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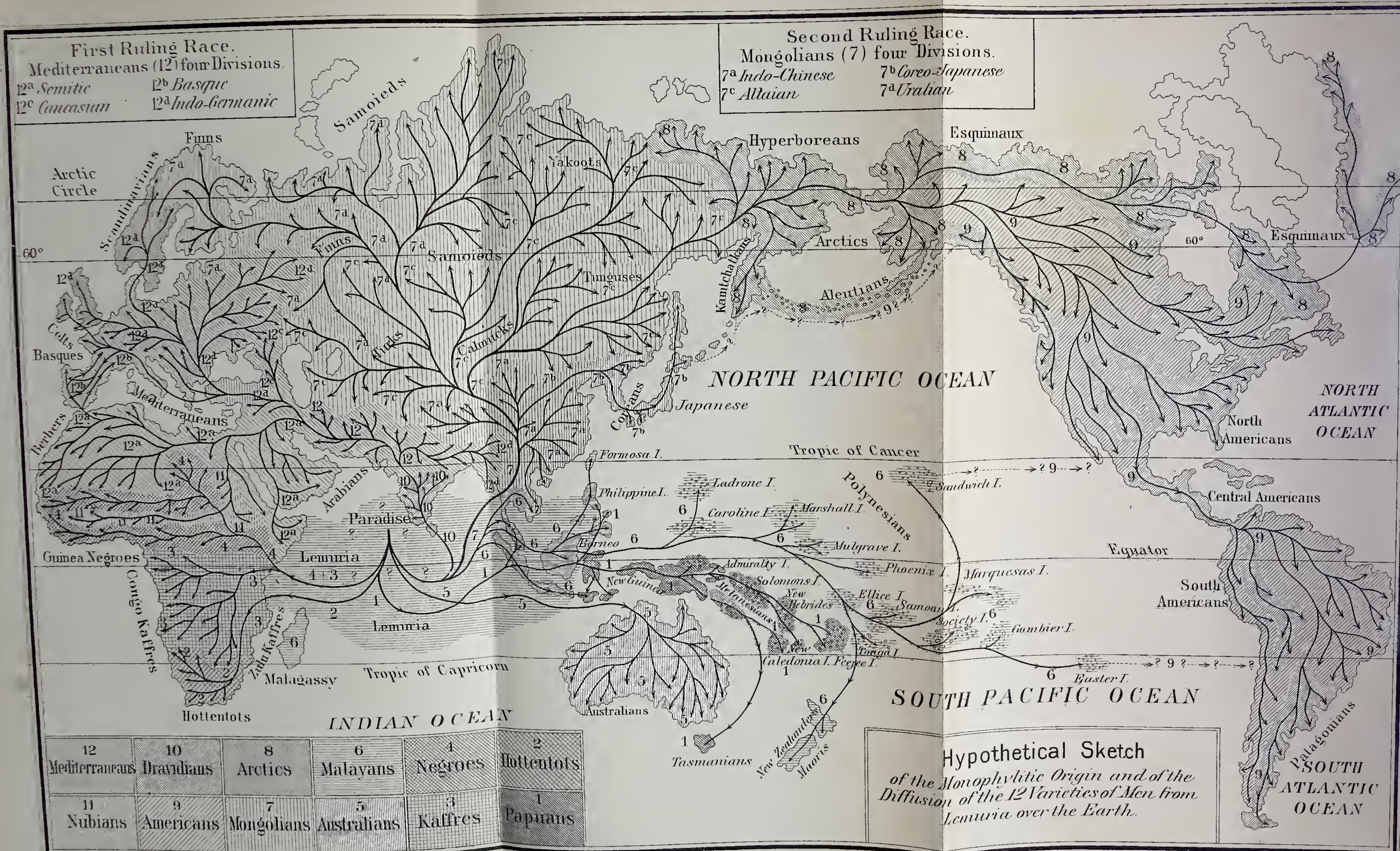

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EVOLUTION OF LIFE.

BY

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"Full fathom five thy father lies;
  Of his bones are coral made;
Those are pearls that were his eyes;
  Nothing of him that doth fade
But doth suffer a sea-change
Into something rich and strange."

SHAKSPEARE.

"If we were capable of following the progress of increase of the number of the parts of the most perfect animal, as they first formed in succession, from the very first to its state of full perfection, we should probably be able to compare it with some one of the incomplete animals themselves, of every order of animals in the creation, being at no stage different from some of the inferior orders."

JOHN HUNTER.

PHILADELPHIA:

J. B. LIPPINCOTT & CO.

1873.

TO

MRS. C. B. P.,

AS A

VERY SMALL ACKNOWLEDGMENT

OF THE

INTEREST EVINCED AND ENCOURAGEMENT EXTENDED

IN THE

COMPLETION OF THIS ESSAY.

HENRY C. CHAPMAN.

PREFACE.

SINCE 1858, the year in which appeared Mr. Darwin's famous book, the literary as well as the scientific world has been deluged with works—great and small—on the subject of the Origin of Species. Notwithstanding, however, the great number of works that have been published in England, Germany, France, and Italy treating of the Development Theory, the Origin of Man, etc., there appears to be still a great deal of misunderstanding in reference to these subjects. It did not seem, therefore, superfluous to bring together a condensed view of the evidences for the theory that the animal and vegetal worlds have been very gradually developed or evolved, as distinguished from the hypothesis of their sudden special creation. We have endeavored to place before the reader, in as popular a manner as possible, the most important generalizations in reference to the structure of plants and animals, their petrified remains, and mode of development, and to point out how the theory of the Evolution of Life follows from the acts of Anatomy, Geology, and Embryology. While we have little new to offer to those who are familiar with the works of Lamarck, Darwin, Wallace, Spencer, Owen, Huxley, Hooker, Lyell, Haeckel, Gegenbaur, Buchner, Vogt, Virchow, Moleschott, Müller, Rolle, Schleicher, Bleek, Meigs, Gliddon, Leidy, Cope, Gray, etc., to the medical and literary world generally, however, whose acquaintance with the writings of the distinguished savans just mentioned is necessarily superficial from the nature of their pursuits, we offer a brief but, we hope, a sufficiently detailed account of a subject which is not surpassed in interest by any other. We take this opportunity of thanking Prof. Hyrtl, Dr. Friedlowsky, Dr. Klein, of Vienna, Prof. Owen, Mr. Flower, of London, and Prof. Gervais, of Paris, for their kindness in furnishing many facilities for study, as also of acknowledging our indebtedness to Profs. Leidy and Aitken Meigs for their many favors and suggestions, and to Dr. Nolan for materially assisting us in seeing this essay through the press.

HENRY C. CHAPMAN.

PARIS, June 21, 1872.

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INTRODUCTION.

By the Evolution of Life we mean the slow and gradual development of life as distinguished from its special and sudden creation; that plants and animals are the modified descendants of pre-existing organisms, not the unchanged posterity of similar forms of life originally specially created. Let us illustrate our meaning by considering the origin of a common animal like the Horse. According to the creation hypothesis, all horses are the descendants of a pair of horses, originally, specially created. Supposing the Evolution theory, however, to be true, the Horse is the modified descendant of an extinct species of Horse, the Hipparion. Preceding the Hipparion there lived the Anchitherium, whose organization bears the same relation to the Hipparion that the Hipparion's does to that of the Horse; while in a still earlier period we find in the Paleotherium the ancestor of the Anchitherium. But the Rhinoceros and the Tapir are also nearly related to the Paleotherium. We see, therefore, why all naturalists are agreed in regarding the Horse, Rhinoceros, and Tapir as the representatives of one group. For, if these animals are the posterity of a common ancestor, it is natural that their organization should have much in common. Through extinct forms, like the Xiphodon and Anthracotherium, the Ruminating animals, the Pig, and the Hippopotamus, are linked with the Anoplotherium; while glancing at Tree VII. we see that the Paleotherium and Anoplotherium are regarded as the descendants of a common stock, represented by extinct forms, like Coryphodon and Lophiodon. Basing the investigation on the facts of Anatomy, Embryology, and Geology, the genealogy of the animal and vegetal kingdoms has, in this manner, been more or less made out, the indefinitely remote ancestors of all plant and animal life being represented by the Monera, structureless, infinitely small, jelly-like beings, belonging neither to the animal nor to the vegetal kingdom. This view of the gradual development of existing forms of life from pre-existing ones is in harmony with the conclusions of other sciences. Most ethnologists are agreed that the different races of men have descended from a common stock, notwithstanding the great differences exhibited in color, shape of the head, and character of the hair. Philologists derive the various languages from one of three or four roots. The history of Art offers us interesting illustrations of the doctrine of Evolution. Thus, the present perfection of music has been attained only through very gradual additions from time to time. Modern orchestration is so complicated that one would hardly believe that it could have been developed out of the simple jingle of barbarians. Astronomers think it highly probable that our solar system was once a chaotic mass, and that from this the planets were thrown off, the central body becoming later the Sun. This theory, which is commonly known as the Nebular Hypothesis of La Place, naturally suggests the name of Kant, the famous philosopher of Königsberg, who first distinctly enunciated the view of the gradual development of the solar system, and the doctrine of Evolution in general. But as the differentiation of the simple into the complex, of the homogeneous into the heterogeneous, of which the development of race and language is an example, has been fully discussed by Mr. Herbert Spencer in his different works, we therefore pass on to the consideration of the objection, that while the origin of races, of languages, of the stars, etc. is a legitimate object of study, the origin of plants and animals is an inquiry of an entirely different nature,—a subject about which man can learn nothing. Those who are continually referring to the mysteriousness of Life as an objection to its study, seem to forget that the ultimate causes of all other phenomena, such as the falling of an apple, the combining of elements, the crystallization of a salt, etc., are equally mysterious. The forces by which these phenomena are brought about are studied in their effects; and the laws according to which these effects are produced belong to Astronomy, Chemistry, Crystallography. But of the cause or essence of gravitation we know nothing. We can only say that bodies attract one another according to a certain law. Equally unknown is the ultimate cause of crystallization. We can only say that in saline solutions, under favorable conditions, according to law, geometrical forms are produced. Compare now the growth of a crystal with that of a plant or an animal. If a seed be sown and it attract certain elements from the soil, a definite form, a plant, is produced; in the same way the chick results from the embryo attracting the material of its future body from the yelk. The laws governing the forces by which these effects are brought about, the phenomena of the growth of a plant or of an animal, are as legitimate objects of study as the growth of a crystal. The nature of the inquiry is the same: the study of the growth of a crystal differing from that of a plant or an animal not in kind but only in degree; the investigation being in each case the redistribution of matter, for there is nothing in the crystal that did not pre-exist in the saline solution, nothing in the plant that was not derived from the seed or the soil, nothing in the chicken that did not pre-exist in the egg or in the air. The ultimate cause of the so-called Vital Force is as unknowable as the cause of all other kinds of Force. The laws, however, by which the effects of the so-called Vital

Force are brought about, will be worked out exactly as the laws of other Forces have been. And as the difficulties experienced in the study of the so-called vital phenomena are due to their complexity as compared with the simplicity of the so-called physical ones, it is quite natural that the organic sciences should be less advanced than the inorganic. These terms, however, Organic and Inorganic, Vital and Physical, Animate and Inanimate, Living and Dead, are very unphilosophical, since their use implies an entirely false view of Nature. The classification of objects into Animal, Vegetal, and Mineral, is a good arrangement for study; but it is a purely artificial one, no such distinction existing in Nature. The usual tests for distinguishing animals from plants, plants from minerals, have been rendered perfectly worthless by the discoveries of late years. Living beings like the Monera, representatives of a kingdom intermediate between the animal and the vegetal, are so structureless, so absolutely homogeneous, that crystals are complex bodies as compared with them. Products like sugar and alcohol, supposed at one time to be purely organic in their origin, to be produced only by the so-called Vital Force, are now made in laboratories by the combination of their inorganic elements. There are no substances in the Organic world whose elements are not resolvable into those of the Inorganic, no Vital Forces which are not convertible into Physical ones. In a word, no one can show where the Inorganic world ends and the Organic begins, the transition being so gradual. The objection is therefore groundless that the study of life is entirely different from that of all other phenomena, and that one can learn little about it. On the contrary, we have every reason to expect that in time we shall have a Science of Life, or Biology, a Science which will bear the same relation to Zoology and Botany that History does to mere Chronicle; that will tell us not only what plants and animals live and have lived, but why some died out and others survived; whether these survivors were modified, and, if so, by what means; why certain plants and animals are found in places not best suited to their structure; why similar forms of life are not always found under similar physical conditions, and why dissimilar plants and animals are often found under similar physical conditions; why animals have organs of no use to them; why some animals are protected, why others are not, etc. etc. We consider that these questions are answered by the theory of the Evolution of Life, and that this theory may be regarded as the fundamental truth of Biology. We propose in this essay to bring together, in as popular a manner as possible, some of the evidence in favor of this theory, endeavoring to show that the different plants and animals are linked together by transitional forms; that there has been a progress from the simple, lowly organized, to the highly complex forms of life; that the transitional stages through which a plant or an animal passes in the development from its primitive to its adult condition are permanently retained in the lower forms of life; that the development of the higher forms of life from the lower has been brought about by Natural Selection; and that Man has descended from a lower extinct form, of which the Gorilla and the Chimpanzee are the nearest living representatives.

Before discussing these different subjects, as there seems to be still some misunderstanding in reference to the views of the predecessors of Mr. Darwin, the most distinguished of the advocates of the Evolution of Life, it may be perhaps not superfluous to glance at the literature of the subject. Here and there among the writings of the ancients, one meets with passages, and even works, like those of Lucretius, from which it is evident that at different times some doctrine like that of the Evolution of Life was held by the thinkers of antiquity. Passing by the speculations of

De Maillet, the first attempt in modern times to bring together the evidence in favor of the Evolution of Life, with the causes sufficient to produce it, is to be found in the writings of Lamarck,—the Philosophical Zoology (1809), and the History of Animals without Vertebræ (1815). Lamarck was Professor of Zoology at the Garden of Plants, in Paris, and, far from being a mere dreamer, was an eminent naturalist, as every one admits, whatever may be thought of his speculations. Many of these speculations, however, are regarded by distinguished living Biologists as profound truths, such as, that "there is no distinct vital principle," that "life is only a physical phenomenon," that "the nervous system produces ideas, and all the acts of the intelligence," etc.

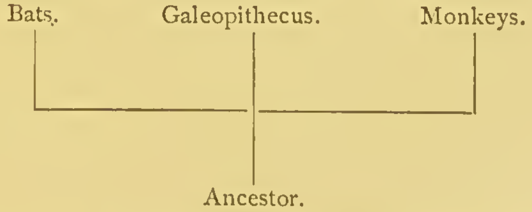
In the works just alluded to, Lamarck, basing his views on the structure of plants and animals, and their petrified remains, develops the theory of there having been a progress in the organic world from the simpler forms of life to the higher; that all organisms in the lapse of ages had descended from pre-existing ones. As causes of the transmutation of species, Lamarck held that the force of the will, as exhibited in the use and disuse of organs, exercised great influence in modifying the structure of animals; he attached also great importance to the facts of inheritance. While it is admitted that there is a great deal in the writings of Lamarck that cannot be maintained, still, he must be considered as the first who attempted to develop in detail the theory of the Evolution of Life, and one of its most distinguished advocates. Noticing that Lamarck held that the Monkey descent of Man, previously advocated by Monboddo, was a necessary consequence of his theory, we pass on to Geoffroy St.-Hilaire, the distinguished and constant opponent of Cuvier in the discussions on the Origin of Species at the Garden of Plants. Although for a long time St.-Hilaire had thought as Lamarck, it was not till 1828 that in his essay "On the Principle of the Unity of Organic Composition" he openly defended the doctrine of the transmutation of species. While in France Lamarck and St.-Hilaire were studying the transmutation of species, Goethe and Oken were investigating the same subject in Germany. Goethe is famous as a poet, but is not so well known as a man of science. He, however, made the capital discovery of the intermaxillary bone in Man, which gives him rank as an anatomist, while his theory of the "Metamorphosis of Plants" has always been regarded as a most important contribution to philosophical Botany. In this work on Plants, Goethe develops the view of the different parts of the flower being modified leaves. This theory, which is a beautiful illustration of Evolution, had been previously promulgated by Wolff, but had fallen into perfect oblivion. Goethe was always pointing out the "unity of Nature," and advocating the doctrine of Development, and must be considered one of the most distinguished of the German Biologists. Oken was one of the most remarkable men Germany has ever seen, not only for the extent of his knowledge, but for the originality of his views. Although his ideas are very often mystified by obscure language, nevertheless it is certain that he had a clear perception of some of the most important modern truths, such as the mechanical theory of Heat, the doctrine of Cells, etc. His idea of a "primordial mucosity" as the basis of life is very much like that of the "protoplasmic" doctrine of the present day. However this may be, there is no doubt that Oken was a firm believer in the Development theory of Lamarck.

Notwithstanding that the theory of the Transmutation of Species was defended by men of such ability as Lamarck, St.-Hilaire, Goethe, and Oken, it fell entirely into disrepute after 1830, the year of the famous discussion between Cuvier and St.-Hilaire at the Academy of Sciences. From that time the question of the origin of species was considered transcendental, not a subject for inquiry. It seems proper now to mention the influence of the "Principles of Geology," by Sir Charles Lyell, published in 1832. The doctrine of Catastrophes, or the supposition that at different times all life had been destroyed by the convulsions through which the earth had passed, and that a new life had been created from time to time, was supported by the high authority of Cuvier. Lyell, in the work just mentioned, put forward the view that these catastrophes had been only local, and that they had been brought about by the same forces that are now modifying the earth; that life has always existed,—new forms appearing, old forms passing away; that disturbances have taken place at different times in different places, just as at present we have earthquakes, volcanic eruptions, etc. This view is at present accepted by most Geologists, very few believing any longer in the Cuvierian theory of the "Revolutions of the Globe." The effect of the "Principles of Geology" on the progress of the Development theory was very great, since one of the objections to it, of life having been often extinct all over the globe, was therein shown to be groundless. Although the doctrine of Development was opposed by naturalists, nevertheless from time to time it was advocated, as in 1837 by Dean Herbert, in 1844 by the anonymous author of the Vestiges of Creation, in 1846 by D'Omalius d'Halloy, in 1852 by Naudin, in 1855 by the Rev. Baden Powell and by Büchner, and from 1852 to 1858 by Mr. Herbert Spencer. Remembering the vast discoveries that had been made since the days of Lamarck in Zoology, Botany, Geology, that the study of Embryology had been raised to a science, that of the Geographical Distribution of plants and animals more was known, etc., let us now call attention to the famous book on the Origin of Species, by Mr. Darwin. The two great merits of this work are its bringing together in a condensed form the evidences in favor of the Evolution of Life, and its offering Natural Selection as a cause of this Evolution. We will not dwell now on Natural Selection, as we endeavor to explain it in a chapter devoted to that subject. It seems proper, however, to mention that the discovery of Natural Selection was made independently by Mr. Wallace, who, having spent seven years in the Malay Archipelago, sent a paper to London containing his views on the Origin of Species. Following the advice of mutual friends, Mr. Darwin brought forward an abstract of his views, and the two papers appeared simultaneously in the publications of the Linnæan Society. Since the publication of the Origin of Species, many works have appeared in which this subject is discussed more or less in detail, among which may be mentioned the later ones of Messrs. Darwin and Wallace; the General Morphology and Natural History of Creation, by Prof. Haeckel; the Principles of Biology, by Mr. Herbert Spencer; the various works of Dr. Büchner; the Origin of Species, etc., by Prof. Huxley; the Introduction to the Flora of Tasmania, by Sir William Hooker; the Comparative Anatomy of Prof. Gegenbauer; the Crustacea of Fritz Müller; the different papers by Prof. Cope, etc. etc.

Hoping now to have made clear the general object of our essay, to have shown how gradual has been the development of the theory of the Evolution of Life, and having merely noticed some of the important literature on the subject, we pass on to the consideration of the Evidences, the Causes, and the Consequences of this Evolution.

ZOOLOGY.

One cannot glance at the opening pages of any work on Zoology without being struck with the difficulty that naturalists experience in classifying the objects of their study. This difficulty arises from the fact of there being many animals whose organization presents characters which combine the peculiarities of different families or orders. The Flying Lemur (Galeopithecus volans) of the East Indies was for a long time considered to be a bat; modern anatomists place it among the monkeys, and yet, according to some authorities, the grounds for its determination in the one case are as good as in the other. If the Galeopithecus, the monkeys and the bats originally appeared as we find them now, why should there be such a difficulty in determining their place in the Animal Kingdom? If, however, there has been an order of Galeopitheci, of which the present species are the only surviving representatives, and we regard these extinct forms as the common ancestors of the bats and the monkeys, we have an explanation of the peculiarities which are shared by these three orders:



If the theory of the gradual transformation of animals be true, it is quite natural that we should find transitional forms, such as the Flying Lemur. There are many similar examples: the Aye-Aye (Cheiromys) has teeth like a rat, while in other respects it is a monkey. The Duck-bill Platypus of Australia (Ornithorhynchus) combines the organization of lizard in its breast-bone, crocodile in its ribs, and bird in the skull and digestive apparatus, and yet is a four-footed animal.

KINGDOM INTERMEDIATE BETWEEN ANIMALS AND PLANTS.

In modern times, through the assistance of the microscope, many minute beings have been discovered which have been successively classified as plants or animals, according to the botanical or zoological tendencies of their describers. As these microscopic beings present the life of both plant and animal at different stages of their existence, it is quite impossible to say to which kingdom they belong. Many naturalists are, therefore, agreed to consider them as a something apart, an intermediate original kingdom, out of which the plant and the animal worlds have been evolved. If life has been gradually developed, and there has been a progress from beings of low organization to higher, it is natural that such a kingdom should exist, partaking in its nature of animal and plant characters. The origin of life is to be sought, therefore, in this main root, of which animals and plants are the rising diverging branches. The beings of this animal-plant kingdom* which still exist are only the descendants of a larger kingdom long since extinct, or perhaps some of the most simple are still formed through spontaneous generation.

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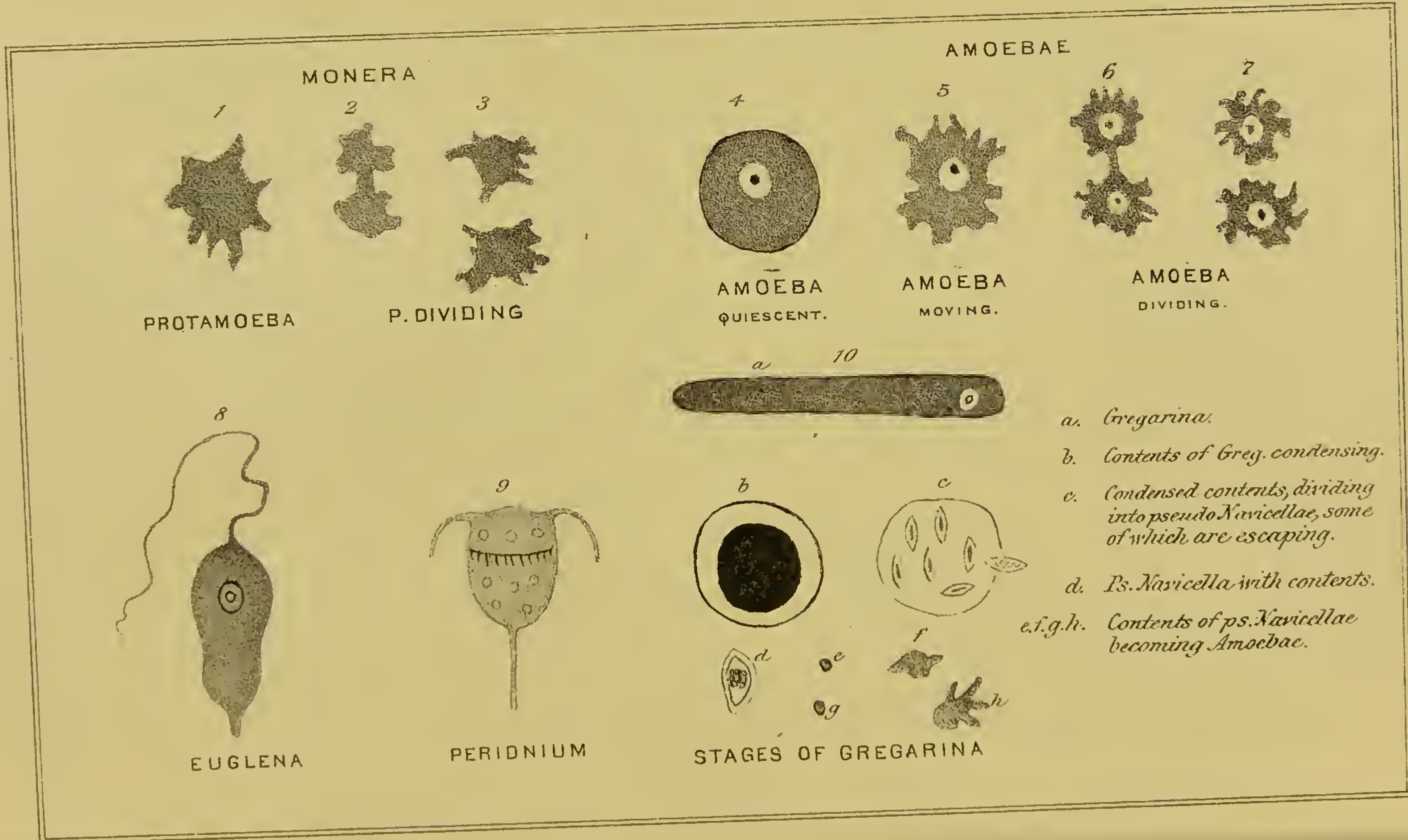
* The limits of this essay permit the noticing of only a few of the orders of the intermediate kingdom.


MONERA
AMOEBAE
1
2
3
4
5
6
7
PROTAMOEBA
P. DIVIDING
AMOEBA
QUIESCENT.
AMOEBA
MOVING.
AMOEBA
DIVIDING.
a
10
8
9
b
c
d
e
f
g
h
a. Gregarina.
b. Contents of Greg. condensing.
c. Condensed contents, dividing into pseudo Navicellae, some of which are escaping.
d. Ps. Navicella with contents.
e.f.g.h. Contents of ps. Navicellae becoming Amoebae.
EUGLENA
PERIDNIUM
STAGES OF GREGARINA

MONERA.

The simplest forms of life known are the Monera (Figs. 1, 2, 3), which may be defined as living jelly,—formless, structureless, in every sense of the word. Their movements are restricted to a gliding or crawling, a drawing in or putting out of their jelly-like body; their reproduction is a simple splitting of their body into two halves, each half becoming a new Monas. Such a living slime is seen in Protogenes. The first sign of structure we meet with in this kind of being is where a wall has been exuded inclosing the jelly-like body, as in Protomonas, or as in Amœba (Figs. 4, 5, 6, 7), where the slime has aggregated in the middle, forming a nucleus. These two different conditions, a nucleated slime and a walled slime, are combined in Arcella, these last being undistinguishable from the young of the simplest water-plants (Algæ) and the undeveloped forms of certain jelly-fish (Siphonophoræ). In the springtime the ponds are often covered with a green matter, which, when examined with a microscope, is found to consist of Euglena (Fig. 8), minute flask-shaped bodies with little tails; when these bodies are covered with hairs (cilia) they are known as Peridnium. They, like the Arcella, cannot be distinguished from the young of the simplest plants and animalcula (Infusoria). What conclusions can be drawn from the existence of Monera, Amœbæ, Euglena? How have they originated? Either they have come from pre-existing forms, or have arisen through spontaneous generation. Where have the pre-existing forms come from, is immediately suggested by the first answer, which only waives the question, and is therefore no answer at all. It will not suffice to say that they were created; as well might an astronomer explain the motion of the moon around the earth by saying it was created so to move. What is meant by spontaneous generation?

Let us illustrate by the example of the formation of a crystal out of a simple solution. A nucleus first appears, then increment after increment is added, according to laws, until the crystal is formed. The case of the origin of a Monad is a parallel one. We have a solution; in this solution appears the Monad. There is no more necessity for the pre-existence of a Monad in the solution than that there should have been a pre-existing parent crystal. In both solutions exist the elements of which the Monad and Crystal are formed; the laws according to which they are formed are as susceptible of study in the one case as in the other. Theoretically, therefore, there is no objection to the idea of Spontaneous Generation, the laws of which must be investigated as any other mechanical problem has been; the problem being a question of the redistribution of matter. In fact, according to the experiments of Pouchet, Pennetier, Bastian, Wyman, and others, Vibrios and Bacteria do appear in solutions where there was not previously a trace of these minute beings.

