fill them up directly by ontogenetic research. It is therefore all the more important that we are acquainted with a considerable number of lower animal forms which still find place in the history of the individual evolution of man. In such cases, from the nature of the transient individual form, we may quite safely infer the nature of the ancestral animal form.

For example, from the fact that the human egg is a simple cell, we may at once infer that there has been at a very remote time a unicellular ancestor of the human race resembling an Amœba. Again, from the fact that the human embryo originally consists merely of two simple germ-layers, we may at once safely infer that a very ancient ancestral form is represented by the two-layered Gastræa. A later embryonic form of the human being points with equal certainty to a primitive worm-like ancestral form which is related to the sea-squirts or Ascidiæ of the present day. But the low animal forms which constitute the ancestral line between the unicellular amœba and the gastræa, and further between the gastræa and the ascidian form, can only be approximately conjectured with the aid of Comparative Anatomy and Ontogeny. On account of a shortened process of Heredity, various ontogenetic intermediate forms, which must have existed phylogenetically, or in the ancestral lineage, have in the course of historic evolution gradually dropped out from these gaps. But notwithstanding these numerous and sometimes very considerable gaps, there is, on the whole, complete agreement between the two series of evolution. Indeed, it will be one of my principal objects to



prove the deep harmony, and original parallelism, between the two series. By adducing numerous facts, I hope to convince my readers that from the actually existing series of embryonic forms which can be shown at any time, we are able to draw the most important conclusions as to the genealogical tree of the human species. We shall thus be able to form a general picture of the series of animal forms which succeeded each other as the direct ancestors of man, in the long course of the history of the organic world.

In this phylogenetic significance of ontogenetic phenomena, it is of course most important to distinguish clearly and exactly between the original, palingenetic processes of evolution, and the later kenogenetic processes of the same. The term *Palingenetic process*<sup>8</sup> (or reproduction of the history of the germ) is applied to all such phenomena in the history of evolution as are exactly reproduced, in consequence of conservative heredity, in each succeeding generation, and which, therefore, enables us directly to infer the corresponding processes in the tribal history of the developed ancestors. The term *Kenogenetic process*<sup>9</sup> (or vitiation of the history of the germ) is applied to all such processes in the germ-history as are not to be explained by heredity from primæval parent-forms, but which have been acquired at a later time in consequence of the adaptation of the germ, or embryo form, to special conditions of evolution. These kenogenetic processes are recent additions, which do not allow of direct inference as to the corresponding processes in the tribal history of the ancestral line, but which rather falsify and conceal the latter.

This critical distinction between the primary palingenetic, and the secondary kenogenetic processes is of course

of the greatest importance to scientific Phylogeny, which, from the available empiric material supplied by Ontogeny, by Comparative Anatomy, and by Palæontology, seeks to infer the long extinct historical processes of tribal evolution. It is of the same importance to the student of evolution as is the critical distinction between corrupt and genuine passages in the text of an old writer to the philologist; the separation of the original text from interpolations and corrupt readings. This distinction between Palingenesis or inherited evolution, and Kenogenesis or vitiated evolution, has not, however, yet been sufficiently appreciated by naturalists. But I believe that it is the first condition requisite, if the history of evolution is to be really understood, and I think that two separate main divisions, based on this distinction, must be made in germ-history; Palingenesis or inherited history, and Kenogenesis or vitiated history.

Let us illustrate this highly important distinction by a few examples taken from the evolution of man. In Man, as in all other higher Vertebrates, the following incidents of germ history must be regarded as palingenetic processes: the formation of the two primary germ-layers, the appearance of a simple notochord (*Chorda*) between the spinal tube and the intestinal tube, the transitory formation of gill-arches and gill-openings, of primitive kidneys, of the primitive brain bladder, the hermaphrodite rudiment of the sexual organs, etc. All these, and many other important phenomena have evidently been accurately handed down, by constant heredity, from the primæval ancestors of Mammals, and must, therefore, be referred directly to corresponding palæontological evolutionary incidents in the history of the tribe. On the other hand, this is not the case with the following germinal



incidents, which must be explained as kenogenetic processes; the formation of the yolk-sac, of the allantois and placenta, of the amnion and chorion, and, generally, of the different egg-membranes and the corresponding systems of blood-vessels; also the transitory separation of the primitive vertebrate plates and the side-plates, the secondary closing of the stomach wall and the intestinal wall, the formation of the navel, etc. All these, and many other phenomena are evidently not referable to corresponding conditions of an earlier, independent, and fully developed parent form, but must be explained as solely due to adaptation to the peculiar conditions of egg-life or embryo-life (within the egg-membranes). With reference to this fact we may now define our "first principle of Biogeny" more exactly as follows: "The evolution of the germ (Ontogeny) is a compressed and shortened reproduction of the evolution of the tribe (Phylogeny); and, moreover, this reproduction is more complete, in proportion as, in consequence of constant heredity, the original inherited evolution (Palingenesis) is more closely retained; on the other hand, the repetition is more incomplete, in proportion as the later vitiated evolution (Kenogenesis) is introduced by changing adaptation."<sup>10</sup>