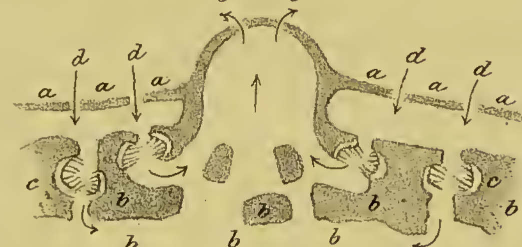
Want of space prevents us from discussing this question in detail. We can only say that at present the evidence seems to us in favor of the view that Spontaneous Generation takes place at the present day under favorable conditions. We turn now to the consideration of living Monera and Amœbæ. Whatever their present or remote origin may have been, an Amœba is a Monas with a nucleus. The Amœbæ probably came originally from Monera, if they are not now so produced, and in some cases colonize themselves, forming the Sponge,—this view being suggested by the young of the Sponges, which cannot be distinguished from Amœbæ,—or the Amœbæ gaining tails and hairs, like the Euglena, gave rise to the Animalcula or Infusoria. But as certain Amœbæ and Euglena cannot be distinguished from the spores or young of the simplest plants, the origin of the vegetal world must be sought also in these minute

11

SPONGE

SPONGE
IN ACTION

12



HYPOTHETICAL SECTION OF SPONGILLA.
a. Superficial layer — *d. Inhalent apertures*
b. Deep layer — *e. Exhalent apertures*
c. Ciliated Chambers
Arrows indicate direction of water

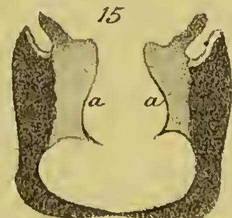
13

FOSSIL SPONGE
(VENTRICULITES)

14

ANEMONE

15



LONG SECT. OF
ANEMONE

16

FRONT PART OF
ANEMONE
CUT AWAY

17

FOSSIL SPONGE
(GUETTARDIA)

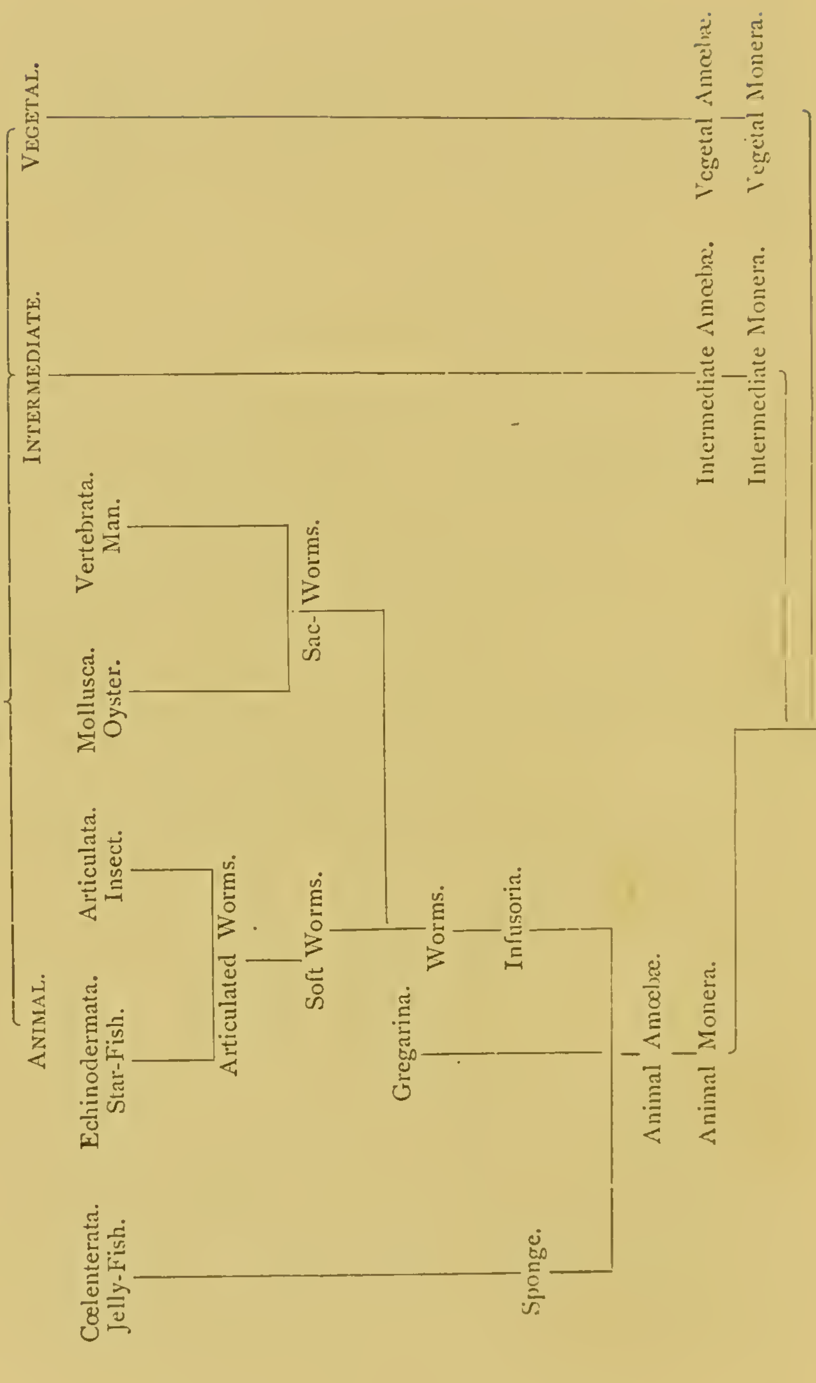
beings. If, now, Spontaneous Generation does not take place, the Monera and Amœbæ of the present day, and the other orders of the Intermediate Kingdom also, are the posterity of the long dead original forms, the ancestors of the three kingdoms,—the animal, the vegetal, and the intermediate world. (See Tree I., page 24.)

SPONGES.

The sponge of every-day use (Figs. 11, 12) is composed of a horny, fibrous material, produced by a colony of Amœbæ, and if a section of the fresh-water Sponge (Spongilla) be made, a glance will explain by what means the currents of water are produced, which can be seen under the microscope. The outer layer is composed of a number of Amœbæ, with little openings, through which the water enters the cavity between the outer and inner layers, this inner layer being also composed of Amœbæ, in the deep substance of which are chambers lined with fine hairs (cilia), which, working in the same direction, force the water through them into a common outlet; in this manner strong currents of water pass in and out of the sponge, making a little whirlpool, into which minute particles of matter are dragged.

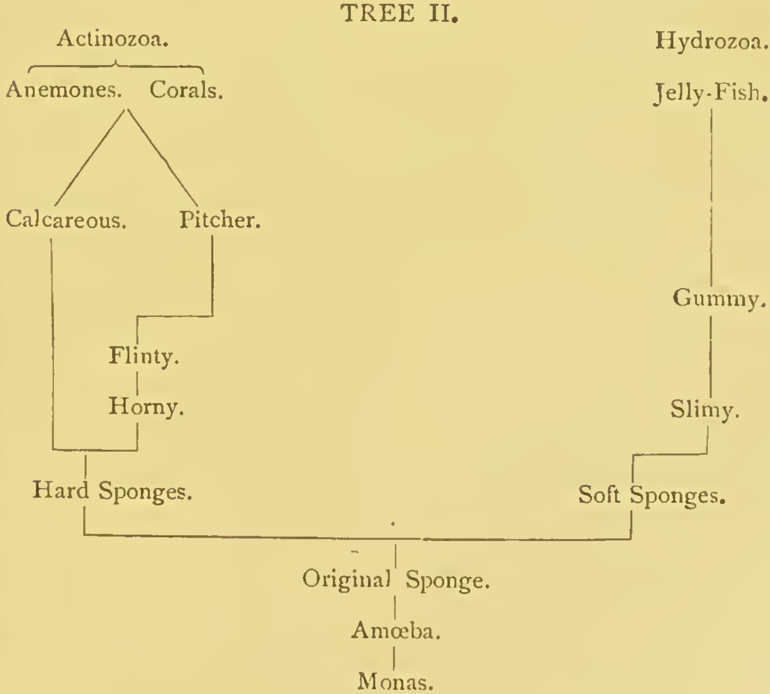
Sponges are found attached to all kinds of rocks, and often to shells, both in the sea and on the beach, and are of two kinds, soft and hard, of which the soft are probably the ancestors of the hard. The Halisarca, or Slimy Sponge, is found attached to the leathery sea-weed, and is composed of slimy Amœba-like bodies, in which the canal system just described is only imperfectly developed. From this kind were derived the Gummy Sponges, so called from their gumlike consistency; their canal system foreshadows the homologous structure in the Jelly-fish. Sponges like the Halisarca were probably the ancestors of the first kind of

TREE I.
Kingdoms.



hard sponge,—the horny kind (common bathing sponge),—which, when alive, has the interstices filled with these Amœba-like bodies. Some of the descendants of the Horny Sponges were metamorphosed into the flinty kind, to which our fresh-water sponge belongs, and the Venus's flower-basket (Euplectella), whose framework rivals in delicacy the most beautiful lace. From the flinty kind were derived most likely the Pitcher Sponges, in which the framework takes the form of a goblet or pitcher. These are often beautifully preserved in a fossil state (Ventriculites, Guettardia); they are nearly allied in their structure to Corals and Anemones. Still closer to the Corals are the calcareous sponges in their affinities. The natural history of Sponges, to those to whom it is known best, is full of evidences in favor of the theory of Evolution.

TREE II.



upside down, and swims off, stomach hanging downward from an umbrella or bell-shaped body; we would then have a jelly-fish.

HYDROZOA.

Every one who has visited the sea-shore must have had his attention called to the jelly-fishes (Fig. 20), as they floated along by means of the pulsations of their disc-bearing bodies, the animal looking somewhat like an umbrella, and he remembers well the sensations suffered while bathing when his skin came in contact with the long streamers floating about, which are so characteristic of these organisms. The stinging is due to a poison which is contained in vesicles situated in the skin, often millions in number. In the beautiful Blue Physalia, known to sailors as the Portuguese man-of-war, this poison is so powerful that it has been known to cause death. The jelly-fishes and Anemones alike possess these poison-cells; but the Sponges, although having the rudimentary canal system, are devoid of the stinging structures. The most simple example of the Hydrozoa is our common Green Hydra (Fig. 18), so called from the fact that when cut in pieces each piece becomes a new individual. It looks to the naked eye like a piece of green silk thread. When magnified, it is seen to be a simple tube, the digestive cavity and general cavity of the tube being the same; its mouth is surrounded by a circle of arms or tentacles, by means of which it seizes its prey, paralyzing or destroying it by the poison just spoken of. The importance of the Hydra, as part of the evidence for the evolution of life, may be seen in the development of the so-called Hydroid jelly-fishes, such as the Campanularia and Sertularia (Fig. 19), which look like little trees covered with flowers. The branches of these tree-like beings are little tubes, in which the flowers (Hydroid polyps) live; the tubes are all connected, so the colony has a common

18

HYDRA

19

SERTULARIA

24 B

A. Upper view or dorsal.
B. Lower view or ventral.
c. Contractile Chamber
g. Gullet
e. Nucleus

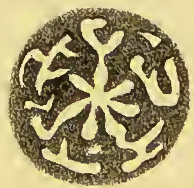
20

JELLY FISH

21

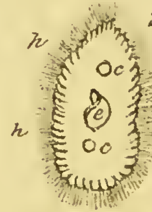
JELLY FISH
(UNDER VIEW)
2 parts of stomach removed
aa gastro. vascular system

22



SECTION OF SPONGE
white spaces same as vas. system of 21

24 A



PARAMŒCIUM

digestive cavity. Such beings as the Campanula produce, through budding, beautiful little jelly-fishes, which swim freely about. They in their turn produce eggs, from which spring the stationary colonies of Hydræ. There is an alternate generation, Campanulariæ producing jelly-fish, jelly-fish producing Campanulariæ. We see the Hydra living as an independent organism—the Hydra of our fresh-water ponds—and in a transitory stage, as the Campanula. Sometimes a colony of these Hydroids form a freely swimming organism, as the Portuguese man-of-war. The Ctenophoræ, or comb-bearing jelly-fishes, pure as crystal and transparent as glass, are characterized by their organs of motion, which are eight delicate combs, by the graceful movement of which the Beroes and Cydippe glide through the sea. They are intermediate in some respects between the Anemones and common jelly-fish (Aurelia). By glancing at Tree II. we see the probable origin of the Anemones, Corals, and Jelly-fish in the Sponges, the Anemones and Corals coming from the hard sponges, the fossil forms of which, like Ventriculites and Guettardia (Figs. 13, 17), closely resemble in the arrangement of their chambers those of the Anemone and Coral. By comparing the transverse section of a sponge (Fig. 22) with that of the jelly-fish (Fig. 21), we see that the canals of the sponge are the same as those of the jelly-fish, though more simple in their arrangement. Though objections have been, and will be, raised to this view of the origin of the Actinozoa and Hydrozoa, that they have so descended from stationary beings the Anemones and Hydroid polyps are the living proofs. That these stationary ancestors were sponges, or beings allied to them, is rendered very probable by the harmonious evidences of the structure, development, and fossil remains of the entire group.

We will now leave the Cœlenterata, considered as a distinct division of the animal kingdom on account of its simple and characteristic structure, and turn to the other descendants of Amœbæ, as seen in Tree I.

GREGARINÆ.

In the alimentary canal of the earth-worm, of cockroaches, etc., are often found sac-like bodies, called Gregarinæ. (Fig. 10.) These simple creatures are nearly destitute of organs, having simply in one part of their body a small nucleus and nucleolus, and a delicate muscular fibre. Nourishing itself by imbibing the juices of the animal in which it lives, slowly narrowing or lengthening its body in different directions,—this motion being probably caused by the delicate muscular fibre just mentioned,—the Gregarina passes its existence. At times, however, this motion ceasing, it takes the shape of a sac. (Fig. 10, *b*.) The nucleus and nucleolus disappear. The substance of the body breaks up into what have been called pseudo-navicellæ, from their resemblance to the Navicula. The contents of the navicellæ (Fig. 10, *d*) are changed under favorable circumstances into Amœba-like bodies (Fig. 10, *e*, *f*, *g*, *h*), which, in their turn, become Gregarinæ. By looking at Tree I. we see Amœbæ, or their haired descendants most likely, divided into four groups:—1st, the Sponges, whose supposed progeny we have treated of as Cœlenterata; 2d, Gregarinæ, whose Amœba-like development clearly indicates their ancestry, which we now leave; 3d, Infusoria, whose young show in a marked degree their affinity to the Amœbæ and to the Worms; 4th, the Noctilucæ, the animals (allied to the Infusoria) causing the phosphorescence of the sea by the immense numbers of them found together in tropical climates.

INFUSORIA.

The animalcula of ditches and ponds are made up, in a great measure, of the microscopical beings called Infusoria.

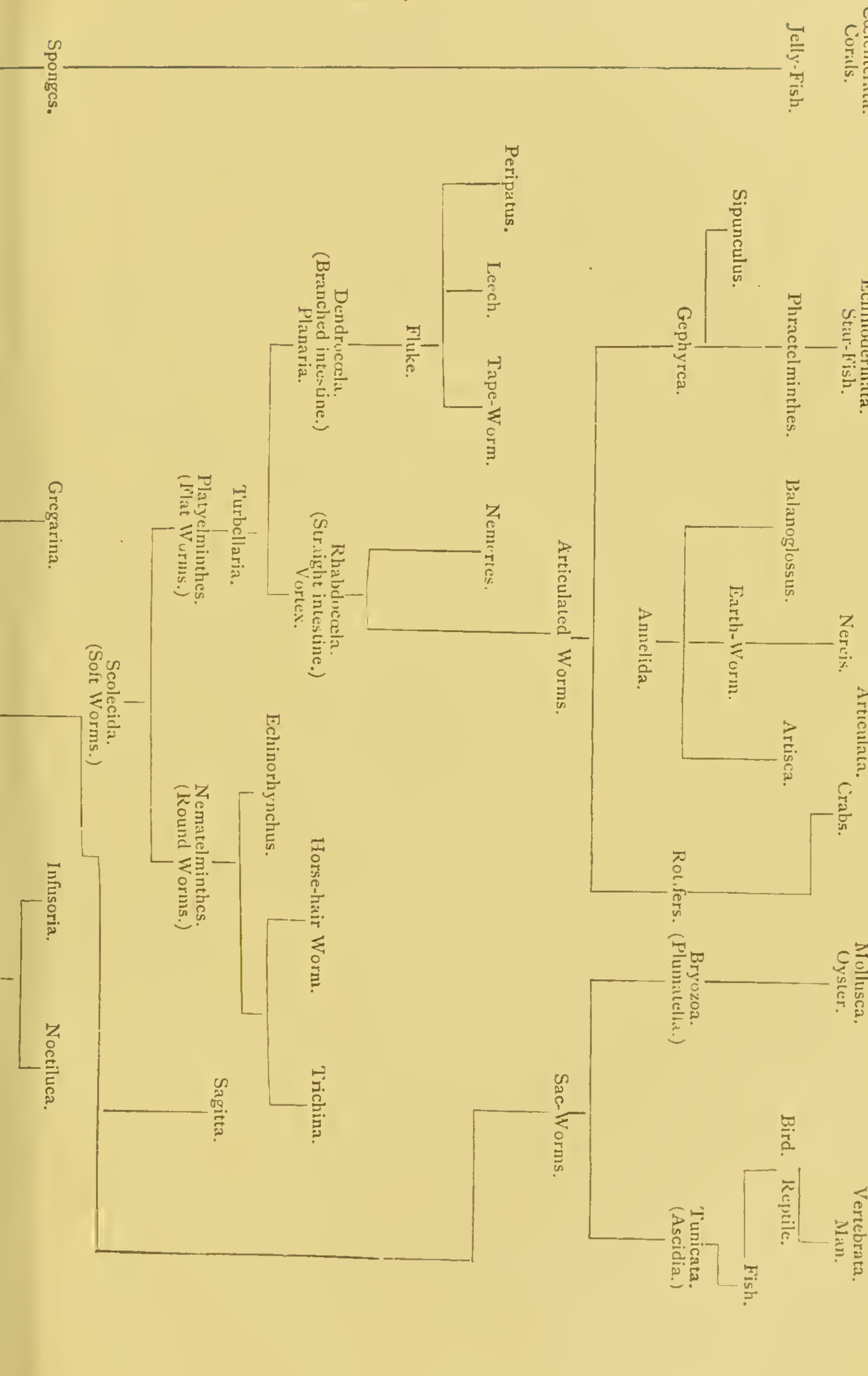
from their being found in infusions. One of the most common of these forms is known as Paramœcium; and its structure will serve to illustrate this group. The Paramœcium (Fig. 24) is often compared to a slipper-shaped body of semi-fluid consistency (central substance), inclosed in a rind (cortical layer); the rind running insensibly into the semi-fluid substance. This rind is coated on its outside with a delicate layer (cuticula), bearing on certain parts hairs. (Fig. 24, *h*.) If the animal remain quiet, we can see a depression in the middle of the body, which leads into the so-called mouth; this opens into a kind of gullet. (Fig. 24, *g*.) This is all the digestive system the Paramœcium possesses. In certain parts of the body one can observe spaces opening and shutting (Fig. 24, *c*), and through these spaces certain canals are said to be visible, filled most likely with water. It is said these canals or vessels communicate with the exterior by means of holes in the layers forming the walls of the body. If such a system of vessels have really been found in the Infusoria (and many competent observers are confident that they do exist), they furnish an important proof of the derivation of the Worms from the Infusoria, as this rudimentary water-vessel system is much developed in the Worms. (See Aspidogaster.) The hairs on the outer layer of the Paramœcium serve as organs of movement, and, in making currents of water, drag small particles of food, etc. into the body of the animal. These hairs (Fig. 24, *h*) are called cilia, and their movement ciliary action. The Infusoria have been divided according to the presence or absence of these hairs into Ciliata and Acinetæ (sucking); but the transition between the two seems to be furnished by the bell-shaped Vorticellæ, which are said to produce Acinetæ, while the Acinetæ produce Vorticellæ. If this be correct, the Acinetæ are only a transition stage of Vorticellæ, and all Infusoria are Ciliata or haired.

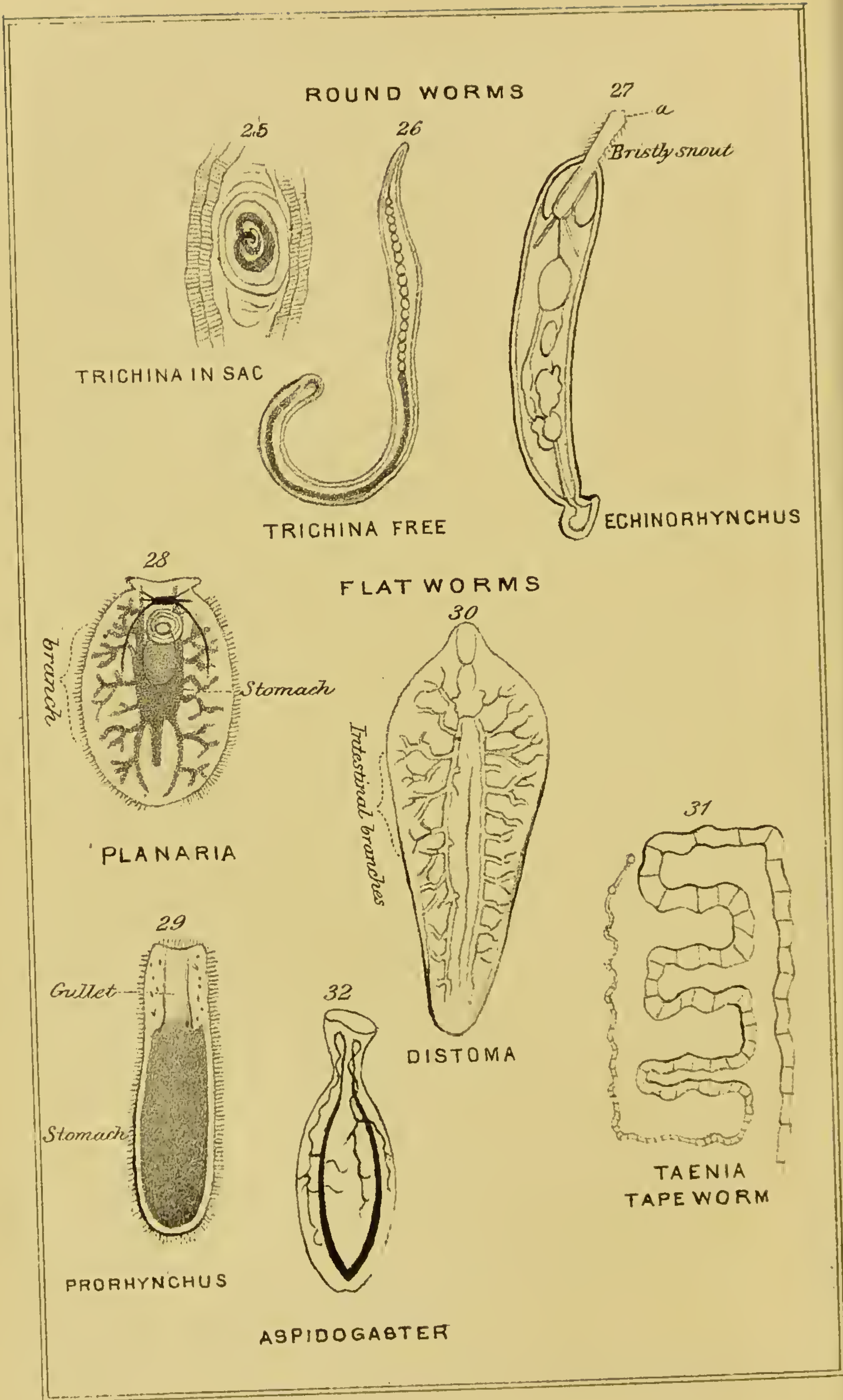
The Infusoria are not to be distinguished in their early stages from Amœbæ. Kolpoda-like forms, supposed at one time to belong to the Infusoria, have since been shown to be the young of Turbellarian Worms. The Infusoria seem then to be essentially a transition group; so much so that some naturalists have held that the group is not a distinct division of the animal kingdom, but simply a collection of the young of higher animals. It seems proper to mention now the necessity of learning the condition of the young, or embryonic stage of animals, whose origin we are seeking. Supposing the animal kingdom is really represented by a tree, of which the main branches, twigs, and leaflets are the orders, families, and species into which animals are divided, common features of structure in these groups must not be sought at the ends of the branches which are far apart, but at the point where the branches diverge. To make my meaning clear, take the case of young babies, which look very much alike, but owing to certain hereditary influences, and the effects of a different mode of bringing up, can be readily distinguished later in life. The origin of Worms is not to be sought in comparing a highly-organized member of the group with one of the Infusoria, but by placing side by side a simple worm like the Planaria and one of the Animalcula. The proofs of the Worms coming from Infusoria are furnished by the resemblance of the young of the Soft Worms to existing Infusoria, and the peculiarities of structure common to both.

WORMS.

By looking at Tree III. we see the root of the Worms divides into two branches,—the Soft Worms (Scolecida) and Sac-worms,—the Soft Worms giving rise to the Articulated Worms, in which are seen the beginnings of the Echinodermata and Articulata, while the Sac-worms are the com-

TREE III.

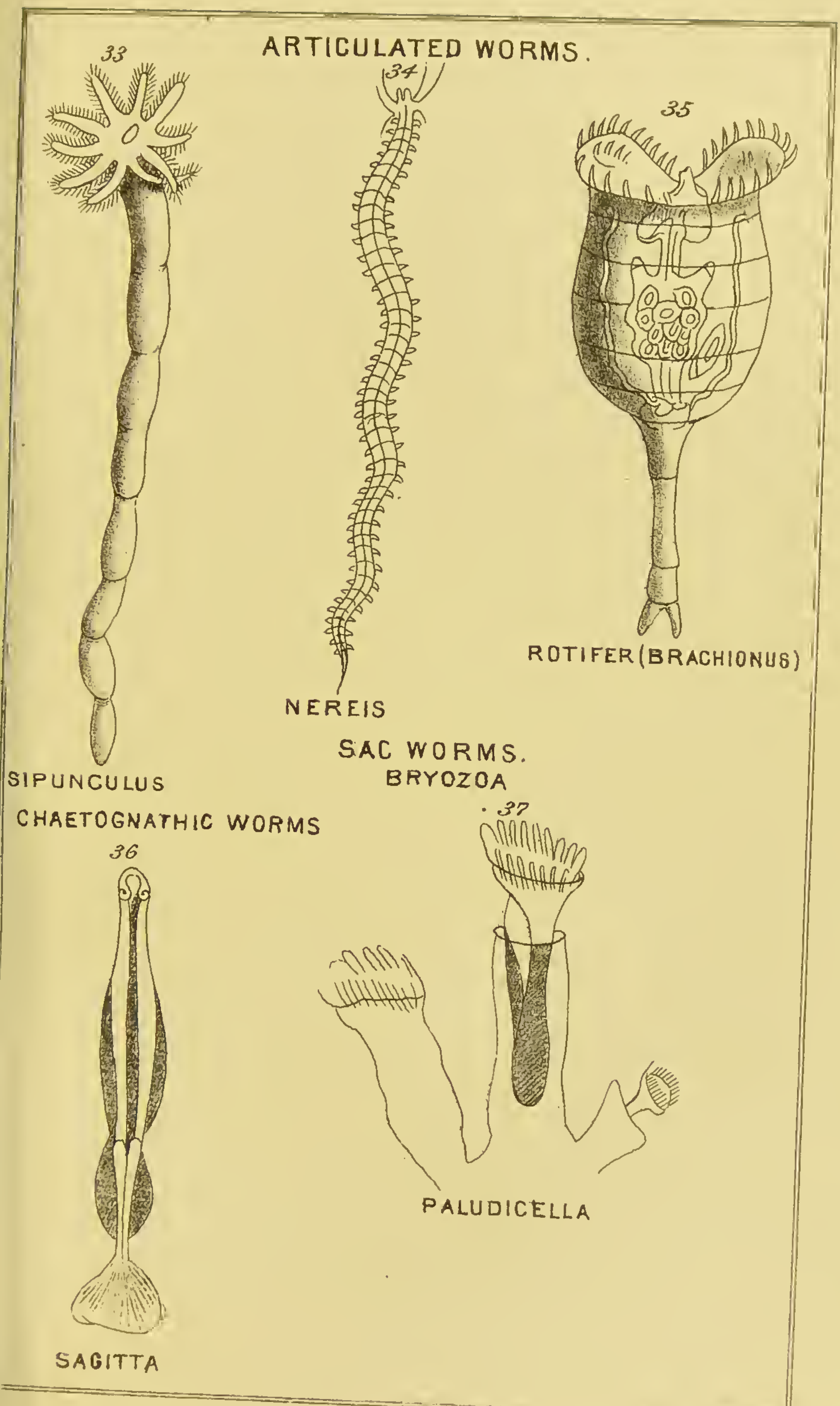

Cœlenterata.
Corals.
Jelly-Fish.
Sponges.
Echinodermata.
Star-Fish.
Phractelminthes.
Sipunculus.
Gephyrea.
Peripatus.
Leech.
Tape-Worm.
Fluke.
Dendrocœla.
(Branched intestine.)
Planaria.
Balanoglossus.
Nereis.
Earth-Worm.
Annelida.
Articulata.
Artisca.
Crabs.
Articulated Worms.
Nemertes.
Rhabdocœla.
(Straight intestine.)
Vortex.
Turbellaria.
Platyelminthes.
(Flat Worms.)
Gregarina.
Scolecida.
(Soft Worms.)
Echinorhynchus.
Nematelminthes.
(Round Worms.)
Horse-hair Worm.
Trichina.
Rotifers.
Bryozoa. (Plumatella.)
Mollusca.
Oyster.
Sac-Worms.
Sagitta.
Infusoria.
Noctiluca.
Bird.
Reptile.
Vertebrata.
Man.
Fish.
Tunicata.
(Ascidia.)


ROUND WORMS
25
26
27
a
Bristly snout
TRICHINA IN SAC
TRICHINA FREE
ECHINORHYNCHUS
28
FLAT WORMS
30
branch
Stomach
Intestinal branches
31
PLANARIA
29
Gullet
32
Stomach
DISTOMA
TAENIA
TAPE WORM
PRORHYNCHUS
ASPIDOGASTER

young Trichina is set free, and deposits eggs, the embryos from which bore through the viscera of the unfortunate one. The Trichina belongs to the family of thread-worms or Nematoda. Associated with the horse-hair and thread-worms is the Echinorhynchus, or Bristly-snout (Fig. 27), so called from the proboscis or snout (Fig 27, *a*), armed with recurved hooks, being the most striking feature in its organization. The three families of Round Worms live within other animals,—the Trichina in the pig and man, the Echinorhynchus in the flounder, the Gordius, or horse-hair worm, in insects. They are sufficiently alike in their general organization to be the descendant of a common ancestor; their modifications are due to their different modes of life. Turning now to the Flat Worms, we see, according to Tree III., that the Turbellaria are probably the oldest of this group. They are arranged in two families, Dendrocœla and Rhabdocœla, according as the intestine is branched, as in the Planaria (Fig. 28), or straight, as in the Prorhynchus (Fig. 29) or Vortex. The Planaria are found principally in fresh water, but also in the sea, adhering to stones or stems of plants. In the haired covering of their bodies, in their internal organization and embryo forms, the Turbellaria are closely allied to the Infusoria, from which, most likely, they have been derived. From the Turbellaria have retrograded the Trematoda, of which the liver fluke (Distoma) (Fig. 30) is a common example. By retrograding, I mean that the Flukes have lost organs, from want of use, which they would have retained had they not lived as parasites in the viscera of other animals. The Flukes are found in almost every kind of animal. Imagine a long chain of Flukes living as one individual, and we have the Tape-worm, or Tænia (Fig. 31), as a representative of the Cestoda. Either the Tape-worm has split into Flukes, or the Flukes have colonized and made the Tape-worm, or possibly they are both aborted Turbellarians.

The reproduction of the Tape-worm, long involved in obscurity, is now known to be as follows. There exists in the Pig at certain times a sac-like worm called the Cysticercus; this never progresses; but should the part of the pig containing this worm be eaten by man, this sac will be transformed into the Tænia, or Tape-worm. The Leech and the Peripatus are so nearly allied to the Trematoda that they may be regarded as offshoots of that stem. Turning back now to the Turbellarian Worms with a straight intestine (Rhabdocœla), while noticing that the family represented by the Nemertes is given off here (see Tree III.), we see, in following the stem upwards, its importance, in that it furnishes the origin of the Articulated, or Segmented Worms, with their progeny, the Echinodermata and Articulata. Before leaving the Soft Worms, attention must be called to the system of vessels which is found in most, if not all, of this group. It is well developed in the Aspidogaster Conchiola (Fig. 32), a Trematode worm found in the heart-sac of the fresh-water mussel. The worm is shaped somewhat like a vase. Coursing through its body is seen a system of vessels, beginning as large tubes, which, getting smaller, are finally lost as twigs. This system of vessels is supposed to be the same as that observed in an undeveloped condition in the Paramœcium among the Infusoria, and is found also in the Rotatoria, one of the divisions of the Articulated Worms.

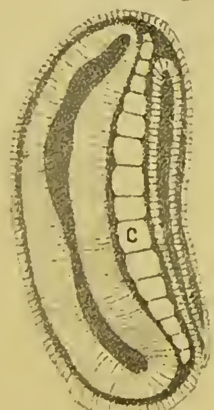
The Articulated Worms include the three groups of the Gephyrea, Annelida, and Rotatoria. They are called articulated or segmented, from the fact of their bodies being composed of segments or pieces joined together. This arrangement is carried to the furthest extent in the Annelida, the Nereids (Fig. 34) numbering as many as hundreds in their segments. This segmentation is only just perceptible in the Sipunculus (Fig. 33), one of the Gephyrea. The bodies of the Rotatoria (Fig. 35) are inclosed in a


ARTICULATED WORMS.
33
34
35
SIPUNCULUS
NEREIS
ROTIFER (BRACHIONUS)
SAC WORMS.
BRYOZOA
CHAETOGNATHIC WORMS
36
37
SAGITTA
PALUDICELLA

transparent case or hardened skin, which is slightly segmented, and through which the jointed intestine may be seen. The Sipunculus (Fig. 33) resembles somewhat our earth-worm, and is found at low-water mark buried in the sand. When the tide comes in, the Sipunculus, rising to the surface, exhibits a circle of tentacles surrounding its mouth: this can be drawn in by the animal and quite concealed. They resemble slightly the Sea-cucumbers, animals included in the Echinodermata. Within a few years a remarkable group of Gephyrea have been found well preserved in a fossil condition. They have been called Mailed Worms, or Phractelminthes, and are considered by Haeckel as furnishing the link between the Worms and the Star-fishes. We will refer to them again. The Annelida, or second division of Articulated Worms, are among the most beautiful of living creatures, of every size and color, sometimes seen as pretty little white or red worms swimming about in our fresh-water streams and ponds, or living, as sedentary organisms, in tubes constructed out of the sand and other materials found near the sea-shore, or swimming along by a kind of undulatory movement. The Nereids (Fig. 34) are composed in some examples of many hundred joints or segments; each segment is furnished with a little paddle attached to the side. The blood, rushing into the little tufts of hair, which are seen on the upper surface of each segment, gives the animal a brilliant appearance,—the little hairs refracting the light make so many rainbows. The whole effect of the Nereid gliding through the sea is so beautiful that it has called forth the admiration of the poets. The Annelida increase their length by adding segments to those already formed. In this respect they resemble the Centipedes, etc., which belong to the Myriapoda, of which we will speak again. The Rotatoria (Fig. 35), or third division of the Articulated Worms, are microscopical. They live in fresh or salt water; they are composed of a head and a body; sometimes the head and body coalesce. The head is furnished with fine hairs arranged in different manners, and when these cilia are in action they look like wheels. The other end of the body terminates in a jointed foot. Both the wheel-organs and foot can be drawn within the case in which the body of the Rotifer is inclosed. This case resembles that of the Crabs. The Rotatoria possess the water-vascular system of the Worms, as described in Aspidogaster. The group is intermediate in its structure between the Soft Worms, the Annelida, and the Crabs,—the Rotatoria having been considered to belong to each of these groups by different naturalists. They represent very naturally that point of the tree where the Soft Worms end and the Crabs begin. Before leaving the Articulated Worms, the position of the Artisca must be noticed. They have been called Tardigrada, from the slowness of their movement; they are usually considered as nearly related to the Spiders; others have looked upon them as Annelids, while some have considered them as the links between the Soft Worms and Rotatoria. They are placed, therefore, near these groups, without assigning to them a definite position. From the difficulty experienced in their classification, the Rotatoria and Artisca afford a striking proof of the truth of an evolution of these worms in some such manner. Having called attention briefly to the Soft and Articulated Worms, we pass to the last division, the Sac-worms, which includes the Bryozoa and Tunicata.

The Bryozoa resemble living moss, and are found both in fresh and salt water. When observed under the microscope, this moss is seen to be composed of minute tubes, in which the Paludicella, a Bryozoon (Fig. 37), lives. Though this creature is small, it is more complex than many of the animals we have called attention to. The Paludicella has a mouth, gullet, stomach, and intestine, which are entirely

39



YOUNG AMPHIOXUS

38 a

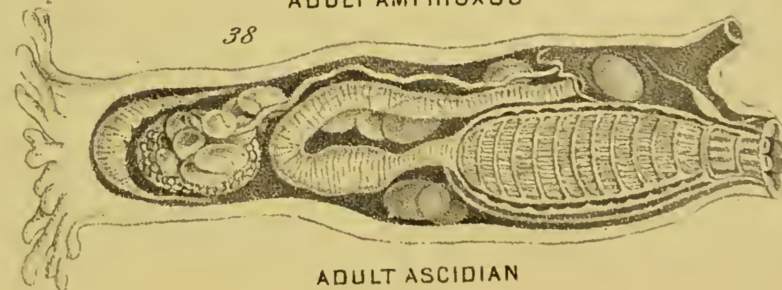
YOUNG ASCIDIAN

C. Back Bone

40

ADULT AMPHIOXUS

38



ADULT ASCIDIAN

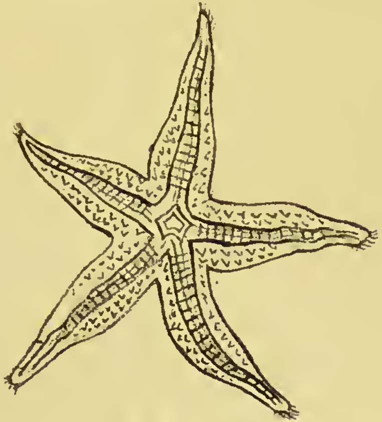
shut off from the general cavity of the body: a great advance in structure as compared to that of the Anemone and Jelly-fish. The Bryozoa are usually classed with the Clams and Oysters (Mollusca); but, from their development from worm-like embryos, they are more justly considered as a group of worms. This view of the position of the Bryozoa is confirmed by the recent discoveries of the worm-like development of the Brachiopoda, the first class of the Mollusca. The Bryozoa are probably the root of the Mollusca, and the connecting link between them and the Worms. The Tunicata, the other division of the Sac-worms, are so called from the animals representing them being inclosed in a bag or tunic. They are a very important group, as showing probably that point where the stem of the Fishes originated. The young Ascidian (Fig. 38, *a*), one of the Tunicata, resembles a tadpole, and in this condition has quite as much of a backbone (Fig. 38, *C*) as the Amphioxus (Fig. 39, 40, *C*), the simplest vertebrate known. The Ascidian, when mature, is like a double-necked vase. The arrangement of the nervous system in the Tunicata differs from that of the Bryozoa, and serves as a distinguishing mark. The curious worm Sagitta (Fig. 36), the only representative of the Chætognathi, has certain affinities with the thread-worm as well as with the simplest of the vertebrata; it is therefore placed between the two.

The Cœlenterata are characterized by the want of specialized structures; that division of labor, so conspicuous in the higher animals, begins to be seen in the Worms, the digestive system in them being more or less developed, together with a rudimentary heart, respiratory and excretory apparatus, and the elements of a nervous system. The Tree of Worms is essentially an intermediate one,—its roots intimately connected with the simplest forms of life, Gregarinæ, Infusoria, etc.,—its branches expanding into the rest of the animal kingdom. By looking at Tree IV. may be seen the stem of the Gephyrea, giving origin to the Star-fishes, the simplest of the Echinodermata. In the Annelida will be found the roots of the Tracheate, or tube-breathing Articulata, while the Rotatoria lead equally naturally to the Crabs. The Articulated Worms furnish us with the roots of the Echinodermata and Articulata, while the Sac-worms contain the foreshadowing of the Vertebrata and Mollusca.

ECHINODERMATA.

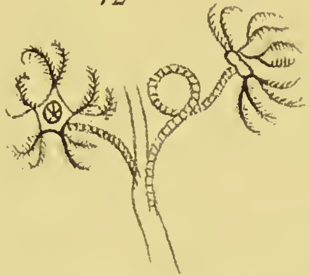
This division of the animal kingdom includes the Star-fishes, Feather-stars, Sea-urchins, and Sea-cucumbers. (Figs. 41, 43, 44, 45.) Every one who has visited the sea-shore is familiar with the appearance of the star-fish. (Fig. 41.) From the mouth, which lies in the centre of the body, fork out five arms, which run insensibly into each other, the mouth lying in the middle of the space formed by the union of the diverging or radiating arms. The number of arms in some star-fishes is as many even as forty, but the most common number in all the Echinodermata is five. Each arm in the star-fish is composed of movable segments. There exists also a water-vascular system, which terminates externally in suckers, serving as organs of locomotion. There is a rudimentary blood-vessel system, beginning as a tube in the body of the star-fish, and which courses outwards. On the under surface of the arm is found a fine nervous thread, coming from a ring surrounding the mouth, and, finally, at the free end of each arm eyes are found. The arm of a star-fish is, in fact, a worm; not simply resembling one, but structurally the same, the segmentation, the water-vascular system, the nervous cord in each arm of the star-fish being exactly the same as that of an articulated worm. The star-fish has probably been produced through

41



STAR FISH

42

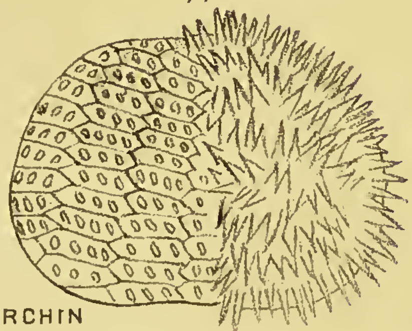


PENTACRINUS

43

FEATHER STAR

44



SEA URCHIN
SPINE REMOVED ON LEFT SIDE

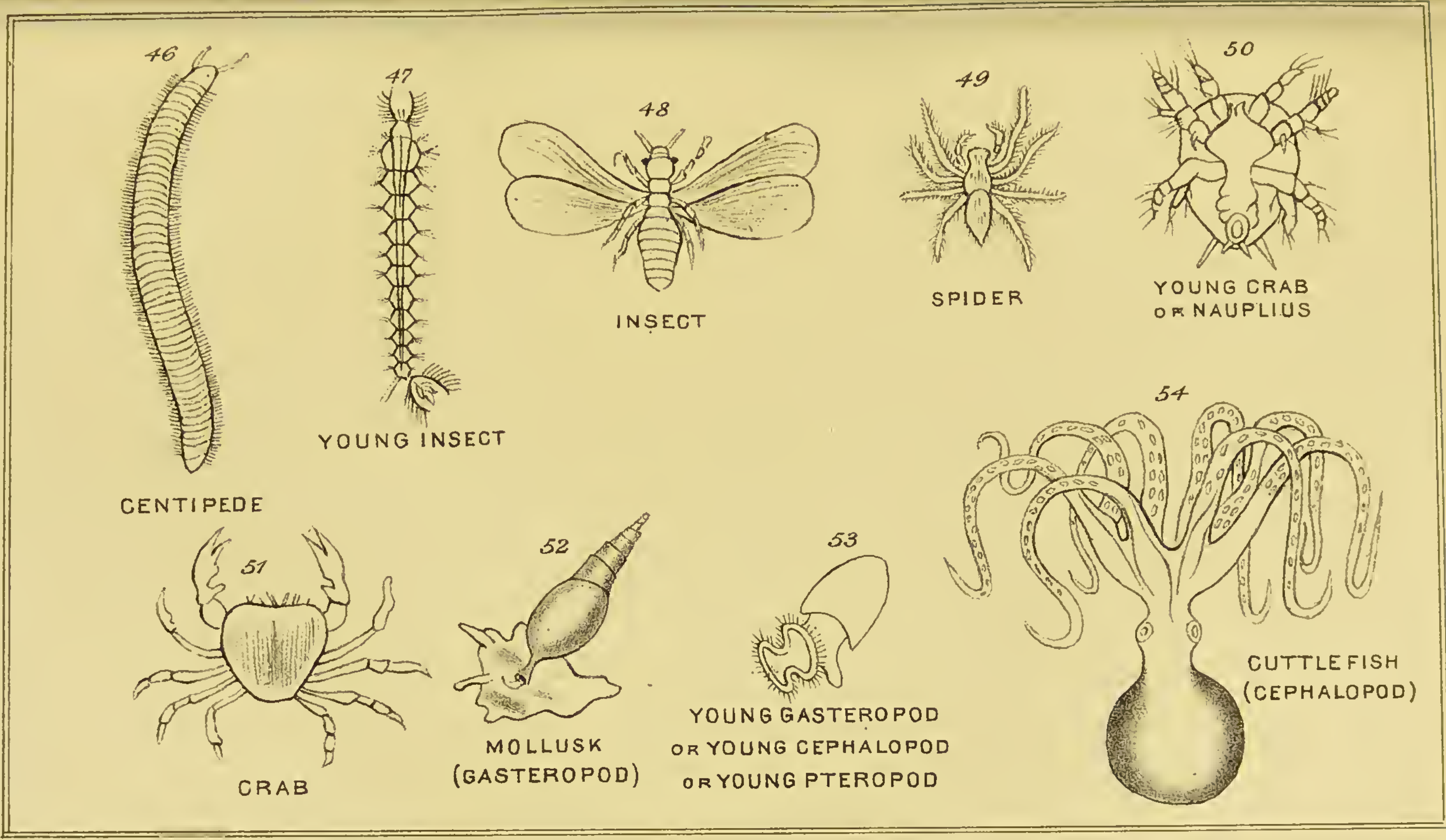
45

SEA CUCUMBER

the union of five worms, the worms having united at their posterior ends, since the eyes are seen at the free ends of the star-fish. This interpretation of the structure of the star-fish is not without a parallel among the worms. The Botryllus, one of the sac-worms, is really composed of many little Ascidians living as one individual. There is nothing more extraordinary in five worms living together as a star-fish, than in many little Ascidians living together as a Botryllus. This view of the origin and the structure of the star-fish, first proposed by Haeckel, is in perfect harmony, according to the same author, with the facts of its development. The egg of the star-fish is transformed into a larva, provided with an intestine from the inner part of the body of the larva. Around its mouth appear five distinct layers, which, uniting at their posterior ends, form the body and arms of the mature animal. The same kind of reproduction is seen in the Sipunculi, which are supposed to be indirectly the ancestors of the star-fish, and also in the Nemertian worms, from which, or their allies, the Sipunculi and other articulated worms have descended. Within a few years there have been found a very well-preserved group of fossil worms,—the Phractelminthes, or mailed worms. These are considered by Haeckel to be intermediate between the Sipunculus and the star-fish, they being scarcely distinguishable from the arms of the latter. Through the union of worms, like the Phractelminthes, have the star-fishes been produced. The origin of the Asteridæ, or star-fishes, from the worms, is in perfect harmony with the structure, development, and petrified remains of the group. The most striking facts of their economy are explainable on such a theory, but are perfectly meaningless on any other. The star-fishes are probably the ancestors of the remaining Echinodermata. Passing over the Ophiuridæ, which differ but little from the star-fishes, we come to the Feather-stars, or Comatula (Fig. 43), which, when young, live in a stationary condition, rooted by a stem; in this immature state it was supposed for a long time to be a distinct animal, known as the Pentacrinus. (Fig. 42.) After a time, however, the stem disappears, and the little creature floats off as the very pretty Comatula. The Comatula is very interesting, as its early Pentacrinus stage is the only living representative of the Crinoids, known commonly as lily stones, and as St. Cuthbert's beads, when segments of the stem alone are preserved. The Crinoids are now extinct, but are preserved in great profusion in the fossil state. As the star-fishes in one stage of their existence are more or less fixed, and as the Crinoids have died out, save the only living example, the young of the Comatula, it is possible that the Crinoids are the earliest of the Echinodermata. Haeckel, however, considers the Crinoids as a very ancient offshoot of the star-fishes, adapted to the fixed state of living. Perhaps the Crinoids and star-fishes are the diverging stems of an intermediate group, partaking in its nature of the peculiarities of both these classes. In either case the star-fishes are the progenitors of the sea-urchins, and they of the sea-cucumbers. Imagine the five arms of the star-fish bending down until their free ends, uniting in the middle, form a ball-shaped figure; suppose the empty spaces between the arms to be filled up, and a sphere will be formed. Such are the relations of the star-fish to the sea-urchin, or Echinus. Many intermediate fossil forms have been found connecting these extremes. The sea-urchins, or sea-eggs, are covered with innumerable spines or bristles; hence their name of Echini. (Fig. 44.) These spines are movable, being loosely articulated to little knobs covering the body. When one watches a living Echinus, there may be seen protruding between the spines sucker-like appendages, which serve as a means of progression. If the spines be removed, the body of the Echinus is seen to be a hollow sphere, composed of arms (ambulacral plates) and intermediate arms (interambulacral plates). The arms are pierced with holes, hence their name of ambulacra; through these holes or ambulacra are protruded the sucker-like bodies just mentioned. There are ten ambulacral plates, arranged in pairs, and between these ten interambulacral plates, also in pairs; so, starting from right to left, we have two ambulacral plates united, then two interambulacral plates united, and so on around the shell. The plates are composed of still smaller pieces, these minute plates being formed through the secreting power of the skin, which dips down between the different plates. The shell of an Echinus, with its innumerable pieces, plates, spines, and suckers, is therefore quite a complex organism. If we turn to the interior of the animal, we find the intestine loosely attached, but possessing in its jaws a most complicated apparatus, the so-called Lantern of Aristotle. This lantern-shaped apparatus is composed of five triangular pieces, united at their bases. Crowning the apex of each triangle is seen a tooth, the sides of the triangle being furnished with fine saw-like teeth. The five triangles are kept firm by clamps, and movable through delicate muscles, the whole forming a most efficient, though delicate, arrangement. The nervous system is a simple ring surrounding the mouth, with radiating threads; the organs of reproduction are arranged in a direction corresponding to that of the arms. The structure of the Echinus is essentially radiate. Suppose, however, that an Echinus be drawn out until its length exceeds its breadth, and the mouth be encircled by a wreath of tentacles, we would have then a sea-cucumber, or Holothuria. (Fig. 45.) The Echinodermata agree in the structure of their water-vascular locomotor system, in the peculiar lining or hardening of the skin which incloses their bodies, and in many other respects. They may be regarded, therefore, from their structure and manner of development, as a distinct division of the animal kingdom. The origin of the Echinodermata from the Soft Worms, with which they are most closely allied, is in harmony with the views of the most eminent naturalists of the present day.

ARTICULATA.

We turn now to a consideration of the Articulata, so called from their bodies being composed of distinct pieces jointed or articulated together. They include the Centipedes, known as the Myriapoda, from their numerous feet, the Spiders, or Arachnida, with eight feet, and the Insects, which have only six feet. We will pass over for the present the Crustacea, or last order of Articulata, and confine ourselves for the moment to the Centipedes, Insects, and Spiders (Figs. 46, 48, 49), which agree in breathing by means of fine tubes opening externally. These tubes pass from the walls of the body, getting smaller and smaller, until they are lost in a net-work. In the inside of these tubes, arranged in the form of a spiral, is found a delicate wire, which serves to keep the tubes expanded. This respiratory system is known as the Tracheate: hence the Centipedes, Insects, and Spiders are joined in one division, the Tracheata. A Myriapod, or Centipede (Fig. 46), is composed of numerous segments resembling a Nereid; in fact, it has been observed that the Myriapoda are to the land what the Annelida are to the water. In the Insect (Fig. 48) we can distinguish only three segments, known as head, thorax, and abdomen. There are seen usually in Insects two pairs of wings, less often one pair, and in some cases none are apparent. In the Spider (Fig. 49) the head and breast are soldered into one piece, known as cephalo-thorax. So in the Arachnida we find only two segments. While the Myriapoda, Insecta, and Arachnida breathe by tracheæ, the Crustacea, including the Crabs, Lobsters, etc., breathe by gills. They live in the water, and are of every size,


46
CENTIPEDE
47
YOUNG INSECT
48
INSECT
49
SPIDER
50
YOUNG CRAB
OR NAUPLIUS
51
CRAB
52
MOLLUSK
(GASTEROPOD)
53
YOUNG GASTEROPOD
OR YOUNG CEPHALOPOD
OR YOUNG PTEROPOD
54
CUTTLEFISH
(CEPHALOPOD)

shape, and color. The question now arises, Do the Tracheata come from the Crustacea, or are they modified Annelida? Plausible arguments have been advanced for the first of these views; but the second, or that of the Tracheata coming from the Annelida, will be the one here adopted. On seeing for the first time the minute worm resembling an Annelid (Fig. 47), moving through the water, it would surprise the observer to learn that it was the larva, or undeveloped young, of an Insect. The numerous segments of which the immature Insect and Spider are composed gradually coalesce, until finally the perfect Insect exhibits only three pieces, the Spider two. In the young of the Ephemera, or the one-day fly, and of the Libellula, small respiratory tufts are found externally, exactly as in the Annelida, which were alluded to in speaking of the brilliant colors of the Nereis. The existence in the larva of these external respiratory tufts, the manner of the development of the young of Insects and Spiders, furnishes the clue to their origin.

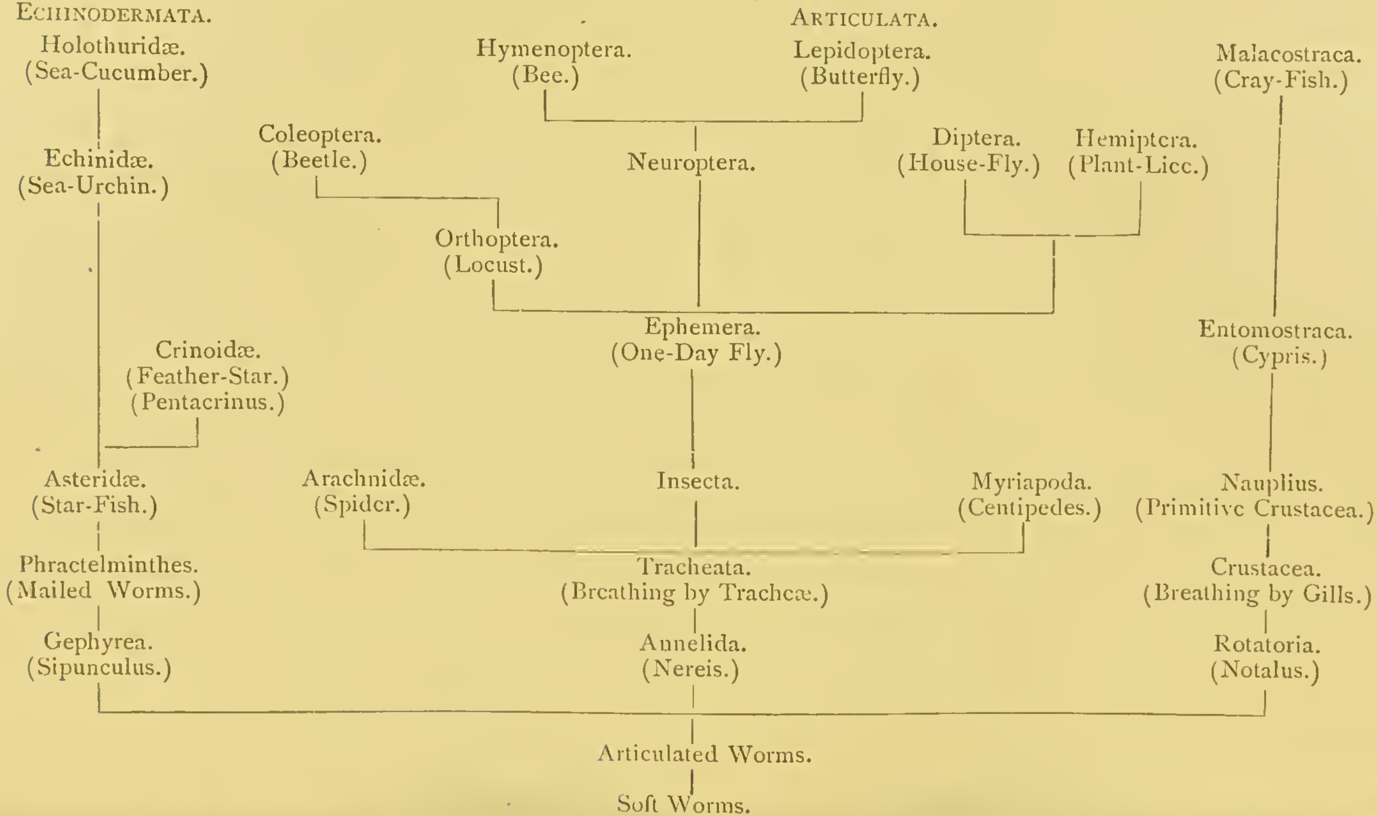
The development, however, of the Myriapoda is just the reverse of that of the Insects, the Centipedes, etc. increasing instead of diminishing the number of their segments. Originally the body is composed of a congeries of cells, segment after segment being added, exactly in the same manner as in the case of the Annelida, with which in structure they closely agree, being adapted, however, to live on land. The Annelida seem then to be the ancestors of the Myriapoda, Insects, and Spiders, the Myriapoda retaining much of the Annelid structure through life, whereas the Insect is an Annelid or Myriapod only when in a larval or undeveloped condition. That the development of the different kinds of insects has been gradual, Geology seems to show, the evidences for which will be brought forward in the chapter on that subject. By looking at Tree IV. the Hymenoptera will be seen very high up; this family includes the Bees, Ants, etc., whose economy has always been the subject of admiration on the part of naturalists. The Articulata are the most complex in structure of the Invertebrata, or animals without a backbone. The nervous system is highly developed, compound eyes are present, the digestive system has various parts, excretory glands and ducts have been discovered, respiration is carried on by the beautiful system of tracheæ, and of their powers of jumping, flying, stinging, biting, and making noises every one is aware.