The kenogenetic vitiations of the original, palingenetic incidents of evolution depend in great measure on a gradually occurring displacement of the phenomena, which is effected in the course of many thousands of years by adaption to the changed conditions of embryonic existence. This displacement may effect either the place or the time of the phenomena. If the former, it is called Heterotopy; if the latter, Heterochrony.

"Displacement in position," or "Heterotopy," especially affects the cells or elementary parts which compose the organs; but it also affects the organs themselves. For example, the sexual organs of the human embryo, as well as those of many higher animals, appear to originate from the middle germ-layer. But the comparative Ontogeny of the lower animals shows, on the other hand, that these organs did not originally arise from this layer, but from one of the primary germ-layers; the male sexual organs from the outer germ-layer, the female from the inner. Gradually, however, the germ-cells have altered their original site, and have made their way, at an early period, from their original position into the middle germ-layer, so that they now appear actually to originate in the latter. An analogous heterotopism affects the primitive kidneys in the higher Vertebrates. Even the appearance of the mesoderm itself is very greatly affected by a displacement in position, which is connected with the transition of embryo cells from one germ-layer into another.

The kenogenetic "displacements in time," or "Heterochronisms," are equally significant. They are seen in the fact that in the germ-history (Ontogeny) the sequence in which the organs appears differs from that which, judging from the tribal history (Phylogeny), would be expected. By heterotopy the sequence in position is vitiated; similarly, by heterochrony the sequence in time is vitiated. This vitiation may effect either an acceleration or a retardation in the appearance of the organs. We must regard the following incidents in the germ-history of man as examples of ontogenetic acceleration: the early appearance of the heart, the gill-openings, the brain, the eyes, the chorda,

etc. It is evident that these organs appear earlier in relation to others than was originally the case in the history of the tribe. The reverse is true of the retarded completion of the intestinal canal, the body-cavity, and the sexual organs. It is evident that in these cases there is an ontogenetic postponement or retardation.

It is only by critically appreciating these kenogenetic incidents in relation to the palingenetic, and by constantly allowing for the changes in inherited evolution effected by vitiated evolution, that it is possible to recognize the fundamental significance of the first principle of Biogeny, which in this way attains its true value as the most important explanatory principle of the history of evolution. When it is thus critically appreciated, this first principle also proves to be the "red thread" on which we can string every one of the phenomena in this wonderful domain; this is the thread of Ariadne, with the aid of which alone we are able to find an intelligible course through this complicated labyrinth of forms. Even at an earlier period, when the history of the evolution of the human and the animal individual first became somewhat more accurately known—which is hardly half a century ago!—people were greatly surprised at the wonderful similarity existing in the ontogenetic forms, or the stages of the individual evolution, of very different animals. They noticed also the remarkable resemblance between these and certain developed animal forms of allied lower groups. Even the older natural philosophers recognized the fact that in a certain way these lower animals permanently represent in the system of the animal kingdom forms which appear transiently in the evolution of individuals of higher groups. But formerly

it was impossible to understand and interpret aright this remarkable resemblance. Darwin's greatest merit is that he has now enabled us to understand this circumstance. This gifted naturalist was the first to place the phenomena of Heredity on the one hand, and of Adaptation on the other, in their true light, and to show the fundamental significance of their constant interaction in the production of organic forms. He was the first to point out the important part played by the continual Struggle for Existence in which all organisms take part, and how under its influence, through Natural Selection, new species of organisms have arisen, and still arise, entirely by the interaction of Heredity and Adaptation. Darwin thus enabled us properly to understand the immensely important relation existing between the two divisions of the History of Evolution: Ontogeny, and Phylogeny.

If the phenomena of Heredity and Adaptation are left unnoticed, if these two formative physiological functions of the organism are not taken into account, then it is entirely impossible thoroughly to understand the History of Evolution; so that before the time of Darwin we had no clear idea of the real nature and causes of the development of germs. It was utterly impossible to explain the strange series of forms through which a human being passes in its embryonic evolution; it was impossible to comprehend the reason of the curious series of various animal-like forms which appear in the Ontogeny of man. Previously it was even generally believed that the whole human being, with all its parts foreshadowed, existed even in the egg, and that his evolution was only an unfolding of the form, a simple process of growth. But this is not at all the case. On the contrary,



the entire process of the evolution of the individual presents to the eye a connected series of diverse animal forms; and these various animal forms exhibit very diverse conditions of external and internal structure. The reason why every human individual must pass through this series of forms in the course of his embryonic evolution, was first explained to us by the Theory of Descent of Lamarek and Darwin. From this theory we first learn the efficient causes (*causæ efficientes*) of individual evolution; by the aid of this theory we first perceive that such mechanical causes alone suffice to effect the evolution of the individual organism, and that the co-operation of designing, or teleological causes (*causæ finales*), which were formerly universally assumed, is unnecessary. Of course, these final causes still play an important part in the prevailing school-philosophy; but in our new natural philosophy we are enabled to replace them entirely by the efficient causes.

I allude to this matter at this early stage, in order to call attention to one of the most important advances made in any branch of human knowledge during the past ten years. The history of philosophy shows that in the cosmology of our day, as in that of antiquity, final causes are almost universally deemed to be the real ultimate causes of the phenomena of organic life, and especially those of the life of man. The prevailing Doctrine of Design, or Teleology, assumes that the phenomena of organic life, and in particular those of evolution, are explicable only by purposive causes, and that, on the contrary, they in no way admit of a mechanical explanation, that is, one entirely based on natural science. The most difficult problems in this respect which have been before us, and which seemed capable of

solution only by means of Teleology, are, however, precisely those which have been mechanically solved in the Theory of Descent. The reconstruction of the history of the evolution of man, which this theory has effected, has actually removed the greatest difficulties. We shall see in the course of our inquiries how, through Darwin's reform of the Doctrine of Evolution, the most wonderful problems, hitherto deemed unapproachable, of the organization of man and animals have admitted of a natural solution, of a mechanical explanation, by non-purposive causes. It has enabled us to substitute everywhere unconscious causes acting from necessity, for conscious purposive causes.<sup>11</sup>

If the recent progress in the Doctrine of Evolution had accomplished only this, every thoughtful person must have admitted that even in this an immense advance had been made in knowledge. In consequence of it, the tendency called unitary or monistic, in contradistinction to the dualistic, or binary, which has heretofore prevailed in speculative philosophy, must ultimately prevail throughout philosophy.<sup>12</sup> This is the point at which the history of the evolution of man at once penetrates deeply into the very foundations of philosophy. For this reason alone it is very much to be desired, in fact is indispensable, that any one who aspires to philosophic culture should learn the most important facts in this field of research.

The significance of the facts of Ontogeny is so great and so evident that the dualistic teleological philosophy, finding them extremely inconvenient, has of late endeavoured to meet them by simple denial. Such, for instance, has been the case with the fact that every human being develops from an egg, and that this egg is a simple cell, like the egg-



cell of all other animals. When in my "History of Creation" I had discussed this fundamental fact, and had directed attention to its immense significance, several theological periodicals pronounced it a malicious invention of my own. The evident fact that at a certain stage of their evolution the embryos of Man and of the Dog are entirely indistinguishable from one another was also denied.

The fact is that an examination of the human embryo in the third or fourth week of its evolution shows it to be altogether different from the fully developed Man, and that it exactly corresponds to the undeveloped embryo-form presented by the Ape, the Dog, the Rabbit, and other Mammals, at the same stage of their Ontogeny. At this stage it is a bean-shaped body of very simple structure, with a tail behind, and two pairs of paddles, resembling the fins of a fish, and totally dissimilar to the limbs of man and other mammals, at the sides. Nearly the whole of the front half of the body consists of a shapeless head without a face, on the sides of which are seen gill-fissures and gill-arches as in Fishes. (Cf. Plate VII. at the end of Chapter XI.) In this stage of evolution the human embryo differs in no essential way from the embryo of an Ape, Dog, Horse, Ox, etc., at a corresponding age. Even such facts as these, which can be easily and promptly demonstrated at any time by placing side by side the corresponding embryos of Man, a Dog, a Horse, etc., have been spoken of by theologians and teleological philosophers as inventions of materialism; and even naturalists, who were presumably acquainted with them, have tried to deny them. No stronger proof, surely, of the immense radical importance of these embryological facts in favour of the monistic philosophy can be given than