The remaining division of the Articulata, including the Crabs, etc. (Fig. 51), though differing greatly in shape, size, etc., are all alike in their early stages. The Nauplius (Fig. 50), or primitive stage of every Crustacean, seems to be more nearly allied to the Rotatoria than any other group of animals. Some of the microscopic forms of the Crustacea, as Cypris, Daphnia, Cyclops, furnish the transitions from the Rotatoria to the Crustacea; indeed, the Rotatoria have been considered as a group of the Crustacea by many naturalists.

MOLLUSCA.

The most striking difference in the Mollusca, as compared with the Articulata, is seen in the entire want of that segmentation which is so apparent in the Insects or Centipedes. The body of an Oyster, a molluscous animal, is a soft mass, and, though possessed of organs, never exhibits the slightest trace of joints, as seen in the higher worms, insects, etc. The nervous system is composed of a few scattered nervous masses or ganglia, there being no distinct chain of ganglia running through the body from head to tail. Indeed, some of the Mollusca have no head, being known as the Acephala. For this reason the Acephala include the Brachiopoda and Conchifera. The Brachiopoda, Lamp Shells, or Arm-foot Mollusca, are better called Spirobranchiæ, as their branchiæ, or gills, are arranged in the

TREE IV.

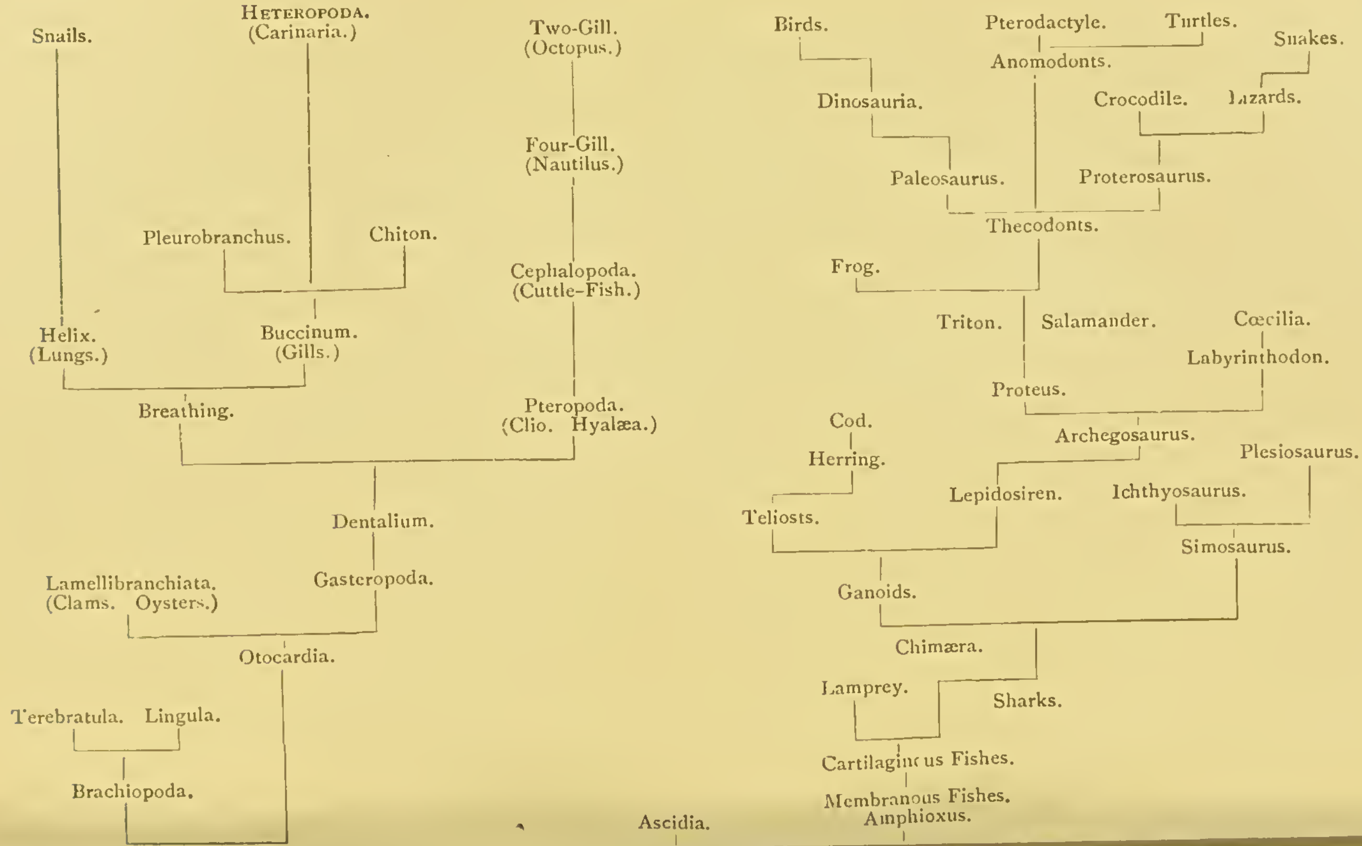

ECHINODERMATA.
Holothuridæ. (Sea-Cucumber.)
Echinidæ. (Sea-Urchin.)
Crinoidæ. (Feather-Star.) (Pentacrinus.)
Asteridæ. (Star-Fish.)
Phractelminthes. (Mailed Worms.)
Gephyrea. (Sipunculus.)
ARTICULATA.
Hymenoptera. (Bee.)
Lepidoptera. (Butterfly.)
Neuroptera.
Coleoptera. (Beetle.)
Orthoptera. (Locust.)
Diptera. (House-Fly.)
Hemiptera. (Plant-Lice.)
Ephemera. (One-Day Fly.)
Arachnidæ. (Spider.)
Insecta.
Myriapoda. (Centipedes.)
Tracheata. (Breathing by Tracheæ.)
Annelida. (Nereis.)
Malacostraca. (Cray-Fish.)
Entomostraca. (Cypris.)
Nauplius. (Primitive Crustacea.)
Crustacea. (Breathing by Gills.)
Rotatoria. (Notalus.)
Articulated Worms.
Soft Worms.

form of a spiral. They are represented in the present seas by very few genera, Lingula, Terebratula, etc. These spiral-shaped gills were supposed to be used as arms or feet: hence their common name of Arm-feet or Brachiopoda. The Conchifera are better named Lamellibranchiata, from the gills in this class being arranged in the shape of plates or lamellæ. This class includes the oysters, clams, mussels. The remaining classes of the Mollusca, the Gasteropoda and Cephalopoda, differ from the Acephala not only in having heads, but in many other respects. The Gasteropoda, or Belly-feet, are so called from these creatures moving on that part of their body. This class is represented by the Whelks (Fig. 52), most of the shells on the sea-shore, and the Snails. The common garden-snail is remarkable on account of the great number of teeth which arise from the tongue: as many as twenty-five thousand are said, according to competent authority, to have been discovered. The Cephalopoda (Fig. 54) are distinguished by having long arms or feet radiating from the head; hence the name of this class, which includes the Cuttle-fish and the Pearly Nautilus of the Indian Ocean. Gasteropoda like the Dentalium are so rudimentary as regards the development of the head, that they may be looked upon as offering the transition from the Gasteropoda to the Lamellibranchiata. The Spirobranchiata, or Brachiopoda, in their development and structure are so closely allied to the Bryozoa that perhaps they ought to be considered rather as part of the Worms than as belonging to the Mollusca. The curious affinities of the Brachiopoda, Bryozoa, and Worms are striking proofs for the view that the Mollusca have come from the Bryozoa, or animals allied to them, and they from the Worms. That the Brachiopoda were the first Mollusca that appeared on the earth is at once suggested from the enormous number of fossil forms that are found in the oldest rocks. They are so numerous that the name "Age of Mollusca" has been given to the time during which these creatures lived, there being found in great numbers also representatives of the other classes of Mollusca, though not in so great a profusion as Brachiopods. The Brachiopoda of the present seas are restricted to a few genera, the class having nearly died out. This is true, comparatively speaking, of the rest of the Mollusca, though not in so great degree. This fact of the abundance of the Mollusca in the oldest rocks, and of the Brachiopoda in particular, harmonizes with the facts of their structure and development in showing that the group must have branched off from the main trunk (worms) very early in time, and that of the Mollusca the Brachiopoda are the oldest. In some Gasteropoda the feet appear modified as wings, as in Hyalæa and Cleodora, constituting the Pteropoda, and offering the transition to the Cephalopoda. This view is confirmed by the embryos of the Gasteropoda, Pteropoda, and Cephalopoda (Fig. 53) being so very similar. The Gasteropoda breathe both by gills and lungs; examples of the gill-breathing kind are seen in the Whelks (Buccinum) (Fig. 52) often picked up on the sea-shore while the garden-snail will represent the lung-breathing kind. The beautiful Carinaria, with its delicate propeller, is a highly specialized gill-breather. The Cephalopoda are the most highly organized of the Mollusca. The Cuttle-fishes (Fig. 54), with their long arms, are familiar to all who have read the "Toilers of the Sea." In them we find the nervous system well developed, eyes are present, the viscera are large, while blood circulates through arteries and veins. The Cuttle-fish is able to conceal itself through emitting a very brownish-black fluid, which is contained in the so-called ink-bag. They breathe by two gills, but in one genus, the Pearly Nautilus, four gills are present. The Nautilus is the only living representative of myriads of fossil forms, the Ammonites, and is probably the ancestor of the two-gilled Cephalopods. The evidences of

ANIMAL KINGDOM.

Invertebrata.	Protozoa.	Monads. Amœbæ. Gregarinæ. Infusoria. Sponges.
	Cœlenterata.	Corals. Jelly-Fishes.
	Vermes.	Worms.
	Echinodermata.	Star-Fishes. Feather-Stars. Sea-Urchins. Sea-Cucumbers.
	Articulata.	Crabs. Centipedes. Insects. Spiders.
	Mollusca.	Lamp Shells. Oysters. Snails. Cuttle-Fishes.
Vertebrata.		Fishes. Batrachia. Reptiles. Birds. Mammals.

TREE V.


Snails.
HETEROPODA. (Carinaria.)
Two-Gill. (Octopus.)
Four-Gill. (Nautilus.)
Pleurobranchus.
Chiton.
Cephalopoda. (Cuttle-Fish.)
Helix. (Lungs.)
Buccinum. (Gills.)
Breathing.
Pteropoda. (Clio. Hyalæa.)
Dentalium.
Gasteropoda.
Lamellibranchiata. (Clams. Oysters.)
Otocardia.
Terebratula.
Lingula.
Brachiopoda.
Ascidia.
Birds.
Pterodactyle.
Turtles.
Snakes.
Anomodonts.
Dinosauria.
Crocodile.
Lizards.
Paleosaurus.
Proterosaurus.
Thecodonts.
Frog.
Triton.
Salamander.
Cœcilia.
Labyrinthodon.
Proteus.
Cod.
Archegosaurus.
Herring.
Plesiosaurus.
Lepidosiren.
Ichthyosaurus.
Teliosts.
Simosaurus.
Ganoids.
Chimæra.
Lamprey.
Sharks.
Cartilaginous Fishes.
Membranous Fishes.
Amphioxus.

Anatomy, Embryology, and Geology, when taken together, make it most probable that the Tree of the Mollusca is such as represented.

With the Mollusca we leave the Invertebrata, or animals without a backbone, and turn to the Vertebrata.

VERTEBRATA.

This division includes—1st, the Fishes; 2d, the Batrachia (frogs, etc.); 3d, the Reptiles (snakes, etc.); 4th, the Birds; 5th, the Mammals (animals suckling their young). They all possess a backbone, rudimentary in some fishes. This backbone is composed of separate bony pieces known as vertebræ; hence the name of Vertebrata given to the five classes just mentioned. Running through this backbone, spine, or vertebral column, as it is differently called, is seen the marrow or spinal cord,—a nervous cord which expands into the brain, which is inclosed by the skull-bones. Such a structure is never seen in a star-fish, insect, or mollusk. The Vertebrata never possess more than two pairs of limbs. The muscles moving these limbs are attached to bones, which, together with the skull and backbone, form the skeleton. The skeleton is the most characteristic feature of the Vertebrata, and nothing like it is met with in the Invertebrata, called also Evertebrata, that is, without vertebræ. There are apparent exceptions, such as the wing of an insect, among the Invertebrates, which is used like the wing of a bird; but the wing of the insect is only an expansion of the skin, whereas the wing of a bird is always supported by bone. The wing of the insect and that of the bird are said to be analogous, because they are used for the same purpose; they are not homologous, because they have not the same structure. The jaws of a Vertebrate are always parts of the head, never, as in many of the Crabs, modifications of the anterior limbs. There are found at different stages of existence in the Vertebrata, behind the mouth, thickenings; they are known as the visceral arches. (Fig. 178, *c*.) The spaces between these thickenings finally disappear, so that the interior of the mouth communicates with the exterior. Such a condition is retained in fishes, where we see the water entering the mouth and passing out through the gills. The visceral arches are never seen among the Invertebrates. Such structures as those just mentioned were often quoted as separating the Vertebrates entirely from the Invertebrates; and these differences, as well as others, were so great that they were considered as offering an insuperable objection to the view that the Vertebrata had been developed from the Invertebrata. Recently it has been shown, however, that the Ascidia, one of the Tunicate saç-worms, develops in the same manner as the Amphioxus, the simplest fish known. The young Ascidian (Fig. 38, *a*) resembles a tadpole, and swims freely about by means of its tail. In this state it has as much of a backbone as the Amphioxus. After it matures it becomes stationary (Fig. 38), remaining attached to objects by means of a root-like foot. The gulf between the Vertebrates and Invertebrates is now bridged over by this discovery of the identical development of the Amphioxus and Ascidia. The Amphioxus is the only living representative of a group probably long since extinct. This group, allied to the sac-worms in its structure, has in one direction retrograded, the Ascidians, in another progressed, the Amphioxus.

The structure of the skull offers one of the most striking proofs for the common origin of the Vertebrata. If we compare in this respect a fish, turtle, bird, mouse, elephant, and man, we shall find that, notwithstanding the great difference in appearance of these animals, their skulls are fundamentally composed of the same bones arranged in the same manner.

Remembering the different uses of the arm of man and monkey, the wing of bat and bird, the pectoral fins of whale and Ichthyosaurus, the fore limb of horse and frog, one would not believe that they are all identical structures. Nevertheless, Comparative Osteology has shown that the fore limb in every Vertebrate is composed of the same bones, joined in the same way (Figs. 82 to 86), giving attachments to the same kind of muscles, though serving very different purposes, as in the cases just mentioned. There seems to be but one explanation for the existence of these similar parts with dissimilar uses, namely, that the Vertebrata have descended from one common ancestor, and that their posterity, subjected to different conditions of existence, have had their originally similar structures more or less modified.

Embryology has shown that the early conditions of all Vertebrata are alike, so much so that it is impossible to distinguish the young turtle, chicken, dog, and man (Figs. 178 to 181) from one another at certain stages of their existence; and that in proportion as the animals are alike when mature, the longer will their young resemble each other, whereas in those animals which are most unlike when adult, it will be found that their young early indicate difference; and that what is transitory in the higher animals is retained permanently in the lower,—the higher animals representing at some time the lower. These facts can only be explained by the theory that the Vertebrata are the descendants of a common ancestor. Geology has shown that the earth has experienced great changes through past time,—the sea washing away the land, the land filling up the sea, together with other causes, changing entirely the conditions of existence. Some of the animals living at that day, not capable of resisting such changes, perished, in many cases leaving their skeletons well preserved, as imperishable proof of their having lived. Such are known as fossils, and the study of these ancient remains constitutes Paleontology. This science has shown that forms so different as the Horse and Rhinoceros are linked together by the fossil forms of Coryphodon, Paleotherium, etc.; that the Pig and Hippopotamus represent another group, connected by Anoplotherium and Dichotrum, etc.; that the Fishes and Batrachia form one great division, the Reptiles and Birds another,—forms linking indissolubly together these divisions of the Vertebrates having been discovered in different parts of the world. The structure, the development, and fossil remains all harmonize in proving without a doubt that they are only the modified posterity of a class now extinct, which the Amphioxus nearly represents. That the Amphioxus came from Worms in their structure allied to Ascidians, is highly probable. But, given the Amphioxus, that the genealogy of the Vertebrata is represented by a tree, like that provisionally offered in Tree V., seems to us to follow, without doubt, from the facts of Anatomy, Geology, and Embryology.

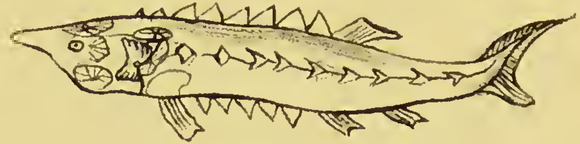
FISHES.

The Amphioxus, or Lancelet, is a little animal about two inches long, found generally buried in the sand on the coasts of different seas. It does not possess head, brain, eyes, or limbs, and yet there exists a backbone in a rudimentary condition (notochord), and marrow. Its gills are not like those of fishes, but its branchial apparatus is that of an Ascidian (Fig. 40), confirming the view of the origin of the Amphioxus from the Ascidian Worms, suggested by their identical development. What is the Amphioxus? It seems to be an intermediate animal, a link connecting the Ascidian with the Fishes. The part of the body containing the mouth is usually regarded as the head, and is membranous in structure, which condition is found in fishes at certain periods of their existence. We may designate the class of fishes of which the Amphioxus is the representative, then, as Membranous Fishes. The first step in complexity of structure is presented by the simplest of the gristly (cartilaginous) fishes, Lamprey. They possess a gristly skull, with brain, etc., but there is no lower jaw attached to the skull, their mouth being of the sucking kind (Cyclostomi). There are no traces of limbs as yet; but the sucking fishes have a distinct heart, differing from the Amphioxus, wherein we find only slight dilatations of the blood-vessels. The Myxine, or Hag-fish, and the Petromyzon, or Lamprey, are representatives of this order. In the Chimæra we find a lower jaw, but its suspensorium is still immovable. It furnishes the transition from the Lamprey kind to the Sharks. (Fig. 55.) The Sharks and Rays (Devil-fish) are still gristly in structure, but their jaws are very freely movable, and furnished with numerous teeth, which are very characteristic in the different kinds. These teeth are found fossil in great numbers in the early rocks, and prove that the gristly fishes were among the first Vertebrates that appeared in the seas. The Sharks possess two pairs of fins, and their intestine is furnished with valves arranged in a spiral or transversely. We come next to a class of fishes known as Ganoids, that is, shining. In some of these, as in the Sturgeon (Fig. 56), we have the backbone still gristly, while in others, as in the Gar-pike, it is bony. The outer part of the body is covered either with shiny plates (Placoganoids), as in the Coccosteus, Sturgeon, or with shiny scales (Lepidoganoids), as in the Gar-pike. It is by means of these shiny plates and scales, as well as the whole fish, found in great profusion, well preserved in the early rocks, that we know that the Ganoids are very old fish, and that they existed in great numbers in the early ages of the earth; whereas at the present day the Ganoids are represented only by half a dozen kinds, the Sturgeon, Gar-pike, Polypterus, etc. The

55

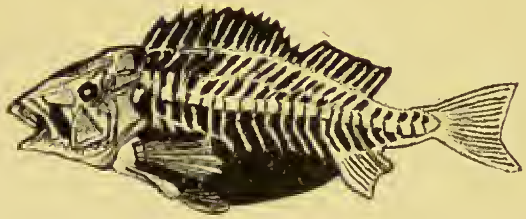
SHARK

56



STURGEON

57

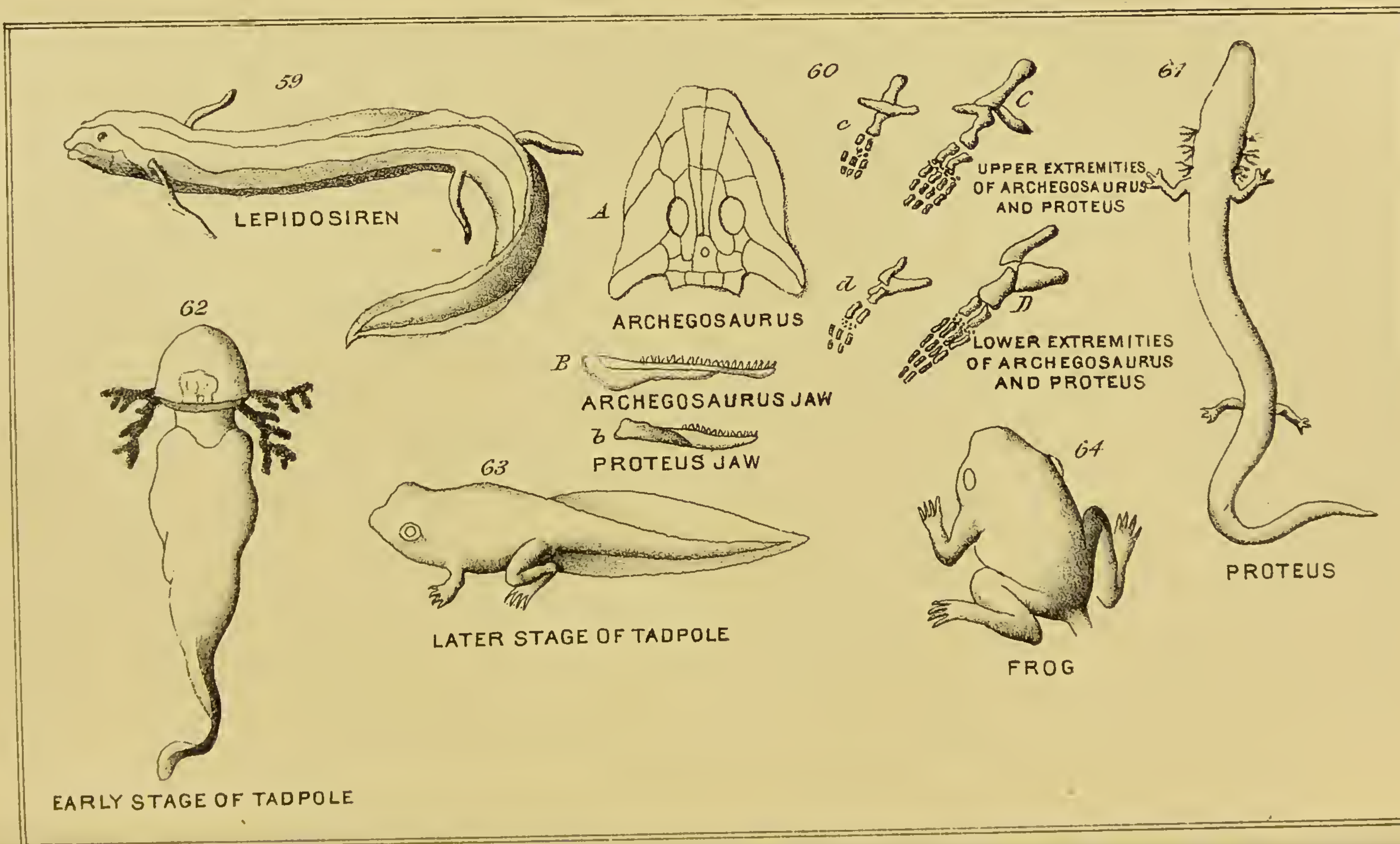


PERCH

58

ICHTHYOSAURUS

Ganoids agree with the Sharks in the structure of their heart and optic nerves, and Polypterus has the spiral intestinal valve of the Sharks, but their skulls have true bones, and they possess a gill-cover (opercular appendage). In this respect they agree with the Teliosts, or bony fish, of the present day. If we compare the tail of one of our common fish, a Cod, or Shad, or Perch (Fig. 57), with the tail of a Shark (Fig. 55) or a Sturgeon, we see that in the Perch the end of the tail divides into two equal parts, whereas in the Sturgeon (Fig. 56) the tail divides unequally. The unequally-ending or heterocercal tail is characteristic of these Ganoid fishes, and the equally-ending or homocercal tail is equally characteristic of our common fishes; but the tail of the embryo of one of our common fishes ending unequally is as heterocercal as the tail of the Sturgeon. The embryo fish is composed also of gristle, as regards its backbone and skull. Hence the transitory stage or embryo condition of our common fish represents the permanent stage of the Sharks and Sturgeons,—a striking proof of the truth of the view that the Bony Fish, or Teliosts, are the posterity of the Ganoids and Sharks. Fossil Ganoids, like the Cœlacanthes, Holoptychii, Coccolepis, and Amia of the present day, were probably the ancestors of fishes in which the air-bladder has a duct, as seen in the Carp, Herring, Salmon, while they were probably the progenitors of those fishes in which the duct is absent or rudimentary, as in the Perch, Cod, Sole. We turn now to a consideration of the remaining order of fishes, known as Dipnoi, and represented by the Lepidosiren (Fig. 59) of South America and the African rivers. During the rainy season in Africa, large tracts of land are overflowed by the rising of the rivers. With the retreating waters are carried most of the fish; but the Lepidosiren remains, and, burrowing in the mud (hence its name of mud-fish), constructs a hole, leaving only a small opening for the passage of air. Exuding a sort of slime as a covering for its body, and remaining in this torpid condition, it breathes by means of lungs until the return of the water, when it rises to the surface and breathes by its gills. Hence the Lepidosiren is both Fish and Amphibian. As regards its respiration, it is truly an Amphibian. It differs from the ordinary fish in the structure of its heart, which is composed of three chambers in the Lepidosiren and Amphibian (Siren, Frog, etc.), whereas in the Fishes the heart is composed of only two. The Lepidosiren and Polypterus both have the spiral valve in the intestine, so characteristic of the Sharks. The air-bladder in Polypterus, and the lungs of Lepidosiren, are the same in their structure as regards the arteries of these parts and the relations of their air-ducts. The form of the brain is the same in Lepidosiren and Polypterus. The skull of Lepidosiren is intermediate between the gristly and the bony fishes. The backbone is gristly; in this respect it agrees more with the Fishes than with the Amphibia. In the structure of the liver apparatus and the limbs it agrees with the Amphibia. What is the Lepidosiren? Is it a Fish, or is it an Amphibian? The Lepidosiren is the intermediate form linking the Fishes and Amphibia together, and is more closely allied to the Ganoid Polypterus than any living fish. Among the fossil Ganoids the Coccosteus would represent the Lepidosiren should its skeleton be fossilized. The Ganoid fishes, although intermediate between the Sharks and common bony fishes or Teliosts, have many affinities with the Amphibia: thus, the Amia and Lepidosteus, among the Ganoids, have the air-bladder filled with air-vesicles and resembling strongly the lung of the Amphibia. So the backbone of the Lepidosteus in the ball-and-socket joint of the pieces forming its spine differs from all Fishes, and agrees with many of the Amphibia. The structure of the Ganoids, Lepidosiren, and Amphibia seems to warrant the conclusion


59
LEPIDOSIREN
A
ARCHEGOSAURUS
B
ARCHEGOSAURUS JAW
b
PROTEUS JAW
60
c
C
UPPER EXTREMITIES
OF ARCHEGOSAURUS
AND PROTEUS
d
D
LOWER EXTREMITIES
OF ARCHEGOSAURUS
AND PROTEUS
61
PROTEUS
62
EARLY STAGE OF TADPOLE
63
LATER STAGE OF TADPOLE
64
FROG

that they are but the links in a chain with the Fishes at one end and the true Reptiles at the other.* Among the most perfectly preserved fossils are the Ichthyosauri (Fig. 58) and Plesiosauri. They seem, on the whole, to be more allied to Fishes in the structure of their paddles, backbone, etc., and Amphibia in other respects, than to true Reptiles, and must have diverged early from the main fish stem. Their position is somewhere near the Lepidosiren, Archegosaurus, and Labyrinthodon stems.

BATRACHIA.

The Batrachia, or Amphibia, as they are often called, include the Frogs, Salamanders, Siredons, Tritons, Cœcilia, and the fossil Archegosaurus and extinct Labyrinthodons. They breathe by gills, at least at some period of their existence, and in this respect agree with Fishes. Some of the Batrachia, as the Siren, Proteus (Fig. 61), and Menobranchus, retain their gills throughout life, and for this reason are called Perennibranchiata; whereas others, as the Frog (Fig. 64), lose them after passing through their tadpole stage. (Figs. 62, 63.) The Batrachia present two types for consideration: in the one we find the body covered over with bony plates or scales, as in the extinct Archegosaurus (Fig. 60), Labyrinthodons, and Cœcilia; in the other, the body is naked, as in the Siren, Salamander, and Frog. A considerable advance in structure is seen on comparing the Batrachia with Fishes; but the Lepidosiren links together the Ganoid Fishes with the Frog division of the Batrachia, while the Archegosaurus leads up from the Ganoids through the Labyrinthodon to the Cœcilia.