these efforts on the part of the dualistic school to meet them by simple denial or utter silence. They are indeed extremely distasteful to that school, and are totally irreconcilable with their teleological cosmology. We must therefore take especial care to place them in their true light. We are entirely of the opinion of Huxley, who, in his able "Evidence as to Man's Place in Nature," says that these facts, "though ignored by many of the professed instructors of the public mind, are easy of demonstration, and are universally agreed to by men of science; while their significance is so great, that whoso has deeply pondered over them will, I think, find little to startle him in the other revelations of Biology."

Although our chief inquiry is primarily directed to the history of the evolution of the bodily form of Man and of his organs, and to their external and internal structural relations, I must here at once observe that the history of the evolution of the functions is inseparably connected with this. Everywhere in Anthropology, just as in Zoology, of which the former is but a part, and throughout the whole field of Biology, these two branches of research are thus inseparably connected. The peculiar form of the organism and its organs, both internal and external, is always closely related to the peculiar manifestations of life, of the organism and its organs, or, in other words, to the physiological functions performed by these. This intimate relation between form and function is also shown in the evolution of the organism and its various parts. The history of the evolution of forms, which primarily occupies us, is at the same time the history of the evolution of functions; and this is equally true of the human and of all other organisms.

But I must here add at once, that our knowledge of the evolution of functions is as yet far from being so advanced as our knowledge of the evolution of forms. Indeed, properly speaking, the entire history of evolution, or Biogeny, including both Ontogeny and Phylogeny, has as yet been almost exclusively a history of the evolution of forms, while the Biogeny of functions hardly exists even in name. The fault lies solely with Physiology, which has as yet scarcely given a thought to the history of evolution, which it has left entirely to the care of Morphology.

The two chief divisions of biological research—Morphology and Physiology—have long travelled apart, taking different paths. This is perfectly natural, for the aims, as well as the methods, of the two divisions are different. Morphology, the science of forms, aims at a scientific understanding of organic structures, of their internal and external proportions of form. Physiology, the science of functions, on the other hand, aims at a knowledge of the functions of organs, or, in other words, of the manifestations of life.<sup>18</sup> Physiology, however, has, especially during the last twenty years, been far more one-sided in its progress than Morphology. Not only has it entirely neglected to apply the comparative method, by which Morphology has gained its greatest results, but it has altogether disregarded the History of Evolution. Hence it has come to pass that, within the past few decades, Morphology has advanced far beyond Physiology, although the latter is pleased to look haughtily down upon the former. It is Morphology which has gained the greatest results in the fields of Comparative Anatomy and Biogeny, and almost everything stated in these pages as to the History of the Evolution of Man, is due to the

exertions of morphologists, and not of physiologists. Indeed the direction at present taken by Physiology is so one-sided that it has even neglected the recognition of the most important functions of Evolution, namely, Heredity and Adaptation, and has left this entirely physiological task to morphologists. We owe to morphologists, and not to physiologists, nearly all that we yet know of Heredity and Adaptation. The latter still works as little at the functions of evolution as at the evolution of the functions.

It will, therefore, be the task of a future Physiology to grasp the history of the evolution of the functions with the same earnestness, and with the same success, with which Morphogeny has long ago undertaken the study of the history of the evolution of forms. A few instances will show how closely the two are connected. The heart of the human embryo has at first a very simple structure, such as appears permanently only in Ascidians and other inferior Worms, and connected with it is a circulation of the blood of the most simple kind. When, on the other hand, we see that with the fully developed form of the human heart there is connected a function of the circulation of the blood totally different from the former one, and far more complicated, the study of the evolution of the heart necessarily enlarges from a task which was originally morphological to one which is physiological also. It is the same in the case of all other organs and their activities.

Thus, for instance, a careful comparative study of the history of the evolution of the form of the intestinal canal, the lungs, and the organs of generation, affords us also most important information as to the evolution of the respective functions of these organs.