The Archegosaurus (Fig. 60), when first discovered, was supposed to be a fish; but more careful study has shown

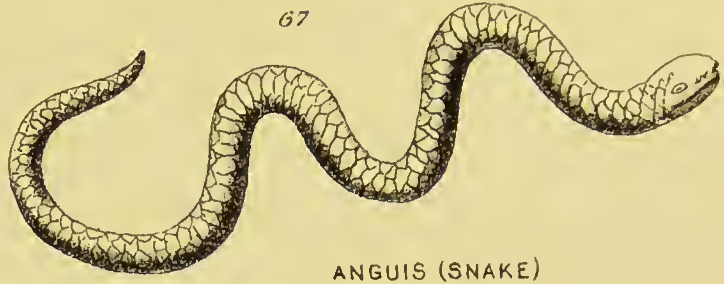
* See page 61 for further proofs of this among the Amphibia.

equal affinities with the Batrachia. The Labyrinthodon is another extinct form, with a very large skull, sometimes three feet in length and two in breadth. The bones of the skull in Archegosaurus and Labyrinthodon recall strongly the skull of the Gar-pike and Sturgeon. The persistence of a gristly backbone in Archegosaurus is the same as in the Sturgeon. The Lepidosiren and Archegosaurus agree in the structure of their backbone, and the retention of the branchial (gill) arches, and in the manner in which their skulls are joined to the backbone (absence of occipital condyles). The teeth are of the same kind (labyrinthic) in the Gar-pike, Archegosaurus, and Labyrinthodon. The large throat-plates in Archegosaurus are like those of Megalichthys (fish) and the Gar-pike; whereas, in the structure of the jaws (Fig. 60, *B*), certain bones called hyoid, and in the shoulder-girdle and extremities (Fig. 60, *C*, *D*), we see striking proofs of the relation of Archegosaurus to Batrachia like Proteus, whose jaws and extremities are (Fig. 60, *b*, *c*, *d*) very like those of Archegosaurus. The Archegosaurus form is the link between the Fishes and Batrachia, on the one hand leading through the Labyrinthodon to the Cœcilia, on the other to the Frogs through Siredon forms. The Archegosaurus came either directly from the Ganoids, or indirectly through the Lepidosiren. Supposing the latter view to be the true one, then the Ganoids divided into two branches, one being transformed into the common fish, the other giving rise to Lepidosiren-like forms, these leading insensibly to the Archegosaurus, the earliest of the Amphibia, the long type represented by Labyrinthodon and Cœcilia forming one stem, the Siredon and Frogs, naked Amphibia, the other. The naked Batrachia are among the most striking proofs of the truth of the Derivation theory, as the links are all living. The Siredons and Proteus (Fig. 65, 61) strongly resemble the Lepidosiren and Archegosaurus; they have tails and external

65

SIREDON

67

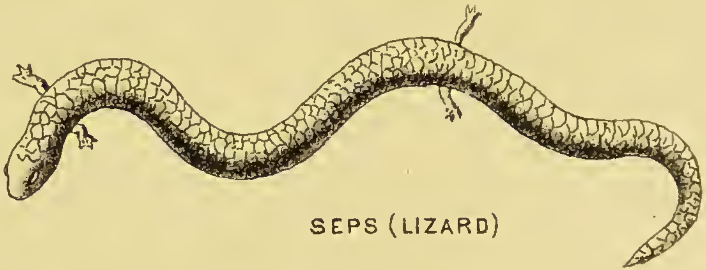


ANGUIS (SNAKE)

66

AMBLYSTOMA

68



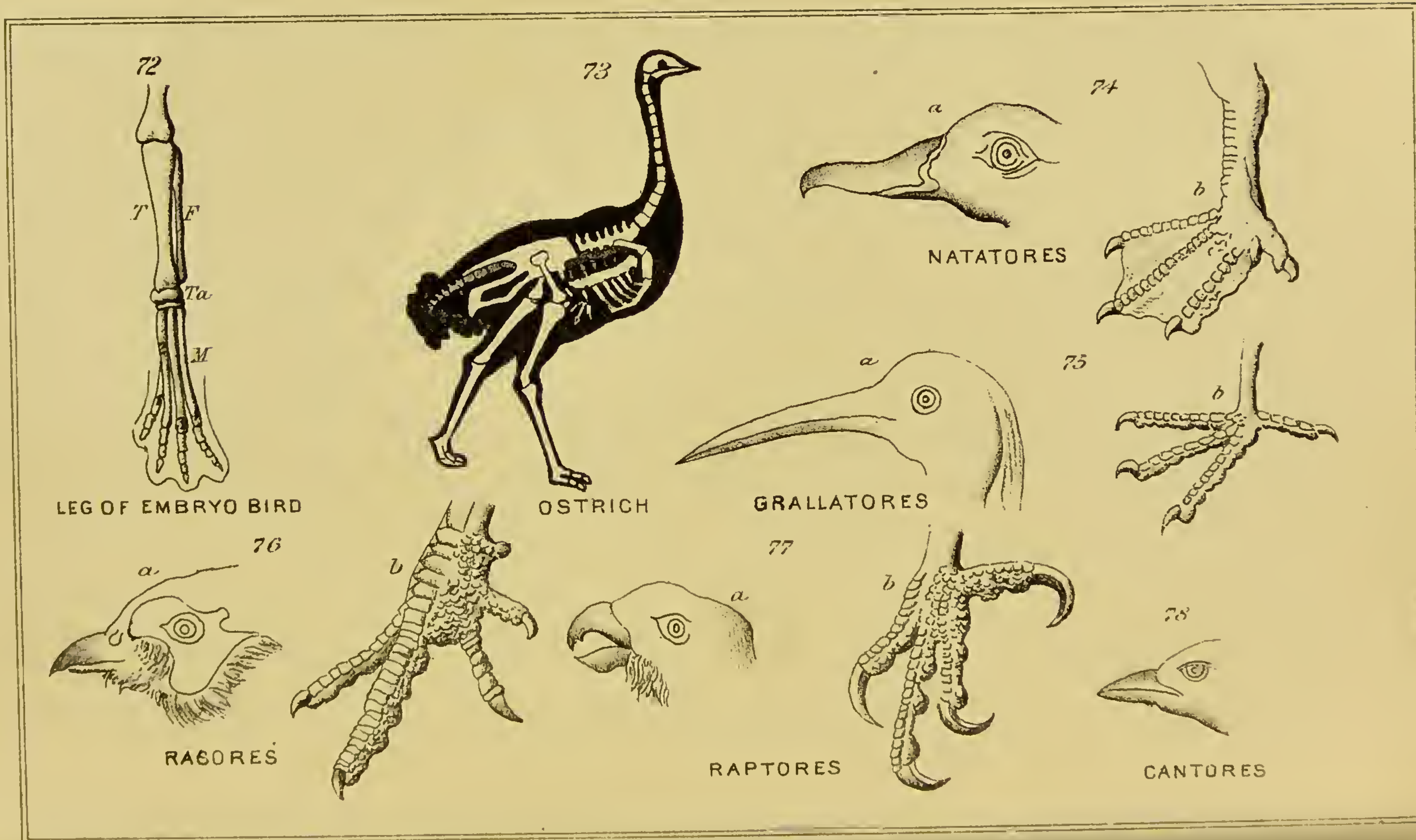
SEPS (LIZARD)

gills. In the next order, that of the Tritons and Salamanders, the tails are retained, but the external gills are lost; finally, the Frog has neither gills nor tail, but the tadpole or the immature frog has both, so that in one stage of its existence (Fig. 62) the Frog is a Siredon, later it is more like a Salamander, finally it (Fig. 63) resembles neither.

REPTILES.

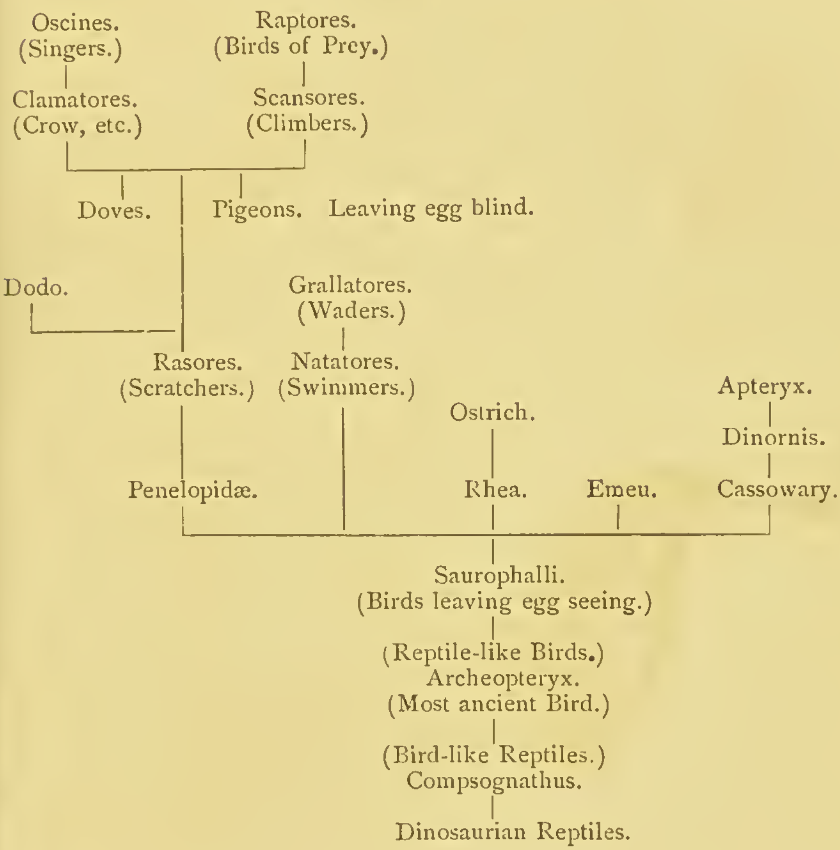
Leaving the Fishes and Batrachia, and turning to the Reptiles, we see that the Fishes and Batrachia breathe by means of gills (the Batrachia at some stage of their existence), whereas the Reptiles always breathe by lungs, as a bird or four-footed creature. The Vertebrates have been divided by some naturalists, for this reason, into the two divisions of the gill-breathing, Fish, Batrachia; and the lung-breathing, Reptiles, Birds, Mammals. The reptiles, birds, and mammals agree with each other in possessing, during embryo life, an amnion and an allantois (see Embryology); the fishes and batrachia never, at any stage of their existence, possess either. The amnion is a transparent sac filled with a fluid (liquor amnii) in which the young bird or reptile floats. The allantois is a vesicle starting from the under part of the body of the bird or reptile, and filling up the interior of the egg. The allantois is filled with blood-vessels; and as the porosity of the egg-shell permits the passing out of the pernicious carbonic acid, and the passing in of the life-sustaining oxygen, it is by means of the allantois that respiration is effected. The visceral arches in the young bird and reptile (Figs. 179, 178 *c*) are converted through growth into part of the jaws and part of the organ of hearing; the visceral arches in the fishes are modified into gills. We see, therefore, that a great progress has been made on comparing the structure of the gill- and lung-breathing division of Vertebrates.

The Reptiles of the present day include, 1st, the Lacertilia (Monitors, Chameleons, Wall-lizards); 2d, the Ophidia (Snakes); 3d, the Crocodilia (Crocodile, Alligator); 4th, the Chelonia (Turtles); and numerous extinct forms. As the reptiles that live at the present day are but a small portion left of those that have once lived, and as these extinct forms are not always entirely preserved, and from the nature of petrifaction very little of their soft parts can be known except from analogy, naturally the ancestors of the reptilian class have not been positively determined. Premising that the tree of the Reptiles, like all other such trees, is only a provisional one, the following line of descent is offered with diffidence. As long ago as 1710 the Proterosaurus—which, when translated, means "first lizard"—was described by Spener, a physician of Berlin. Since that time other reptiles, allied to Proterosaurus, have been discovered, as Belodon, Paleosaurus, etc., which have been classed together as Thecodonts. The skeleton of Proterosaurus resembles most closely, among living reptiles, that of the Varanus, the large African lizard; but among the Thecodonts have been found also scales of a crocodilian nature, so that the Thecodont group seems to be the forerunner in the Proterosaurus of the lizards and crocodiles, while the Paleosaurus and Belodon are the first of a series leading to the Dinosauria. The Snakes are probably an offshoot of the Lizard, to which they are closely allied; the Sepidæ (Fig. 68), among the Lacertilia, leading to the Anguidæ (Fig. 67) among the Snakes. The Anemodonts, of which the Pterodactyle is a remarkable representative, lead to the Turtles through forms like Rhynchosaurus. The Dinosauria were represented by huge reptiles like Iguanodon and Hadrosaurus, of which some were more than thirty feet long. They are very interesting on account of their affinities to birds. The different orders of Reptiles seem to have branched off from a common stock represented by


72
T
F
Ta
M
LEG OF EMBRYO BIRD
73
OSTRICH
74
a
b
NATATORES
75
a
b
GRALLATORES
76
a
b
RASORES
77
a
b
RAPTORES
78
CANTORES

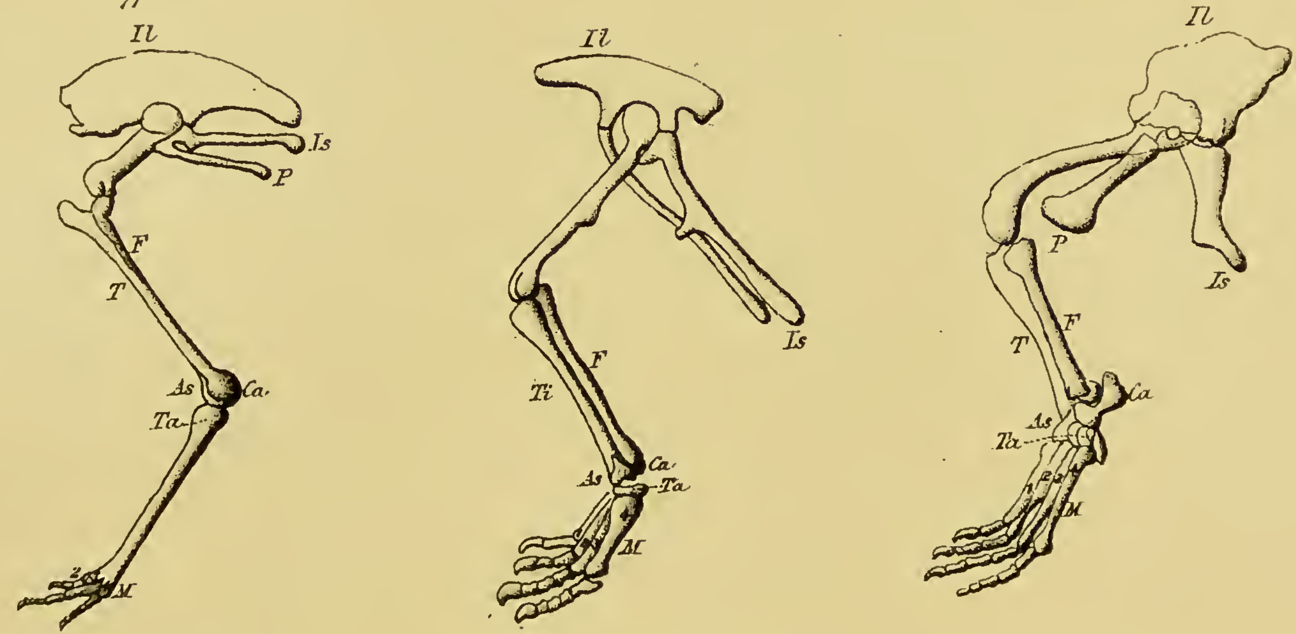
Thecodont forms, which are allied to the Salamanders among the Batrachia. Until some better theory of the origin of Reptiles is offered, this one will be provisionally accepted.

TREE VI.



BIRDS.

Although the class of Birds presents great variety as regards differences in shape, color, manner of living, etc., they can be represented by the types of swimming (Fig. 74) (duck), wading (Fig. 75) (snipe), scratching (Fig. 76) (chicken), singing (Fig. 78) (lark), flying (humming-bird),



71 EMEU

70 DINOSAUR

69 CROCODILE

we find the bones of the foot (first series of tarsal bones) soldered together and with the tibia as in birds, whereas in most reptiles these bones remain distinct. The Compsognathus in this, as well as in other respects, is a very bird-like reptile. The Compsognathus is considered by some anatomists to belong to the order of Dinosaurian reptiles. The Dinosauria agree in many respects with the Ostrich family, perhaps being more nearly allied to them than to any other order of birds. They used their hind limbs only as a means of progression; in this respect they resembled birds more than reptiles; their feet were terminated with claws (Fig. 70), and the curious arrangement by which the bones of the leg (tibia and fibula) are united to those of the foot (astragalus) in birds seems to have been exactly the same in these huge reptiles. The bones of the leg of the embryo bird (Fig. 72) are like those of the adult Dinosaurian and Reptile. (Figs. 70, 69.) There is good evidence for supposing that the muscles moving the foot had the same disposition in some of the Dinosauria as exhibited in the chicken. According to a high authority on this subject, "if the whole hind quarters from the ilium (haunch bone) to the toes of a half-hatched chicken could be suddenly enlarged, ossified, and fossilized as they are, they would furnish us with the last step of the transition between birds and reptiles, for there would be nothing in their characters to prevent us from referring them to the Dinosauria." And according to the same high authority (Prof. Huxley), if certain bones of the Hypsilopodon had been found alone, they would have been certainly described as belonging to a bird. The idea of these huge Dinosaurs having so much in common with birds is not a mere theory, but a truth, whatever inferences may be drawn from it, as the bones of some of them (the Megalosaurus, etc.), at least in reference to the posterior extremities, are absolutely the same as those of a bird. The Compsognathus, in the great number of neck-bones (cervical vertebræ), in the light character of the bones of the head, together with the structure of the foot, is probably the most bird-like of reptiles, and is to be considered together with the Megalosaurus, Hypsilopodon, and other Dinosauria, as the representative of the ancestors of birds. It is not possible to say exactly which Dinosaur was the progenitor of birds, but as the Compsognathus is the most bird-like of reptiles, we take it as our example. The idea of birds coming from reptiles is suggested by the following facts: 1st, existing birds have much in common with existing reptiles; 2d, birds and reptiles, at an early period of their existence, cannot be distinguished from one another, as in the case of the embryo chicken and turtle; 3d, the most ancient bird (Archeopteryx) is very reptilian, while certain extinct reptiles (Dinosauria) are very bird-like. These statements are facts accepted by naturalists, whether they are evolutionists or not; they seem to us to harmonize in warranting the conclusion that birds are modified reptiles. Among existing birds the Ostrich family is particularly interesting, as they seem to be the representatives of a class once much larger. The Ostrich is found in Africa, the Rhea in South America, the Emeu in New Holland, and the Cassowary in the East Indies. They are known as the running birds, their wings being quite rudimentary. With the Ostrich family is generally placed the Apteryx of New Zealand. It is a little bird, the miniature of the gigantic Dinornis, which stood nearly twice as high as the Ostrich. The Dinornis has died out very recently, if it be indeed extinct. This very wide distribution of the Ostrich family suggests that the order was once much larger, extending all over the earth, and that the present representatives are the sole survivors. This seems more natural than to suppose that the Ostrich, Rhea, and Cassowary appeared independently in parts of the earth so remote. If this view be correct, then the running birds are older than the ordinary birds; this harmonizes with the fact that the running birds are of existing birds the most nearly allied to the Dinosauria, the supposed ancestors of birds. The birds called Penelope (Cranes) are generally classed with the scratching birds, but they seem to be more nearly allied to the Rhea, Emeu, and Cassowary, and are joined with them, and called by Haeckel Saurophalli. The tree of descent would be then Dinosaurian reptiles, represented by Compsognathus, etc. Changed into Archeopteryx-like forms, the most ancient of birds, the modified posterity of the Archeopteryx would be represented by the Penelope, Rhea, Emeu, Cassowary, having three toes. The African Ostrich, having only two toes, is probably more modern than the three-toed South American kind, or Rhea. The Cassowary, through the Dinornis, leads up to the Apteryx, while the Emeu and its posterity seem to have remained unchanged. The Penelopidæ are probably the ancestors of the scratching birds, to which are nearly allied the recently extinct Dodo of the Mauritius, and the doves and pigeons. The ducks seem to form the transition between the Saurophalli and the swimming birds, though it must be remembered that the Penguin in its separated metatarsals (bones of the foot) would indicate an ancient bird. The swimming birds gave rise probably to the wading birds. All these birds, excepting the doves, leave the egg in a condition fitted to nourish themselves; whereas the doves, pigeons, etc., and their descendants, leave the egg blind, and are nourished by their parents. The pigeons and doves, descending through the Pteroclidæ from the scratching birds, probably divided into two branches, the Clamatores (crows, etc.) and the Climbers (woodpecker, etc.); the Clamatores were gradually improved into our singing birds, and the climbing birds into birds of prey.

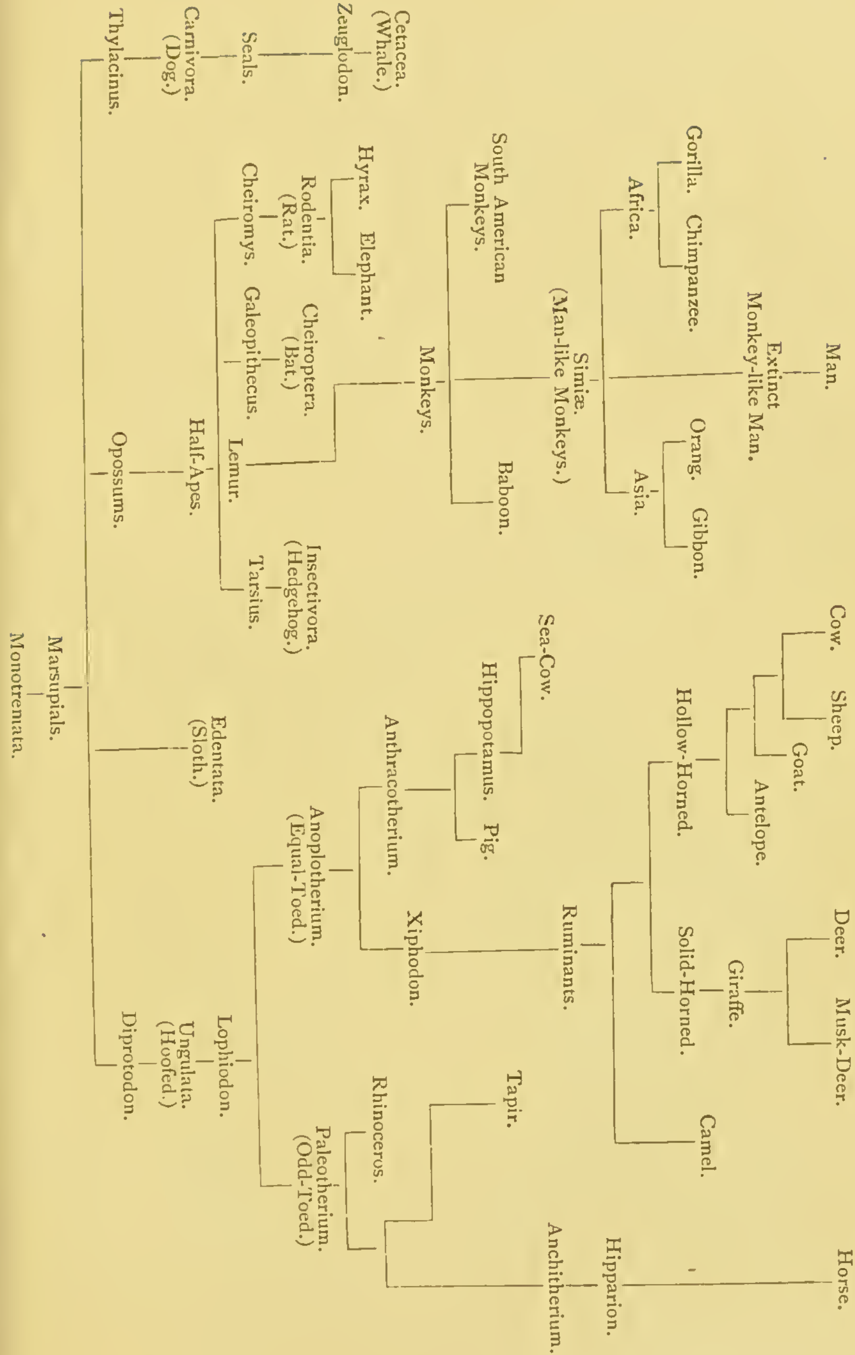
MAMMALIA.

SUB-CLASS.	ORDER.	EXAMPLE.
Ornithodelphia.	Monotremata.	Ornithorhynchus.
Didelphia.	Marsupialia.	Opossum.
Monodelphia.	Carnivora.	Dog.
	Cetacea.	Whale.
	Prosimiæ.	Lemur.
	Simiæ.	Man, Monkey.
	Rodentia.	Beaver, Rat.
	Hyracoidea.	Hyrax.
	Proboscidea.	Elephant.
	Cheiroptera.	Bat.
	Insectivora.	Hedgehog.
	Edentata.	Sloth.
	Ungulata.	Horse, Pig.
	Sirenia.	Sea-Cow, Dugong.

MAMMALIA.

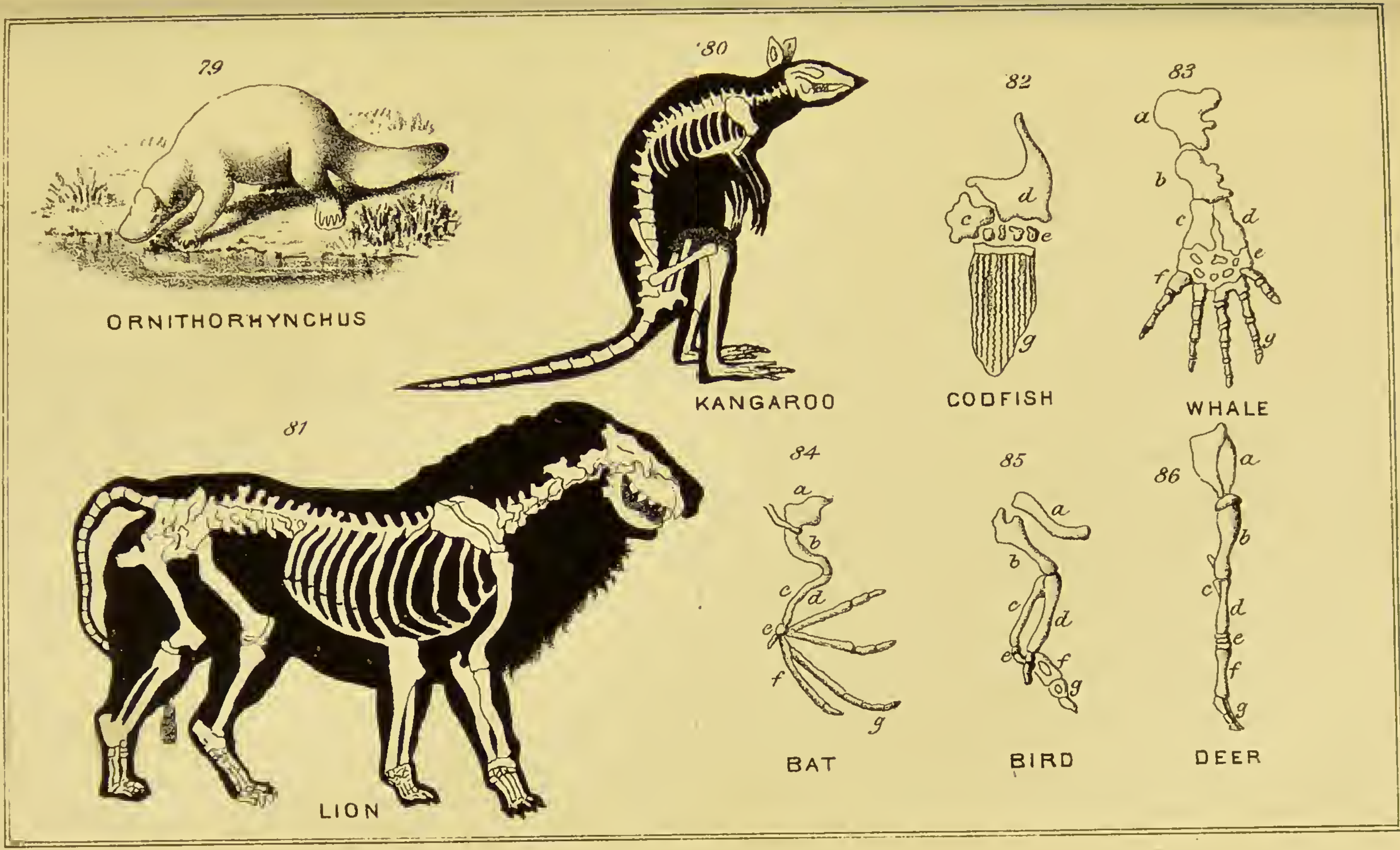
The class Mammalia is so called from the females suckling their young, and includes the domestic animals as well as many other less well-known forms. The mammals differ from the reptiles and birds in many important characters, as in the manner in which the skull and backbone are joined together (two condyles instead of one), in the simple structure of the lower jaw, it being composed of only one piece on each side in the Mammalia, whereas in the reptiles and birds it is made up of several. The skin of the mammals is covered more or less with hairs, never with feathers, as in birds. They bring their young into the world living, and nourish them for a longer or shorter time with milk. These peculiarities, as well as others, separate the birds and reptiles from the mammals. The Mammalia can be divided into three sub-classes, each of which offers well-marked peculiarities, which serve to distinguish

TREE VII.


Man.
Extinct Monkey-like Man.
Gorilla.
Chimpanzee.
Africa.
Orang.
Gibbon.
Asia.
Simiæ.
(Man-like Monkeys.)
South American Monkeys.
Baboon.
Monkeys.
Cetacea.
(Whale.)
Zeuglodon.
Seals.
Carnivora.
(Dog.)
Thylacinus.
Hyrax.
Elephant.
Rodentia.
(Rat.)
Cheiroptera.
(Bat.)
Cheiromys.
Galeopithecus.
Lemur.
Insectivora.
(Hedgehog.)
Tarsius.
Half-Apes.
Opossums.
Marsupials.
Monotremata.
Cow.
Sheep.
Goat.
Antelope.
Hollow-Horned.
Deer.
Musk-Deer.
Giraffe.
Solid-Horned.
Camel.
Ruminants.
Sea-Cow.
Hippopotamus.
Pig.
Anthracotherium.
Xiphodon.
Anoplotherium.
(Equal-Toed.)
Tapir.
Rhinoceros.
Paleotherium.
(Odd-Toed.)
Horse.
Hipparion.
Anchitherium.
Lophiodon.
Ungulata.
(Hoofed.)
Diprotodon.
Edentata.
(Sloth.)

readily these sub-classes. They have been called Ornithodelphia, Didelphia, Monodelphia. The first sub-class is so called from the terminal arrangement of the abdominal viscera being the same as that of Birds and Reptiles. The Ornithorhynchus and Echidna are the only representatives of the Ornithodelphia, and are limited to Australia and Tasmania. They seem to be the survivors of a class once much larger, and now extinct. The Didelphia include the Kangaroos (Fig. 80), Wombats, Opossums, etc. With the exception of the Opossums, they are also confined to Australia and the adjacent isles. The most striking feature in this sub-class is the pouch in which the young are protected in their helpless condition. The third sub-class of Mammalia, the Monodelphia, contains as many as twelve orders, of which the following will serve as examples: Dog, Whale, Lemur (a sort of Monkey, one of the Prosimiæ), Ape, Man, Beaver, Hyrax, Elephant, Bat, Hedgehog, Sloth, Horse, Pig, and Sea-cow. The names of the orders of which these animals are examples may be seen in the accompanying diagram. It is to be understood that there are many other examples of each order, which want of space prevents us from inserting. Of all Mammalia, the Ornithorhynchus (Fig. 79) and Echidna approach nearest the Birds and Reptiles, not only in the characteristic arrangement of the abdominal viscera, but also in the skeleton. The collar-bone (clavicle), the breast-bone (sternum), and the coracoid process of the shoulder-blade (scapula) form together a fork-shaped bone similar to that of Birds and Lizards. This fork-shaped bone is not present in the other Mammalia. The ribs in the Ornithorhynchus offer the same arrangement as seen in the Crocodile, while the skull is very bird-like in the articulations of its bones, and in the arrangement of the organs of hearing (semicircular canals) and the nerve of smell.

While, therefore, there can be little doubt that the class


79
ORNITHORHYNCHUS
80
KANGAROO
82
c d e g
CODFISH
83
a b c d e f g
WHALE
81
LION
84
a b c d e f g
BAT
85
a b c d e f g
BIRD
86
a b c d e f g
DEER

represented by the Ornithorhynchus is the posterity of the Sauropsida (birds and reptiles), yet the imperfect knowledge of the development of the Ornithorhynchus, and the total absence, so far, of fossil remains, make it impossible to designate which particular order of Sauropsida ought to be considered as the progenitor of the Ornithorhynchus, and through it of the rest of the Mammalia. In seeking the origin of the pouch-bearing mammals, we meet with the same difficulties, though not in the same degree. The Marsupialia are intermediate, in many respects, between the Monotremata (Ornithorhynchus) and the ordinary Mammalia. In the present state of our knowledge, it seems more advisable to regard simply some of the Monotremata as the ancestors of the Marsupialia than to attempt to designate which particular one was that ancestor, or exactly the manner of their development. That the Marsupialia came after the Monotremata (Ornithorhynchus, etc.) seems most probable, from the fact of their young, in their transitory condition, offering the arrangement of the viscera so characteristic of the Ornithorhynchus, while in their adult condition they agree with the ordinary Mammalia. The pouch-bearing Mammalia offer examples of meat and vegetal feeders, as well as of the leaping, burrowing, and climbing kinds.

So striking is the parallel between the different kinds of pouch-bearing mammals and the different orders of the ordinary Mammalia that many naturalists seem disposed to consider the different orders of the ordinary mammals as having come directly or indirectly from the corresponding kinds of pouch-bearers; that is, extinct Marsupials, like the grazing and browsing Kangaroo, were the ancestors of the orders represented at the present time by the Pig and Horse. Pouch-bearers like the Opossums, using their big toe as a thumb, gave rise to Monkeys, improperly called four-handed; while the meat-eaters (Dog) are the posterity of extinct Marsupials allied to the Thylacinus. This view has much in its favor, as the transition from the pouch-bearers to the ordinary mammals is very gradual, as, for example, the smaller Opossums lead up to the Insectivora (Hedgehog), the Wombat to the Beaver, etc. The fact of Australia, with few exceptions, containing only the reptile-bird-like and pouch-bearing mammals at the present day seems to confirm the view of the ordinary mammals coming from the pouch-bearers in some such way; for while we find in other parts of the world fossil remains of Marsupials, with the exception of the Opossums, the living pouch-bearers are found only in Australia and the adjacent islands, the fossil remains being Marsupials, but of a much larger size. Australia seems to offer us a living picture of what Europe once has been. Just as in Europe and other places, among the ordinary mammals, we have various kinds preying on each other, so we find the same thing among the existing pouch-bearers in Australia; and this relation existed also in past time. The Diprotodon (a gigantic Kangaroo) was warred upon by the Thylacoleo, a meat-eater of the size of a lion. Supposing this view of the origin of the ordinary Mammalia to be correct, the number of branches descending from the pouch-bearers will depend on the view taken by naturalists of the affinities of the different orders. Although there are twelve orders in the ordinary Mammalia, some of them seem directly or indirectly to be more nearly related than others. Thus, the order of odd-toed (Rhinoceros, Tapir, Horse) and that of even-toed (Pig, Hippopotamus, Sheep, Deer) are joined in one group, the Ungulata, or hoofed animals: they would represent one stem. The Half-Apes, the gnawing animals, with the Hyrax and Elephant, the insect-eaters, the bats, and true Apes, with man, would make a second stem. The meat-eaters (Lion, Fig. 81, Dog, Seal, etc.) may represent a third stem; while the Edentata, or animals without incisor (front) teeth, like the Sloth and Ant-eaters, which have no teeth at all, seem to make a fourth stem.

Without attempting a detailed account of these orders, we will try to call attention to the most important peculiarities connected with their organization and possible origin. The group of odd-toed (Perissodactyla) is so called from its representatives having an uneven number of toes, the Rhinoceros three, the Tapir three (at least in hind foot), the Horse one. These animals, however different in appearance externally, agree further in the structure of the skull and teeth, the number of pieces in the backbone (not less than twenty-two dorso-lumbar vertebræ), the simple stomach, and the peculiar character of the intestine (cæcum). These animals are linked together by fossil forms, the whole series forming a very natural group, the odd-toed, of which the Paleotherium (Fig. 151) is the oldest. 'The Artiodactyle or even-toed group—the Hippopotamus, etc., having four toes, the Cow, Sheep, Deer, etc., two—agree in the structure of the skull and teeth, and in the number of dorso-lumbar vertebræ (nineteen), while some of them in the complex digestive system form the sub-group of the Ruminants, in which there exist three or four stomachs, one of which serves to hold the food until it is chewed a second time, while in the Camel and Llama the second stomach is modified to hold water. The living even-toed animals, linked together by extinct forms, make the second natural order of the Ungulata. The oldest even-toed is the Anoplotherium (Fig. 152). In the age preceding that in which the Anoplotherium and Paleotherium appeared there lived the Lophiodon, Coryphodon, Pliolophus, etc., animals which, in their dentition, seem to have combined the peculiarities of both the even- and the odd-toed orders. They are considered to be the common ancestors of the Ungulata, and the posterity of the Diprotodon and Nototherium, animals allied to the browsing Kangaroo. The line of descent would be: Marsupials like the Diprotodon gave rise to the Lophiodon-like animals; they divided into the Paleotherium and Anoplotherium, the roots of the odd- and even-toed orders. The Rhinoceros, of living even-toed, is the most ancient, the Horse the most modern, the Tapir being intermediate. The links binding the Horse and its ancestor, the Paleotherium, are furnished by the Hipparion and Anchitherium; these extinct animals, in the structure of their teeth and feet, offering us a picture of what we see now in the Horse only in an embryonic condition: that is, the Horse, at one stage of its existence, is an Hipparion, while still earlier it is an Anchitherium. While the Paleotherium, descending from the Lophiodon, originated the odd-toed order, the Anoplotherium, coming from the same stock, divides into the Xiphodon and Anthracotherium branches. The Xiphodon, together with the Dichodon and Dichobune, were the earliest of Ruminants, of which there are the branches of the hollow-horned, Cow, Sheep, Goat, Antelope; the solid-horned, Deer, Giraffe; while the Camel and Llama, resembling each other in many respects, are represented by a separate stem. The Anthracotherium, the other branch coming from the Anoplotherium, divides into the stems of the Pig and Hippopotamus; nearly allied to the latter are the Sea-cow and Dugong, large herbivorous animals, found in bays and at the mouths of large rivers.

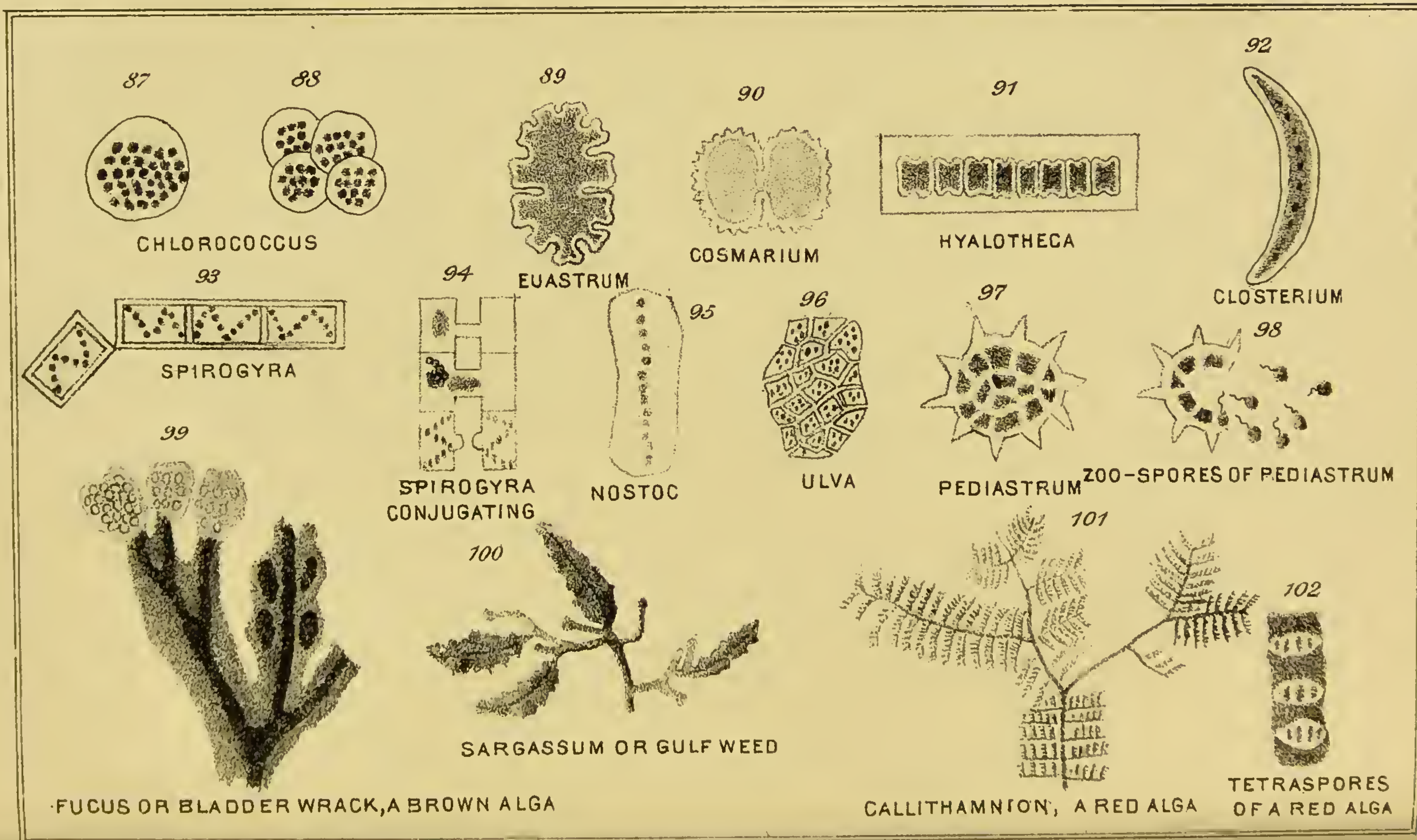
Leaving now the stem of the hoofed animals, or Ungulata, and turning to that of the Monkeys, etc., we find that many of the Prosimiæ or Half-Apes are found in Madagascar, from which island the order spreads to the East Indies and Africa. These Half-Apes were regarded for a long time as Monkeys, but they differ from the true Monkeys in the number and structure of their teeth, as well as being characterized by the claw on the second toe. The different kinds of Half-Apes indicate and are the transitions to the beginnings of other orders. Thus, the Galeopithecus, flying

Lemur, is a perfect link between the Half-Apes and Bats, the Cheiromys foreshadows the order of gnawers, resembling in appearance, as well as in the structure of the teeth, the gnawers (Rat, Squirrel) more than the Half-Monkeys. The short-footed Lemurs (Makis and Loris) are more like the true Monkeys, while the long-footed Tarsius is allied to the Insect-eaters (Cladobates, Hedgehog). A century ago the half-apes, gnawers, bats, and apes, with man, were joined together by Linnæus, and called Primates; and modern research seems but to have confirmed his generalization. Strange as it may at first appear, the Elephant is more nearly allied to the gnawers (Rodentia) in its skeleton, as well as in many other respects, than to any other order of the Mammalia. One can hardly conceive of a mouse and an elephant having anything in common; but it must be remembered that size has nothing to do with community of structure, and that there are Rodents, like the Capybara, as large as a dog. The position of the little Hyrax in the animal kingdom has been a constant subject for discussion since the days of Cuvier. According to some authorities, it stands near the Elephant and Rodentia, while others place it near the Tapir, among the odd-toes. I follow Haeckel in placing it near the Elephant. The true apes have descended from the half-apes, but as, zoologically, man and the true apes are not to be separated, we reserve for a separate chapter the consideration of the Simiæ, the highest order of the Mammalia. The half-apes are probably the posterity of extinct Marsupials allied to the opossums. The Carnivora or meat-eaters include the lion (Fig. 81), dog, cat, bear, walrus, seal, as well as other animals. They have so many characters in common, and differ so much from all other orders, that we regard them as a distinct stem, descending from Marsupials like the Thylacinus or dog-headed opossum. The transition from the seals to the whales (Cetacea) is made through the extinct Zeuglodon, which combines perfectly the peculiarities of both these orders. It must be mentioned, however, that Haeckel considers the whales, etc. as being more nearly allied to the Sea-cow, etc. With the exception of the Ant-eater of South Africa and the Pangolin common to Asia and Africa, the Edentata, so called from many of them having no front or incisor teeth, and some no teeth at all, are confined to South America, represented there by the Sloths, Armadillos, and Ant-eaters. The Sloths differ from all other Mammalia in having more than seven bony pieces in the neck, there being nine cervical vertebræ in the three-toed Sloth, and in the great number of ribs (twenty-three) in the two-toed Sloth, as well as in the bird-reptile arrangement of the viscera, agreeing in this peculiarity with the Ornithorhynchus; in many other respects the Edentata show a low grade of organization. From the wide geographical distribution, the gradual extinction, and the reptile-bird-like organization of the Edentata, we consider them as the survivors of an order which must have diverged very early from the main stem of the Mammalia. Gigantic fossils belonging to this order, like the Megatherium, Megalonyx, Mylodon, have been found in remote parts of the earth, showing the extent and size of the order in past time. The Megatherium (twenty-two feet in length) combines the head of the Sloth with the backbone and extremities of the Ant-eater. In the present state of Paleontology and Embryology, it is impossible to indicate the progenitors of these extinct Edentates.

With the Edentata we leave the Mammalia, and, for the present, the structure of the animal kingdom. We have endeavored to show—following principally Haeckel—that there is a main trunk of life, beginning in the Monads, ending in Man; here and there large branches are given off, terminating in twigs and leaflets. Allusions have been made to extinct animals, often forming an essential part of these branches. The relation, in time, that these extinct animals bear to each other, and to those now living, will be treated of in the chapter on Geology, while the Development or Embryology of the groups will be more detailed in the chapter on that subject. Though Geology and Embryology confirm the view of the gradual production of a tree of life, it seems to us that the structure of animals, without any other evidence, suggests such a conclusion, though we were never able to show the cause of it. Few astronomers after the time of Kepler doubted that the orbits of planets were ellipses: it remained for Newton to show that the attraction of gravitation was the cause of the ellipse; Lamarck and others have been to Biology what Kepler was to Astronomy; if future biologists confirm Darwin's views as to the cause of the evolution of life, as Laplace, Lagrange, D'Alembert, and Euler placed the Newtonian theory on a more secure foundation, then Darwin will be, as he has been already called, the Newton of Natural History.

BOTANY.

While plants, in their external appearance, present every variety of size, shape, and color, their internal structure does not offer the same amount of difference as is observed in the divisions of the animal kingdom. The old dogma that plants live, but animals live and feel, still holds true; there not having been found in the vegetal kingdom a trace of a nervous system. Some other basis for the classification of plants must therefore be chosen. More than a century ago, Linnæus divided the vegetal kingdom into Cryptogamia and Phanerogamia, which may, for the present, be translated Flowerless and Flowering plants. Modern science has offered nothing better than the classification of Linnæus, it being a natural one. The Flowerless plants, or the Cryptogamia, include: 1st, the Algæ, or the greenish matter covering bricks, stones, etc., the green thread-plants of ponds and ditches, and the red and black sea-weed; 2d, the Fungi, or toadstools, mushrooms, etc.; 3d, the Lichens, or the parchment-like growths seen covering fence-rails, etc.; 4th, the Mosses; 5th, the Ferns. The Flowering plants, or Phanerogamia, are represented by: 1st, the Cycadæ, bread ferns, etc.; 2d, the Coniferæ, pine, cypress; 3d, the Monocotyledons (one-seed lobe), lily, banana, palm; 4th, the Dicotyledons (two-seed lobes), elms, mulberry, geranium, rose. The first three classes of the Cryptogamia differ from the Phanerogamia in the absence of flowers, and in wanting roots, stem, and leaves; the Mosses and


87
88
CHLOROCOCCUS
89
EUASTRUM
90
COSMARIUM
91
HYALOTHECA
92
CLOSTERIUM
93
SPIROGYRA
94
SPIROGYRA CONJUGATING
95
NOSTOC
96
ULVA
97
PEDIASTRUM
98
ZOO-SPORES OF PEDIASTRUM
99
FUCUS OR BLADDER WRACK, A BROWN ALGA
100
SARGASSUM OR GULF WEED
101
CALLITHAMNION, A RED ALGA
102
TETRASPORES OF A RED ALGA

Ferns, while cryptogamic in their flowerless condition, agree with the Phanerogamia in having stems and leaves; they are therefore intermediate in their structure; the transition forms leading from the simple water-plants, mushrooms, etc., to the pines and oaks.

ALGÆ.

No class of plants is more interesting than the Algæ. Notwithstanding their very simple structure, they offer every variety of shape, size, and color. While many of them are very minute, the beauty of their form, the delicacy of their structure, and their exquisite coloring, never have failed to attract the attention of the microscopist. The Confervoidæ, or green Algæ, are widely distributed, every pond, ditch, spring, and stream having representatives. The greenish matter seen on old trees, that found in bogs, the slime on stones in ponds, the silk-like threads of troughs, the sea-weed usually seen in marine aquaria, as well as innumerable other examples which might be given, serve to illustrate the green Algæ, or Confervoidæ. Among the green Algæ we find the simplest and smallest of plants, the Chlorococcus viridis (Fig. 87), which, when aggregated in hundreds of millions, composes the greenish matter clothing in layers old trees, wood palings, etc. The Chlorococcus is a simple cell filled with granular contents. Under favorable circumstances each cell divides into halves (Fig. 88), each half becoming a new individual; this process may be continued indefinitely: such is the simple manner of reproduction in this very minute plant. Among the unicellular green Algæ are included the Desmidiaceæ, which are found most often in open situations, as in the pools of bogs and moors. They are among the most beautiful of microscopic objects. Their most characteristic feature is that of bilateral symmetry, giving the impression that their body is composed of two cells, as seen in Euastrum, Cosmarium, Closterium (Figs. 89, 90, 92), or of many cells, as in Hyalotheca (Fig. 91), but they are really one-celled plants, as proved by the fact of all the green contents escaping if the cell-wall be broken, the indentations and constrictions being only superficial. The constriction of Cosmarium indicates the place where the body will divide into two halves, each half becoming a new individual. In some forms, as Pediastrum (Fig. 97), the green contents of the cell are transformed into ciliated bodies, or zoospores, which escape, the cell-wall breaking, and move about for some time (Fig. 98), then settle, coalesce, and finally take on the appearance of the parent plant. The green, thread-like plant of horse-troughs, etc. is generally composed of the Alga known as Spirogyra (Fig. 93). Each Spirogyra is a chain of cells, the green matter of the cells being disposed in the form of a spiral. At certain seasons of the year, adjacent Spirogyræ are seen to push out the walls of their cells towards each other until a communication is formed. (Fig. 94.) The green contents of one individual, leaving its cell, pass through the communicating process, and mix with the contents of its neighbor: this is later the beginning of a future Spirogyra. This kind of reproduction is known as conjugation, and is the simplest type of sexual reproduction, *i.e.*, the union of two distinct germinal masses to form a spore. The Nostochaceæ (Fig. 95) attached to stones are composed of a row of cells or beads, making filaments imbedded in a gelatinous kind of matter which is inclosed by a membrane; the membrane breaking, the gelatinous matter escapes into the water, carrying the filaments with it. The Nostochaceæ have been considered by some botanists as an undeveloped form of Lichen. With the exception of the Ulvaceæ (Fig. 96), which are marine in their habitat, the green Algæ are confined to fresh water. The Ulva, from which the group takes its name, is the green plant which usually adorns marine aquaria. It is composed of layers of cells bound together, and its reproduction is effected by zoospores, such as we noticed in Pediastrum.

FUCOIDÆ.

The brown or olive-colored Algæ, or Fucoidæ, differ not only in their color from the green Algæ, of which we have just spoken, but equally as regards their size and manner of reproduction. They are confined to the sea, and are found generally on submarine rocks, which are exposed, however, at low tide, to heat, light, and atmospheric influences. This seems to be necessary for the healthy growth of the brown Algæ, since the specimens that are brought up from greater depths do not exhibit so hardy a structure as those that live at the surface. The Fucoidæ are commonly known as sea-wrack; but that generally picked up at the sea-shore gives no idea of the immense size which some of the brown Algæ attain, the Macrocystis of the Californian coasts reaching a length of four hundred feet. Among the Fucoidæ are included the Laminaria, or leathery sea-weed; the Fucus (Fig. 99), or bladder-wrack, so called from floating on the surface of the sea by means of air-bladders. This bladder-like arrangement in the Sargassum, or gulf-weed, takes the form of a bunch of berries, and is the most characteristic feature of the plant. The importance of the brown Algæ may be estimated from the fact that forty thousand square miles of the Atlantic Ocean are covered with a kind of oceanic forest of Sargassum. (Fig. 100.) The presence of this plant gave Columbus vain hopes of being near land. The reproduction of the brown Algæ has not as yet been perfectly made out. It is known, however, that the process is sometimes carried on by zoospores, as in Pediastrum, or by the intervention

6

of distinct germinal masses, which unite whilst free in the water, to form a spore, a process corresponding to the so-called conjugation of the Spirogyra.

FLORIDÆ.

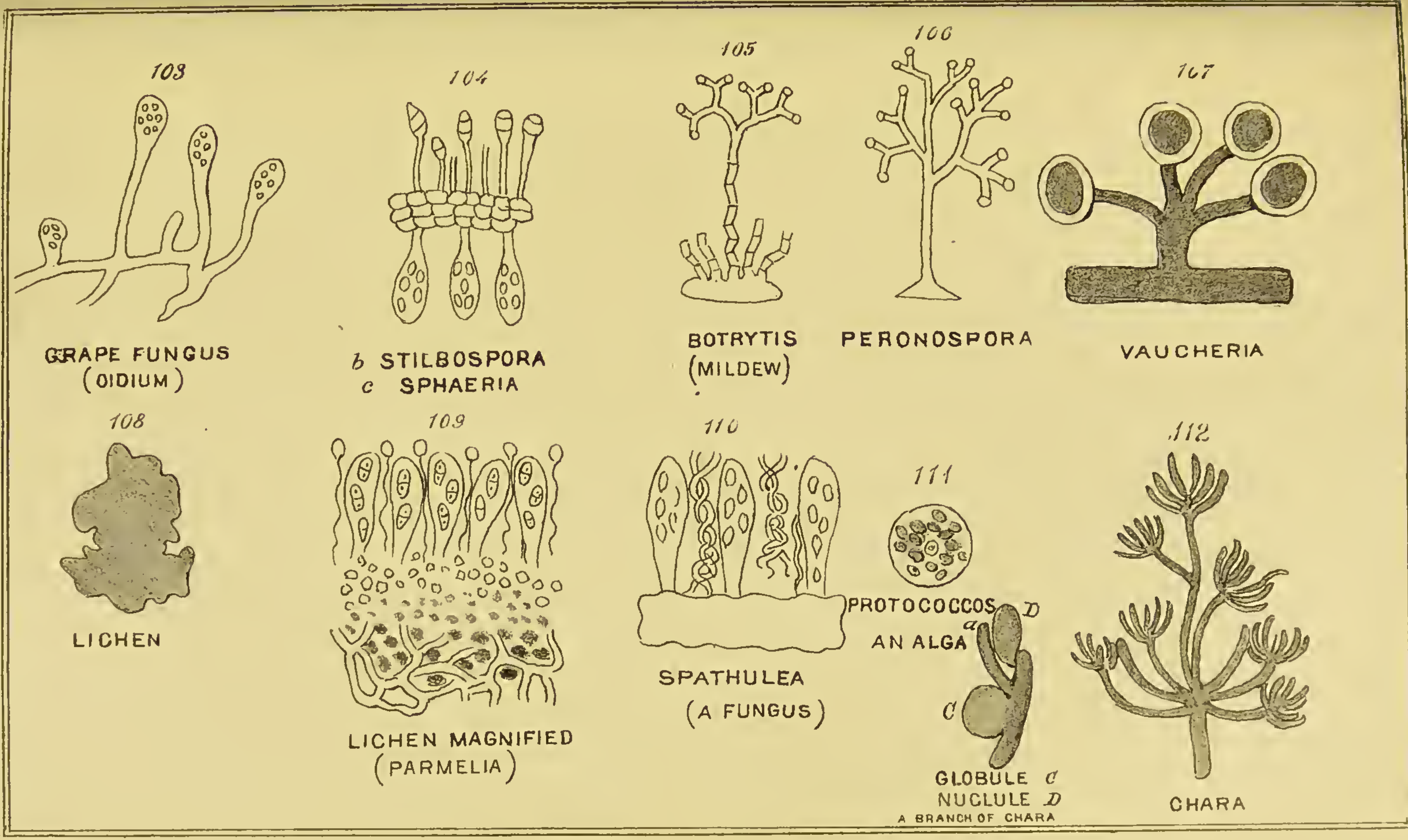
The red or rose-colored Algæ, though much smaller than the Fucoidæ, surpass them greatly in beauty of coloring and delicacy of form. They are commonly known as red sea-weed, and, when dried and arranged on paper, they are often offered for sale. The Floridæ (Fig. 101), or Red Algæ, are from six inches to two feet high, offering in their coloring different shades of red, rose-red, and purple. Their form varies from that of a filament or stalk to that of a leaf or feather. To see them in perfection, they must be studied in a tropical climate. The reproduction of the Floridæ is still involved in some mystery. There are in many species tetraspores (Fig. 102), which are formed by the division of the so-called perispore into four spores, which appear to correspond with the zoospores of the lower Algæ. Besides these tetraspores, other reproductive bodies arise in some species from the union of two germs, which may be looked upon as the representatives of distinct sexes. While the Green, Brown, and Red Algæ differ greatly in their size, form, coloring, and reproduction, they all agree in their cellular structure. When we compare a single individual of the Chlorococcus—so minute that hundreds of thousands might rest on the head of a knitting-needle—with the gigantic Macrocystis, notwithstanding minor differences, we find the essentially cellular structure of both to be the same. The group of Algæ is, therefore, a natural one, the extremes being connected by innumerable links, offering a gradual transition from microscopic forms to the largest of plants. In the preceding chapter we have given reasons for supposing it probable that Monera in past time divided into animal and vegetal Monera, and endeavored to show how the animal kingdom may have descended from animal Monera. Although the precise time and exact manner in which the vegetal kingdom appeared may never, perhaps, from the nature of the case, be demonstrated, still, Prof. Haeckel's view of vegetal Monera having been the remote ancestors of the vegetal kingdom has so much in its favor that it may be accepted as a near approximation to the truth. Following, then, Prof. Haeckel, the vegetal Monera must be regarded as the ancestors of the Protophyta, or primitive plants, those most simple, unicellular Algæ, like the Chlorococcus, etc., while the Green, Brown, and Red Algæ represent the three diverging branches of a stem whose roots originate in the Protophyta.