This important relation is most clearly seen in the history of the evolution of the nervous system. In the economy of the human body, this system performs the functions of sensation, of voluntary movement, volition, and finally the highest psychological functions, namely, those of thought; in a word, every one of the various activities which constitute the special subject of Psychology, or the science of the mind. Modern Anatomy and Physiology have demonstrated that these functions of the mind, or psychic activities, are immediately dependent upon the more delicate structure of the central nervous system, upon the internal conditions of the form of the brain and the spinal marrow. Here are placed the extremely complex mechanism of cells, whose physiological function constitutes the mind-life of Man. It is so complex that to most people its function appears to be something supernatural, and incapable of mechanical explanation. But the history of the evolution of the individual furnishes us with the most surprising and significant information as to the gradual origin and progressive formation of this most important system of organs. For the first rudiment of the central nervous system in the human embryo makes its appearance in the same most simple form in which Ascidians and other inferior Worms retain it throughout life. A perfectly simple spinal marrow, without brain, such as throughout its existence represents the organ of the mind of the Amphioxus, the lowest of Vertebrates, first develops from this rudiment. It is only at a later period that a brain develops from the anterior extremity of this spinal cord, and this brain is of the simplest form, similar to the permanent form of this organ in the lower Fishes. Step by step this simple brain develops still further, passing through forms corresponding to those of

the Amphibia, Beaked Animals (*Ornithostoma*), Pouched Animals, or Marsupials, and Semi-apes (*Prosimiæ*), until the highly organized form is reached which distinguishes the Apes from all other Vertebrates, and which finally attains its highest development in the human brain. But step by step with this progressive evolution of the form of the brain, the evolution of its peculiar function, the psychological activities, moves on hand in hand, and it is therefore the history of the evolution of the central nervous system which for the first time enables us to understand the origin of life of the human mind from natural causes, and the gradual historic development of the psychic activities of man. It is impossible without the aid of Ontogeny to perceive how these highest and most brilliant functions of the animal organism have been historically developed. In a word, the history of the evolution of the spinal marrow and the brain of the human embryo at the same time directly leads us to understand the Phylogeny of the human mind, that most sublime activity of life which in the developed human being we are accustomed to regard as something wonderful and supernatural.

There is no doubt that this special result of the study of the history of evolution is among the greatest and most important. Happily, our knowledge of the Ontogeny of the central nervous system of Man is so satisfactory, and agrees so perfectly with the supplementary results of Comparative Anatomy and Physiology, that it affords us a perfectly clear insight into one of the highest problems of philosophy, namely, the Phylogeny of the *psyche*, the mind, or the history of the ancestral lineage of Man's psychic activities, and leads us into the only path by which we shall ever be able to solve this the highest of all problems.



## EXPLANATION OF PLATES VI. AND VII.

Plates VI. and VII. are meant to represent the more or less complete agreement, as regards the most important relations of form, between the embryo of Man and that of other Vertebrates in early stages of individual development. This agreement is the more complete, the earlier the period at which the human embryo is compared with those of other Vertebrates. It is retained longer, the more nearly related in descent the respective matured animals are—corresponding to the “law of the ontogenetic connection of systematically related forms.” (Cf. Chapter XII., p. 366.)

Plate VI. represents the embryos of two of the lower, and two of the higher Vertebrates in three different stages: of a Fish (Osseous-fish, *F*); of an Amphibian (Land-salamander, *S*); of a Reptile (Tortoise, *T*); and of a Bird (Chick, *C*).

Plate VIII. shows the embryos of four Mammals in the three corresponding stages: of a Hog (*H*), Calf (*C*), Rabbit (*R*), and a Man (*M*). The conditions of the three different stages of development, which the three cross-rows (I., II., III.) represent, are selected to correspond as exactly as possible.

The first, or upper cross-row, I., represents a very early stage, with gill-openings, and without limbs. The second (middle) cross-row, II., shows a somewhat later stage, with the first rudiments of limbs, while the gill-openings are yet retained. The third (lowest) cross-row, III., shows a still later stage, with the limbs more developed and the gill-openings lost. The membranes and appendages of the embryonic body (the amnion, yelk-sac, allantois) are omitted. The whole twenty-four figures are slightly magnified, the upper ones more than the lower. To facilitate the comparison, they are all reduced to nearly the same size in the cuts. All the embryos are seen from the left side; the head extremity is above, the tail extremity below; the arched back turned to the right. The letters indicate the same parts, in all the twenty-four figures, namely: *v*, fore-brain; *z*, twixt-brain; *m*, mid-brain; *h*, hind-brain; *n*, after-brain; *r*, spinal marrow; *e*, nose; *a*, eye; *o*, ear; *k*, gill-arches; *g*, heart; *w*, vertebral column; *f*, fore-limbs; *b*, hind-limbs; *s*, tail.<sup>100</sup>