FUNGI.

Mushrooms, puff-balls, smuts, mildews, truffles, moulds, although offering in minor points variety of structure, still agree in so many important respects, and differ so essentially from all other plants, that they are always associated by naturalists, and are regarded as forming the very natural group of Fungi. One of the most general laws of Biology is that while animals derive their nutriment solely from the organic world, plants, on the contrary, are nourished by inorganic matter; in other words, while plants by their life-processes change inorganic into organic matter, animals by their life-processes reconvert organic into inorganic matter. Fungi, in feeding solely on organic matter, agree with animals, and differ from all other plants. Amylum, or starch-flour. is one of the most constant products of the vegetal kingdom, yet no trace of this important principle is found among the Fungi. The green color so characteristic of plants, due to the presence of chlorophyll, is never seen in any Fungi. With some exceptions, the Fungi nourish themselves on organic matter, whereas plants combine inorganic matter, such as water, carbonic acid, ammonia, phosphates, etc., assimilating these principles in their growth. The life-processes, the absence of amylum and chlorophyll, are such important facts in the economy of the Fungi that some naturalists deny that they are plants at all, and wish to place them in the intermediate kingdom referred to in the preceding chapter. The reproduction of the Fungi, and the many transitional forms hardly distinguishable from Algæ and Lichens, influence most botanists in regarding them as very aberrant, but still members of the vegetal kingdom.

Most Fungi are parasitic in their mode of existence, living at the expense of the plant or animal on which they are found.

The disease known as scald-head is due to the presence of a fungus, the Achorion ; the thrush, a throat trouble, is caused by a fungus, the Oidium. Quite a flora has been described by Leidy and Robin as existing in the intestines of different animals, consisting principally of Fungi. The Fungi are found, however, in the greatest profusion on decaying vegetal matter, stumps of trees, etc. being converted into powder by them. When half-eaten fruit is allowed to stand, soon it is seen to be covered with a whitish film, which, when examined under the microscope, is found to be made up of the filaments of a Fungus. A Fungus, while essentially cellular, consists of two parts, the mycelium, or threads, and the colorless spores, or fruit: the threads are elongated cells, and resemble in position the stems of higher plants ; the spores are seen at the end of the threads. (See Fig. 103, Grape Fungus.) The spores are sometimes free (stylospores), or they are inclosed in what is called an ascus. (See figure of Stilbospora and Sphæria, Fig. 104, *b*, *c*.) The arrangement of the spores


103
GRAPE FUNGUS
(OIDIUM)
104
b STILBOSPORA
c SPHAERIA
105
BOTRYTIS
(MILDEW)
106
PERONOSPORA
107
VAUCHERIA
108
LICHEN
109
LICHEN MAGNIFIED
(PARMELIA)
110
SPATHULEA
(A FUNGUS)
111
PROTOCOCCOS
AN ALGA
D
a
C
GLOBULE C
NUCLULE D
A BRANCH OF CHARA
112
CHARA

or fruit, and the proportion of the size of the fruit to the mycelium or threads, have served as the basis of a classification of the Fungi. The mushroom, the puff-ball, the smut, the mildew, the truffle, and mould, are familiar examples of the different orders of Fungi. This classification, like all similar attempts, suffices, so long as types so different as a mushroom and mildew are compared. What are commonly collected as mushrooms are only the fruit of the fungus Agaricus: the greater part of the mildew examined show only the mycelium or threads of the fungus Botrytis. The mushrooms belong to the order Hymenomycetes, so called from the hymenium, or part supporting the fruit, being so prominent, the threads being inconspicuous. The mildew (Fig. 105) illustrates the Hyphomycetes, which derive their name from the Hyphi, or threads, being so much developed, the fruit dropping off.

The difficulty of classification arises from the fact that from time to time individuals are discovered which do not present such striking contrasts as the mushroom and mildew, their characters being so little defined as to make it impossible to say to what groups they belong. All such intermediate forms, the source of so much trouble in the arrangement of an herbarium, are most important proofs of the truth of the theory of the gradual transformation of plants. Not only is it true that in the Fungi the orders pass insensibly into each other, but there are also forms of which it is doubtful whether they are Fungi, some botanists still regarding them rather as Algæ. Thus, the Peronospora (Fig. 106), differing from Botrytis (mildew) in its continuous cells, the partitions of Botrytis (Fig. 105) being absent, is, according to Prof. Haeckel, a transitional form which links the Algæ through Vaucheria (Fig. 107) with the Fungi, though the Peronospora is usually regarded as a Fungus, it having no chlorophyll. The Achlya, sometimes called Saprolegnia, formerly considered an Alga, seems to be only an aquatic form of the Sporendonema, the common fly fungus. It was long ago observed by Carus that the portions of a salamander which were above the surface of the water produced a Mucor (fungus), while those immersed gave rise to an Achlya (alga). While the Algæ pass very gradually into the Fungi through intermediate forms like Vaucheria, Peronospora, Achlya, and Sporendonema, the transition from the Fungi to the Lichens is equally easy.

LICHENS.

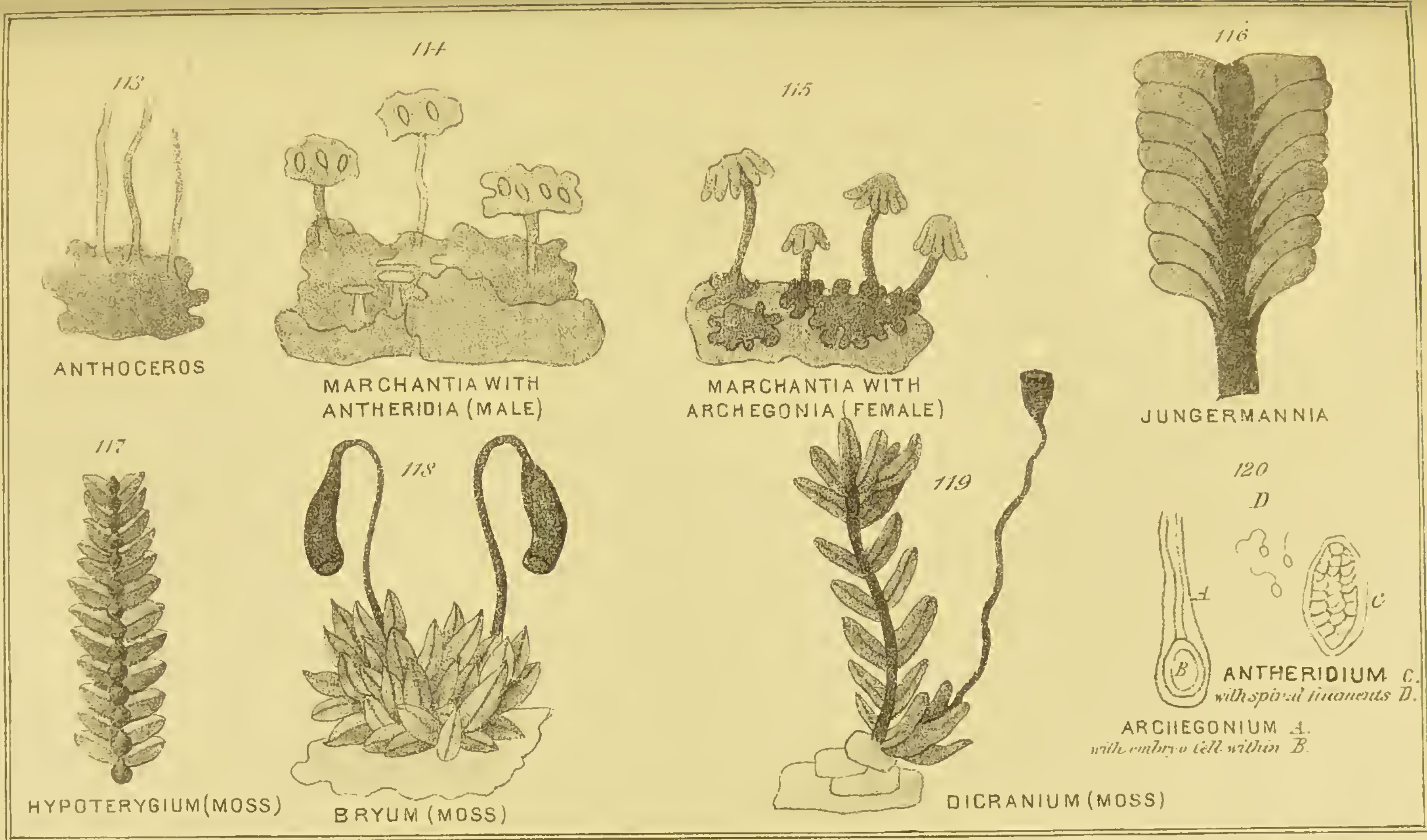
Lichens are dry plants, covering stones and rocks, or creeping over trees, walls, and fences. They are found as gray, brown, yellow patches; as wrinkled, leathery, horny crusts (Fig. 108); and however unattractive, as a general rule, in appearance, are of great importance in the economy of nature, and therefore of interest to the botanist. The Lichens are widely distributed, being found in the icy recesses of Mont Blanc, amidst the recently poured-out lava of Vesuvius, and crowning the summits of most barren rocks. The Lichens, being aerial in habit, and more insensible to changes in climate than any other plants, survive and flourish where all other vegetation would perish. The decaying parts of their bodies furnish the subsoil in which future mosses, ferns, and flowering plants can take root. Their importance, therefore, cannot be over-estimated. A Lichen (Fig. 109) is made of threads, and colorless and green spores. The threads resemble the mycelium, or threads of a Fungus; the green spores (gonidia) are like the spores of the Algæ (the spores of Fungi, being colorless, resemble the other spores). Most Lichens derive their nourishment from the air. This peculiarity is usually regarded as distinguishing them from Fungi, which live parasitically on plants and animals. But as certain forms of Fungi (according to Berkeley) are found on iron, lead, etc., certainly not living at the expense of these metals, the distinction of the aerial nutrition of Lichens from the parasitical of Fungi evidently does not hold good in all cases. The presence of green spores is very constant, but their absence in forms like Alrothallus makes Lichens of this kind undistinguishable from Fungi. Lichens, as a rule, are aerial plants; yet some forms are always immersed in water, as in most Algæ. The early stages of many Lichens resemble so closely certain Algæ that botanists cannot separate them. The Lichens are considered by most naturalists as standing between the Algæ and Fungi. According to Haeckel ("Natural History of Creation," p. 416), "each Lichen is composed essentially of two different plants, of a low form of Alga (Nostoc, Protococcus) (Fig. 111) and of a parasitic Fungus (Ascomycetes) (Fig. 110), which is parasitic on the first, and lives off the assimilated material which this furnishes. The green chlorophyll-holding cells (gonidia), which one finds in every Lichen, belong to the Alga. The colorless threads (hyphi), on the contrary, which, thickly woven, form the principal mass of the body of the Lichen, belong to the parasitic Fungus. But always are both plant-forms—Fungus and Alga, which are considered as belonging to different classes—so firmly bound with one another, and so intimately grown together, that every one regards the Lichen as a single organism."

Notwithstanding the differences in size, color, form, reproduction, and habitat seen in this brief survey, the structure of Algæ, Fungi, and Lichens has always appeared to be the same, cellular. When we compare plants apparently so distinct as mushrooms, mildews, encrusting matter of rocks, greenish layers of ponds, sea-weed, etc., the closest examination rarely reveals more than a combination of cells, no Alga, Fungus, or Lichen offering us the distinction of stem, leaves, vessels, or flowers observed in the higher plants. Botanists join, therefore, these three groups in one division, the Thallophytes or Cellular plants, a thallus being an expansion of cells.

With the Thallophytes we leave the first division of the vegetal kingdom.

CHARACEÆ.

The Characeæ are unique plants, including the Nitella and Chara, which differ only in the structure of their tubes, the Chara having a cortical layer in addition to the simple tubes of Nitella. The Chara is found in ponds and ditches, being composed of elongated tubes giving off at intervals whorls of branches which look very much like small green candelabra. The Chara (Fig. 112) is always an object of interest to the microscopist, as exhibiting the circulation of the chlorophyll, or green matter, the globules of which may be seen ascending and descending along the sides of the tubes. The Characeæ in their structure and general appearance resemble the Green Algæ, while their reproductive apparatus is more like that of the Mosses. This consists of an orange-colored globule and an oval-shaped nuclule. The globule (Fig. 112, *C*) bursting, a number of spiral filaments come forth, which move about in the water; the nuclule (Fig. 112, *D*), falling off in time, gives rise to a new Chara. The globule and nuclule are supposed to be the homologues of the reproductive organs of the higher plants. The Characeæ are isolated plants, seeming to be the only remnant of a group once more numerous: they stand on a boundary-line, so to speak, separating the Green Algæ from the Hepaticæ. Probably extinct plants allied to the Chara gave rise to the Hepaticæ, and indirectly through them to the Mosses and Ferns.


113
ANTHOCEROS
114
MARCHANTIA WITH ANTHERIDIA (MALE)
115
MARCHANTIA WITH ARCHEGONIA (FEMALE)
116
JUNGERMANNIA
117
HYPOTERYGIUM (MOSS)
118
BRYUM (MOSS)
119
DICRANIUM (MOSS)
120
D
A
B
C
ANTHERIDIUM C. with spiral filaments D.
ARCHEGONIUM A. with embryo cell within B.

HEPATICÆ.

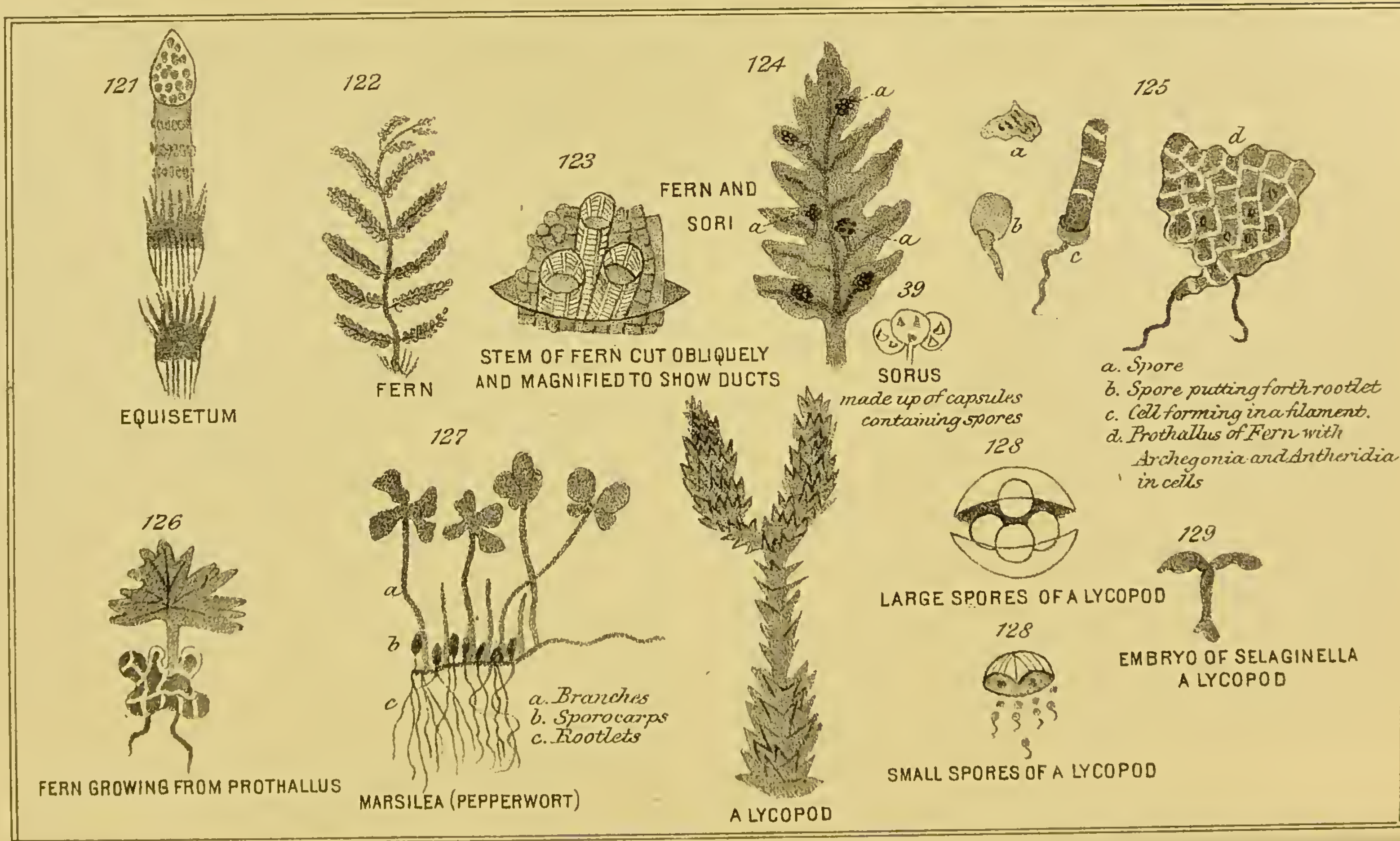
The Hepaticæ, commonly known as Liverworts, are small plants of varied forms found on damp ground, moist parts of trees, or floating on the water. The lowest representatives consist simply of a single layer of cells forming a green membrane or patch, as in Anthroceros (Fig. 113), or there is a double layer of cells, as seen in Sphærocarpus. In Marchantia (Fig. 114) the layers of cells are more numerous and thicker than in the lower forms just mentioned, and the upper and lower surfaces are clothed with a skin or epidermis, on the upper surface of which stomata are seen; stomata are holes in the epidermis through which air can pass from the outside of the plant to the inside. In the middle of the frond or body of the Riccia a distinct line or midrib is seen. This line in the Jungermannia (Fig. 116) becomes a well-defined stem, with leafy appendages on each side. The Jungermanniæ are therefore the first plants in which we meet with the structures so characteristic of higher plants, viz., the stem and leaves; the apparent stems of the Fucoidæ and Floridæ being composed only of a greater number of denser cells, not essentially different from the adjacent parts either in structure or function. While the higher forms of Liverworts, in having stems and leaves, exhibit a marked progress, the lower forms in their cellular structure differ in no way from the Green Algæ. The structure of the reproductive apparatus, however, in all Liverworts is much more complex than that of the Algæ. In the concave receptacles, supported by stalks, as seen in Marchantia (Fig. 114), are found oval cellular bodies, the so-called Antheridia (Fig. 120, *C*), which contain spiral filaments (Fig. 120, *D*) capable of moving after having escaped from the Antheridia. The convex-lobed bodies terminating the stalks of the same plant (Fig. 115) contain flask-shaped bodies, the Archegonia

(Fig. 120, *A*), inside of which will be found the embryo-cell (Fig. 120, *B*). The embryo-cell, after the contact of the spiral filament, is changed into the Sporangium, or case which contains the spores, from which the new plant will be developed.

The Hepaticæ, or Liverworts, seem to be transitional plants, leading up from the Green Algæ and Characeæ to the Mosses and Ferns, they representing, probably, the common stem from which the roots of the Mosses and Ferns have diverged.

MOSSES.

The beautiful green velvety carpeting of woods com monly known as Mosses (Figs. 118, 119), growing most luxuriantly in damp, shady places, so useful from freely absorbing and retaining moisture, to be given out in time of drought, is made up of small delicate plants, each individual consisting of a stem and leaves, exhibiting under a low magnifying power a great variety and beauty of form. While Mosses, in the arrangement of their stem and leaves, differ greatly from the Jungermanniæ, one group of them, the Hypoterygiæ (Fig. 117) furnish perfectly the transition; the erect stem and leaves of the Hypoterygiæ agreeing in structure with the procumbent one of Jungermanniæ. The reproductive apparatus of the Hypoterygiæ, however, is like that of Mosses generally. This consists, as in Hepaticæ, of Archegonia and Antheridia. The Archegonia are flask-shaped bodies containing the embryo-cell. The Antheridia (Fig. 120, *C*) are oval cellular bodies, having inside the spiral filament. (Fig. 120, *D.*) The embryo-cell (Fig. 120, *B*), by the contact of the spiral filament, is changed in Mosses, however, into a stalk supporting an urn-shaped body. In this urn are produced the spores, which do not at once reproduce the new Moss, but protrude a confervoid growth, the so-called Protonema, a structure very like that


121
EQUISETUM
122
FERN
123
STEM OF FERN CUT OBLIQUELY
AND MAGNIFIED TO SHOW DUCTS
124
FERN AND
SORI
a
a
a
39
SORUS
made up of capsules
containing spores
125
a
b
c
d
a. Spore
b. Spore putting forth rootlet
c. Cell forming in a filament.
d. Prothallus of Fern with
Archegonia and Antheridia
in cells
126
FERN GROWING FROM PROTHALLUS
127
a
b
c
a. Branches
b. Sporocarps
c. Rootlets
MARSILEA (PEPPERWORT)
A LYCOPOD
128
LARGE SPORES OF A LYCOPOD
128
SMALL SPORES OF A LYCOPOD
129
EMBRYO OF SELAGINELLA
A LYCOPOD

of an Alga or Fungus. In its Protonema stage the Moss is only a cellular plant, a Thallophyte. Later, out of the Protonema is developed the true Moss, with its stem, leaves, and reproductive organs.

The Mosses have probably descended, through forms like the Hypoterygiæ, from the Jungermanniæ.

FILICALES.

The so-called Horse-tails of ditches, etc., our common Ferns, the aquatic plants known as Pillwort and Club-moss, are generally considered by botanists as representing four different orders of the class Filicales. While Ferns, etc. are as highly organized as Mosses, in having stems and leaves, the vascularity of their stem exhibits a considerable advance as compared with the same structure in Mosses. The Fern and Horse-tail, though differing in appearance, are usually associated, since their reproduction is the same. The Pillwort and Club-moss, agreeing in their reproduction, differ, however, from that observed in the Horse-tail and Fern: hence their frequent union. The Filicales of the present day play an inferior part as compared with those of past time. Tropical climates even do not give us an idea of what the class once was, as regards their size, variety, and importance in the economy of nature. They are sometimes called Acrogens, or summit-growers. We will examine now a little more closely the living Filicales, leaving for the chapter on Geology the account of those forms that have died out.

EQUISETACEÆ.

The Horse-tail, or Equisetum (Fig. 121), is a very common plant, abounding in ditches, woods, marshes, etc., and is readily distinguished by its very characteristic appearance: though small in temperate regions, in the tropics it attains a size of fifteen or sixteen feet. The Horse-tail is composed of a series of hollow tubes joined end to end, the articulations being separable, and these tubes are marked externally by furrows running longitudinally. In place of leaves, the Equisetum exhibits green-colored branchlets; it has also rhizomes, or underground stems, sometimes extending to the depth of many feet. The spores are contained in a spike-shaped or conical cap, terminating the stem of the plant; the spores produce a cellular structure, the Prothallus, from which the new Equisetum will be developed: this kind of reproduction is seen in the Ferns, of which we will presently speak. There is found in all parts of the Horse-tail such a large amount of silex that the plant becomes important in a commercial point of view, it being much used for polishing.

FILICES

Ferns are not only interesting to botanists on account of their structure and reproduction, but also equally attractive to the laity, their graceful stems and exquisite leaves furnishing specimens for the greenhouse and ornaments for the parlor. These beautiful plants are abundantly found in damp, shady places, though a damp soil and moist climate seem more necessary than shade for their luxuriant growth. If an oblique section (Fig. 123) of the stem of a Fern be magnified, the most important features observed are the vessels or ducts running down the middle of the stem, which have in them some woody tissue. So characteristic is the presence of vessels in the higher flowering plants, that Ferns, from having these organs, are often associated with them. At certain seasons there are seen, generally on the under surface of the leaf of a Fern, small bodies usually supported on stems, known as Sori. (Fig. 124, *a.*)

Each sorus, when magnified, is seen to consist of numerous capsules (thecæ); these capsules contain the spores. The spores are angular-shaped bodies (Fig. 125, *a*), with an external coat of a brownish color, which is variously marked, like the pollen of higher plants. The spores, when placed in a damp surface and exposed to the proper influences of heat and light, germinate; that is, the angles of the spore are rounded off, the internal coat of the spore is then protruded, becoming the root-fibre (Fig. 125, *b*); the outer coat of the spore bursting, the inner coat grows in an opposite direction to that of the root-fibre as an elongated filament (Fig. 125, *c*); cell after cell is added in a longitudinal direction, the plant soon resembling an Alga. After a time, however, the cells are produced transversely as well as longitudinally, resulting in the formation of a flattened leaf-like expansion (Fig. 125, *d*), a cellular structure, the so-called Prothallus, which can scarcely be distinguished from a young Marchantia. In this Prothallus are developed Archegonia and Antheridia: the union of the embryo-cell of the Archegonia and the spiral filament of the Antheridia gives rise to the new Fern, which may be seen growing out of the Prothallus (Fig. 126), which soon passes away. These two stages in the life of a Fern represent two distinct plants. The Prothallus stage is a cellular plant closely resembling a young Marchantia, which is later transformed into a stem- and leaf-bearing plant. The growth of the Horse-tail offers the same metamorphosis; spores producing a Prothallus from which the Horse-tail is developed. While the Mosses are probably the posterity of Jungermannia-like plants, the Ferns have most likely descended from forms allied to Marchantia; this view being based on the fact of the Fern passing through a Marchantia-like stage, with similar reproductive organs.

RHIZOCARPÆ.

The Rhizocarpæ, a group of minute water-plants, are represented by four genera found in different parts of the world, of which the Pillwort and Pepperwort are probably the best-known, these plants being rather botanical curiosities than objects of every-day attention. They are inconspicuous plants, growing in the mud at the edges of pools, or floating about in stagnant water. A plant of this group (Marsilea) (Fig. 127) consists of a creeping stem; from the upper side rise stalks ending in leaves, from the lower hang roots; at the base of the stalks, near the roots, are seen the spore-cases (sporocarps): hence the name of this order, Rhizos- (root) carpæ (fruit). The spore-cases of the Pillwort (Pilularia) and Pepperwort (Marsilea) contain both *small* and *large* spores. In Salvinia and Azolla the *large* and *small* spores have each their special spore-case. The importance of this arrangement of the reproductive apparatus in Salvinia and Azolla will appear when speaking of the flowering plants. The development of the future Rhizocarp from the large and small spores is the same as that observed in the Club-mosses, to which we will now turn.

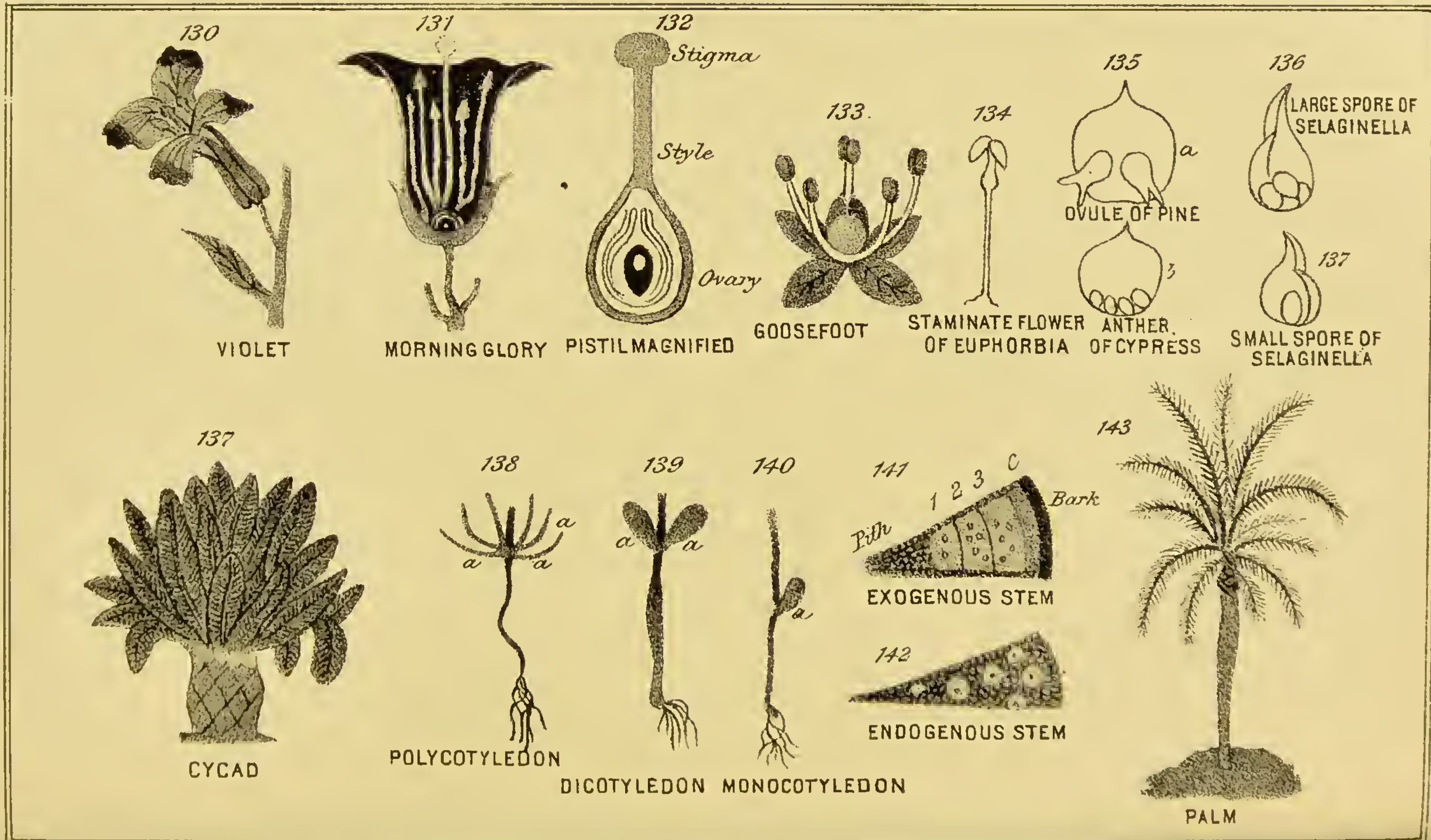
LYCOPODIACEÆ.

The Lycopodiaceæ (Fig. 128), or Club-mosses, are delicate creeping plants, producing leafy-like branches, resembling in their general appearance Mosses, though differing from them in structure and manner of reproduction. The Club-mosses of the present day are small plants; this was not always the case, the order being represented in past time by trees, attaining the height of sixty feet, with gigantic roots, giving the vegetation of that period a very characteristic appearance. The stem of the Lycopodiaceæ exhibits the same vascular and cellular structure noticed in the

Ferns. In the Isoetes (a Lycopod) we see, for the first time in our brief survey of the vegetal kingdom, a stem presenting *woody layers* one inside of the other, one of the distinguishing features of trees like the Oak, Walnut, Chestnut, Pine, Fir, Cycas. This fact is an important one, as will appear later. The reproduction of the Lycopodiaceæ and Rhizocarpæ differs from that of any plants of which we have yet spoken. There are found in the Lycopodiaceæ both large and small spore-cases, of which the former (Fig. 128) contain only four large spores, the latter (Fig. 128) many small ones. In Selaginella the leaves are spike-shaped, and at the base of the leaf is found either a large or small spore-case. Each spore of the large spore-case may produce within its cavity a Prothallus like that of the Fern; but it will be remembered that the Prothallus of the Fern is produced outside of the spore, whereas the Prothallus of the Lycopod is developed inside the large spore. In the Prothallus of the Lycopod, Archegonia, with their embryo-cells, alone are found; the Antheridia, with their spiral filaments, coming only from the small spores. Finally the large spore bursts, freeing its Prothallus. The spiral filament of the Antheridium of the small spore, coming in contact with the embryo-cell in the Archegonium in the Prothallus of the large spore, gives rise to the new Lycopod, which, in Selaginella, is a little stem supporting two leaves, one on each side. (Fig. 129.) This kind of reproduction is seen in the Rhizocarpæ. By comparing the reproduction noticed in the Fern, Horse-tail, Rhizocarp, and Lycopod, the following series becomes apparent: the Ferns and Horse-tails produce one kind of spore; from this spore is developed a Prothallus containing both Archegonia with their embryo-cells, and Antheridia with their spiral filaments. The Rhizocarpæ and Lycopodiaceæ produce two kinds of spores, large and small; in the Pillwort and Pepperwort the large and small spores are found in the same spore-case, but in the Salvinia and Azolla the large and small spores have their special spore-cases, as in the Lycopodiaceæ; the large spore alone develops the Prothallus with Archegonia and embryo-cells, the small spores alone producing Antheridia with spiral filaments. The reproduction, however, of the Horse-tail, Fern, Rhizocarp, or Lycopod is always due to the contact of the spiral filament of the Antheridium with the embryo-cell of the Archegonium, the new plant growing always from a Prothallus. The Lycopodiaceæ appeared on the earth later than the Ferns, and have probably come from them, being closely related at the present time by intermediate forms (Opioglossæ). The Rhizocarpæ may be regarded as aquatic Lycopods. The structure of the stem and reproductive apparatus, and the form of the embryo, are striking proofs of the truth of the view that the Lycopodiaceæ are the intermediate forms, the links uniting the Flowerless and Flowering plants. The importance of the facts just mentioned will be better appreciated when the Lycopodiaceæ are compared with the simplest of flowering plants. We leave now the Flowerless plants, or Cryptogamia, and turn to the Flowering plants, or Phanerogamia.

PHANEROGAMIA.

Flowers, among the most beautiful of nature's works, are always interesting to the laity and the botanist, offering objects of ornament and beauty to the one, and subjects for study and admiration to the other. The flower is the reproductive apparatus of the higher plants, made up of the organs by which the seed is produced, fertilized, and converted into the embryo plant. If we examine the flower of the Violet (Yellow Violet) (Fig. 130), the green cup-like arrangement of leaves first deserves our attention; this is known as the calyx, and the leaves com-


130
VIOLET
131
MORNING GLORY
132
Stigma
Style
Ovary
PISTIL MAGNIFIED
133.
GOOSEFOOT
134
STAMINATE FLOWER OF EUPHORBIA
135
a
OVULE OF PINE
3
ANTHER OF CYPRESS
136
LARGE SPORE OF SELAGINELLA
137
SMALL SPORE OF SELAGINELLA
137
CYCAD
138
a
a
a
POLYCOTYLEDON
139
a
a
DICOTYLEDON
140
a
MONOCOTYLEDON
141
Pith
1 2 3 C
Bark
EXOGENOUS STEM
142
ENDOGENOUS STEM
143
PALM

posing it are called sepals. Within the calyx is seen another whorl of yellow leaves, known as petals; their union forms the corolla. Springing from the middle of the calyx and corolla, and standing erect, is seen a delicate tube, the pistil. Surrounding the pistil, and differing from it in appearance, are found the stamens. If the pistil is examined separately (Fig. 132), it is seen to be composed of the following parts: the head or stigma, the stalk or style, and the ovary. The ovary contains the ovule, or future seed, and if the ovule be magnified it is seen to contain the embryo-sac, and within the embryo-sac is found the germinal vesicle. The germinal vesicle is the rudiment of the future plant. The stamens, or stalks, surrounding the pistil, are composed of the stems or filaments supporting the anthers or little heads. The anthers contain the pollen, or fertilizing principle. Suppose the supreme power of Turkey to be a woman, and the Sultana to have a harem of men, such a condition of social life would represent what is seen in the Violet, or better in a section of the Morning-glory (Fig. 131), where the imaginary Sultana is realized in the pistil, the harem of men in the stamens. The pollen produced in the anthers finds its way to the stigma, or head of the pistil; from the head it passes down through the style, or tube of the pistil, until it reaches the ovary. Piercing successively the ovary, ovule, and embryo-sac, it finally comes in contact with the germinal vesicle. From this moment the life of the new plant begins in the formation of the embryo. The flowers of the Violet and Morning-glory serve to illustrate the reproductive apparatus of many plants. If, however, the flower of the Goose-foot (Chenopodium) (Fig. 133) be compared with that of the Violet, the absence of the corolla at once strikes the attention; and if the flowers of the Bread-tree, Pine, etc. (Fig. 135, *a*, *b*) be now examined, calyx and corolla are both found wanting. Further, in trees like the Pine, etc. there is no ovary, the ovule being exposed to view resting on the edge of the leaf (Fig. 135, *a*); the ovule is fertilized by the falling of the pollen, style and stigma being absent as well as ovary. Plants of this kind are called, therefore, Gymnospermæ, or naked seeds; whereas those having an ovary are known as Angiospermæ, or seed-vessels. The flowering plants divide naturally, therefore, into these two groups. To the Gymnospermæ, or plants with naked seeds, belong the Bread-tree, Zamia, and Cycas (Cycadæ), the Pine, Fir, Cypress, Juniper, Cedar, and Yew (Coniferæ). Among the Angiospermæ, or plants whose seeds are contained in seed-vessels, are found the forest-trees, fruit-trees, grasses, roses, violets, etc.

CYCADÆ.

The Cycadæ are small palm-like trees (Fig. 137), or shrubs with unbranched stems, found principally in the tropical regions of Asia and America. The Bread-tree belongs to this order, supplying the Caffre bread; the Cycas of Japan produces, in its stem, a starchy matter, which is collected and eaten like sago. The Cycadæ are sometimes called Palm-ferns, from their resembling Ferns as well as Palms. In past time the order was much more numerous than at present. The so-called flower of the Cycadæ is very simple. The naked ovules are attached to the bases of contracted leaves: these leaves in some cases overlap each other. The stamens are found on separate leaves, which overlap each other, forming a cone. The leaves containing the ovules and stamens are found on separate plants, the series being quite distinct in the Cycadæ. The reproductive apparatus of the Cycadæ agrees essentially with that of the Salvinia, noticed in speaking of the Rhizocarpæ, the ovule of the Cycas being homologous with the large spore of Salvinia, the pollen corresponding to the small spores. As the reproduction of the Cycas from the ovule, so far as known, is the same as that of the Coniferæ, we turn now to that order.

CONIFERÆ.

The Coniferæ, or cone-bearing trees, are so called from their fruit being in the form of cones, as in the Pines; "these cones are made up of flat scales regularly overlapping each other, and pressed together in the form of a spike or head; each scale bears one or two naked seeds in its inner face." "The pollen is contained in the substance of a body that retains in some degree its leafy type, and an assemblage of such bodies forms the 'catkin.'" In the Cypress we have cells (corresponding to stamens) at the edge of the leaf. The leaves of Selaginella (a Cycopod), with their large and small spores (Figs. 136, 137), are as much flowers as the leaves of Coniferæ with their organs. The Coniferæ are invaluable to man, as including the most important of the timber-trees of cold countries, and furnishing the turpentines, resins, pitch, tar, and Canada Balsam. Among the Coniferæ are found the Pines, Fir, Spruce, Cypress, Cedars, Larch, and Juniper. At certain seasons the ovule of Coniferæ develops in its interior a mass of cells, the Endosperm; later in this Endosperm appear Corpuscles; within the Corpuscle is developed the Embryonic vesicle. The Ovule, Endosperm, Corpuscle, and Embryonic vesicle are to the Coniferæ and Cycadæ what the Large Spore, Prothallus, Archegonium, and Embryo-cell are to the Lycopods, the pollen of the Gymnospermæ corresponding to the small spores of the Lycopodiaceæ: the reproductive organs of Lycopodiaceæ and Gymnospermæ are, therefore, essentially the same. The higher plants differ from these orders in that the embryo-sac contains the embryo-cell only; whereas, in Lycopodiaceæ and Gymnospermæ, a Prothallus or Endosperm with Archegonia or Corpuscles is produced, the embryo-cell appearing in the Archegonia or Corpuscles, to which there is nothing to correspond in the higher plants, which necessarily want the Prothallus or Endosperm as well. After the contact of the germinal vesicle and the pollen, the life of the new Gymnosperm begins in the formation of the embryo, which consists of a stem or radical supporting two or more leaves (Figs. 139, 138, *a*), called cotyledons. The embryo of the Cypress in its two cotyledons recalls that of Selaginella (a Lycopod). Those plants whose embryos have only one leaf (Fig. 140, *a*) or cotyledon are called Monocotyledonous, while those having two are known as Dicotyledonous. The Dicotyledonous plants further offer in their stem the destruction of pith, wood, and bark, and increase the diameter of their stem by layer after layer (Fig. 141, 1, 2, 3) of wood being added, the new layer being deposited between the old layer and the bark, this new layer growing at the expense of the Cambium, a layer (Fig. 141, *C*) found always between the last and most external layer of wood and the bark. Such plants are called outside growths, or Exogens. The Monocotyledonous plants, however, do not present, in their stem, the difference of pith, wood, and bark so well defined as in Exogens; the new wood being added in bundles intermingling with the old, and deposited principally towards the centre of the plant. (Fig. 142.) Such forms are called inside growths, or Endogens. The wood of an Exogen is oldest and hardest in the centre, whereas the wood of an Endogen is newest and softest towards the centre. The increase in the diameter of the trunk of an Exogen, as in the Oak, is indefinite; the stem of the Endogen, as in the Palm, is limited as regards its diameter, the tendency being rather to grow upwards. In speaking of the Lycopodiaceæ, Cycadæ, and Coniferæ, we have noticed they have important features in common: the reproductive apparatus is essentially the same; the form of the embryo in some genera

(Selaginella, Cypress) is two-leaved, or dicotyledonous; finally, there must be added to these facts the additional one of the Cycadæ and Coniferæ being outside growers, and of a similar exogenous mode of growth being seen in Isoetes among the Lycopodiaceæ. The Lycopodiaceæ are, therefore, so closely and intimately allied with the Cycadæ and Coniferæ that the question naturally arises, Does there really exist in Nature such a distinction as that of Flowerless and Flowering plants? The reproductive apparatus of the Lycopodiaceæ is so similar to that of the Cycadæ and Coniferæ that it is impossible to say where the Flowerless plants end and the Flowering begin. In the first page of this chapter we used purposely the expression, translating Cryptogamia "flowerless," Phanerogamia "flowering." The word *cryptos*, literally translated, is "obscure," "concealed;" *phaneros*, "apparent," "evident;" *gamos* referring to the organs of reproduction. Translating literally, the Cryptogamic plants are those in which the reproductive organs are not absent, but only obscure; the Phanerogamia, those in which the reproductive organs are very evident in the form of flowers. The difference between the higher Cryptogamia and Phanerogamia is not one of kind, but only of degree, the apparent gulf between these two divisions being bridged over by the Lycopodiaceæ, Cycadæ, and Coniferæ. The Linnæan classification is the best yet offered, expressing the real nature of plants. The Angiospermæ, as previously stated, are those flowering plants whose seeds have a seed-vessel: their embryo is either Monocotyledonous or Dicotyledonous. The one-leaved or Monocotyledonous form of embryo is universally associated with the endogenous, or inside mode of growth, usually with a threefold arrangement of leaves. The Dicotyledonous or two-leaved embryo, on the contrary, characterizes all outside growers or Exogens, accompanied usually with a fivefold arrangement of leaves. The Monocotyledons include the Palms

(Fig. 143), Bananas, Orchids, Lily, and the Grasses. Among the Dicotyledons are found the Oaks, Elms, the fruit-trees, and the most beautiful flowers. The flower of the different kinds of Dicotyledons offers an interesting ascending series. The flower of the Spurge, or Euphorbia, consists of only a stamen or a pistil, known as Achlamydeous, the flower being called accordingly staminate or pistillate. A slight progress is seen in the flower of the Goose-foot, Fig, Mulberry, Elm, etc., in which, however, the corolla is still undistinguishable from the calyx. Such flowers are called, therefore, Apetalæ: the flowers of the Monocotyledons are of this kind. In the Bean, Clover, Violet, Geranium, etc., the corolla and calyx are distinct, but the petals forming the corolla are still more or less separated, hence they are known as Diapetalæ; in the Gentian, Elder, Ash, Morning-glory, etc., the petals have united; they are known, therefore as Gamopetalæ. How the different orders of the Phanerogamia are related to each other is the last question which yet remains unanswered. The structure and reproductive apparatus of the Cycadæ and Coniferæ would lead us to suppose that they appeared on the earth before the Monocotyledons or Dicotyledons. This view is confirmed by geological evidence, since the fossil Cycadæ and Coniferæ are found in great profusion at a much earlier period than that in which the Monocotyledons or Dicotyledons first appeared. The Cycadæ and Coniferæ are probably the posterity of a common ancestor nearly allied to the Lycopodiaceæ. Among the Coniferæ there is an order, the Gnetaceæ, or the jointed Firs, whose structure links them on to the Monocotyledons and Dicotyledons. Some extinct Conifer, allied to the jointed Fir, was the probable common progenitor of these two orders, of which the Dicotyledons are the most complex, both as regards the structure of the stem and flower.

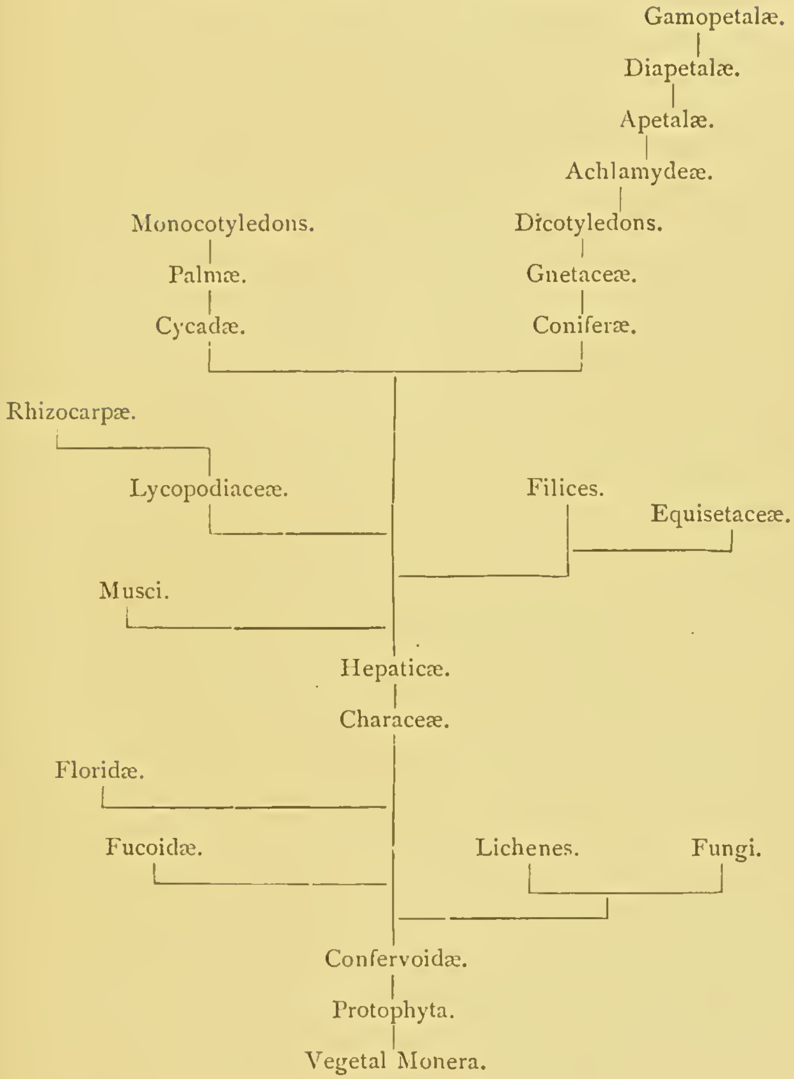
RESUME.

Beginning with the most minute and simplest of plants, such as are found in every pond and ditch, and comparing them with the different sea-weed, Fungi, etc., we found, notwithstanding minor differences, that their structure was essentially the same, cellular; offering no trace in their organization of stem and leaves. Passing from the cellular plants, through transitional forms, to the Liverworts, we noticed that the lower forms of this are still cellular, while the higher exhibit the beginning of a separation into stem and leaves. Forms like these lead the way to the Mosses, in which the stem and leaves are well defined. The Ferns, while agreeing with the Mosses in having stem and leaves, offer an advance in their organization, since their stem contains vessels with more or less woody tissue. Passing from the Ferns to the closely allied Club-mosses, we found in them the links binding the Flowerless with the Flowering plants. Taking up next the Cycadæ and Coniferæ, we saw how naturally they preceded the Endogens and Exogens. Finally, in the different kinds of Exogens we saw an ascending series, as illustrated in the flower of the Spurge, Goose-foot, Violet, Morning-glory. Our brief survey of plants may be expressed in the following conclusion: The vegetal kingdom may be represented by a tree, of which the stems and branches are the classes, orders, etc. The trunk of this tree, being composed of the simplest forms, grows gradually upwards into more complex ones, finally developing the noblest of trees, the most beautiful of flowers. We hope to show in our next chapter that the petrified remains of the animal and vegetal kingdoms offer such a progress from lower to higher forms.

VEGETAL KINGDOM.

	CLASS.	ORDER.	EXAMPLE.
Cryptogamia. (Reproductive organs obscure.)	Thallophyta. (Cellular plants.)	Protophyta.	Green matter of trees.
		Confervoidæ.	Microscopic green water-plants.
		Fucoidæ.	Brown Sea-weed.
		Floridæ.	Red Sea-weed.
		Lichenes.	Yellow crusts of walls.
		Fungi.	Mould of fruits.
		Characeæ.	Chara.
	Anophyta. (Stem and leaves.)	Hepaticæ.	Liverworts.
		Musci.	Mosses.
	Acrogens. (Summit growers. Vessels in stem.)	Filices.	Ferns.
		Equisetaceæ.	Horse-tails.
		Lycopodiaceæ.	Club-moss.
		Rhizocarpæ.	Pillwort.
Phanerogamia. (Reproductive organs evident.)	Gymnospermæ. (Seeds naked.)	Cycadæ.	Bread-fruit-tree.
		Coniferæ.	Pine.
	Angiospermæ. (Seeds in vessels.)	Monocotyledons.	Palm.
		Dicotyledons.	Oak.

TREE OF VEGETAL KINGDOM.



GEOLOGY.

No study illustrates better than Geology not only the advantage but the absolute necessity of general knowledge for the thorough understanding of any particular subject. Geology means literally a discourse on the earth. The student of so vast a theme ought naturally therefore to be familiar with at least the general conclusions offered by Astronomers, Physicists, Chemists, Mineralogists, Botanists, and Zoologists, so far as they relate to the history of this planet, since by astronomical data we picture our earth as a once gaseous, chaotic mass. The study of the cooling of heated bodies under pressure, implying a knowledge of the laws of Heat and Chemistry, furnishes the clue to the explanation of the origin of many formations. Mineralogy distinguishes the different rocks of which the crust of the earth is composed, while Botany and Zoology supply the means by which the life of bygone days is revivified, enabling us to interpret the structure and relations of plants and animals long since extinct. Geology, therefore, is not a separate science, since it consists only of the conclusions of many sciences applied to the investigation of the past and present history of the earth. As three-fourths of the earth are covered with water, with our present resources only a very small portion is susceptible of geological examination. And notwithstanding the great number of surveys and scientific expeditions which have been made during the present century, with the exception of Great

Britain, Canada, parts of Europe and the United States, the geology of the accessible portion, even, of the earth is still very little known, large parts of Africa, Asia, and South America being as yet, comparatively speaking, unexplored. Civilization, through its railroad-building, tunneling, canal-making, and mining operations, furnishes a large amount of the material on which the Geologist bases his science. Through agencies of this kind, rocks have been exposed which otherwise would have perhaps remained forever concealed from view. Through the excavating incidental to mining and tunneling, there have been discovered the remains of plants and animals long since extinct, the relics of an indefinitely remote past, the existence of which had not been previously even dreamed of. The detritus brought down by rivers, and the consequent filling up of their mouths, as seen in the deltas of the Mississippi and the Nile, with the preservation in the mud, etc. of the coral stones, shells, skeletons of fish, etc. which lived and died in the vicinity, give one a good idea of the manner in which petrified organic remains or fossils may have been preserved in the rocks. While in certain rocks of this kind the fossils are found in great profusion and in a very excellent state of preservation, in others very few occur, or only a fragment may have escaped destruction. This is often, however, so characteristic that the comparative anatomist can reconstruct the whole skeleton from a single bone, a knowledge of the correlation of forms enabling the osteologist to infer from the structure of the foot the nature of the jaws, teeth, etc., of the extinct animal. Many such inferences might be mentioned, all of which, while commanding praise as illustrating the osteological knowledge of the anatomist, scarcely merit the astonishment which they invariably excite. While many rocks seem to have experienced but little disturbance since their original deposition, the different layers or strata of which they are composed being easily distinguishable, the convulsions to which others have been subjected have been so great, and the effects of heat so intense, that no sign of such stratification is visible, if it ever existed. The old Geologists resembled the knights who fought about the color of the shield. The early German school, influenced by the character of the rocks in that part of the world, attributed a great deal to the action of water; while the Scotch school, equally impressed by the features of the formations in their country, attached great importance to the effects of heat. Hence arose the sects of the Neptunists and Plutonists. Both were right in attributing the formation of the rocks in their respective countries to the action of water and heat. Both were wrong in applying to the whole world conclusions drawn from such local data. Modern Geologists steer a middle course,—avoiding these extremes,—considering the effects of the combined action of water and heat, as well as admitting the influence exerted by these agents separately. Rocks the origin of which is supposed to be due to the gradual deposition under water, in layers or strata, of the materials composing such formations, are called Aqueous Rocks; while those of which the structure clearly testifies to the action of heat in producing them are known as Plutonic Rocks. Finally, the Metamorphic Rocks illustrate the alternate action of water and heat. Geologists classify rocks according to their mineral composition, their organic remains, and the order in which they follow or overlie one another. The Geologist, starting in Canada, and traveling through New York and Pennsylvania, notices continually as he advances southward the change in the minerals composing the rocks, and the different aspects of their organic remains. Thus, in Canada and the east of New York, granite, gneiss, and syenite are common minerals. These rocks were originally called Azoic, or without life; improperly, however, as within a few years the Eozoon, or

Morning being, was discovered, so called from representing the very simple beings which first appeared on our continent during the dawn of life. The term Azoic is still retained by Geologists as meaning a scarcity of life, not implying, as formerly, entire absence of it. Continuing his journey, our Geologist soon reaches the Potsdam Sandstone, abounding in characteristic fossils, of which the Brachiopod shells and Trilobites, extinct Crustaceans, are very common. Passing by the town of Oriskany, he comes to what is known as the Schoharie Grit, in which the remains of fishes are first found. Finally, he reaches Pennsylvania, abounding in coal, with its ferns and traces of reptiles. If he goes over to New Jersey, he finds in the chalks the reptiles more abundant. To see the higher forms of life in profusion, he must turn to the West, Nebraska and Dakota having furnished the remains of deer, rhinoceros, hyena, lion, etc. The rocks of Canada and New York are the successive beaches left dry by a retreating ocean. This is very evident from the manner in which the rocks follow each other, the ripple-marks still visible on them, and their marine remains. The animals and plants found in the rocks of New York and Pennsylvania, from bearing the stamp of age, are called Paleozoic, or old beings, and the age in which they lived is known as the Primary. The fossils of New Jersey, though still old, are more modern in their appearance than those of New York; they are called, therefore, Mesozoic, or middle-aged beings; the rock containing them forming, with some others not well represented on our continent, the Secondary Age. The Cenozoic, or recent beings, those of Nebraska, for example, lived during the Tertiary Age. Not only are the fossils invaluable to the Zoologist and Botanist, as representing the life of the past, but they are equally important to the Geologist, as we have just seen; his classification of the rocks is principally based on the extinct remains which they contain. The

Primary, Secondary, and Tertiary Ages, with their characteristic fossils, according to many Geologists, were not confined to America, but extended all over the globe; the whole earth having passed at the same time successively through the Primary, Secondary, and Tertiary Ages. Some few Geologists do not accept this onion-coat hypothesis, which supposes that similar rocks, with similar remains, were deposited at the same time all round the earth, like the layers in the coat of an onion. With all deference to Geologists, let us examine the tests used for determining the time of the deposition of foreign rocks as compared with our own. The test of having similar minerals, when applied to elucidating the age of foreign rocks as compared with those on this continent, is worthless, since the chalk, sandstone, etc. of which the rocks are composed are forming in all ages; while a determination of the age of rocks, based on the order in which they follow or overlie one another,—when applied, for example, to New York and England, separated by an ocean,—to say the least, is very unreliable. The third test, that rocks having similar organic remains are of the same age, considered by most Geologists as settling the question, whenever such comparisons are possible, may be as fruitful a source of error as the view that similar minerals deposited in the same way are of the same age. Nor does the reverse of this proposition hold good, that rocks are of a different age because they contain different fossils. Suppose, for example, that the western part of North America and Australia were gradually to sink into the sea, as parts of the world are now doing, and then slowly to rise again, the Geologist of an indefinitely remote future might argue, because he found many fossil pouch-bearing animals in Australia, and the bones of an extinct human race in America, that the Kangaroo was not contemporaneous with the Indian. From the distribution of plants and animals at the present time, we know that remote parts of the earth have very different animals; the preservation of organic remains at the mouth of the Mississippi being no index of what is going on at the mouth of the Ganges. While it is possible, it is certainly not proved by the structure of the rocks, their deposition, and organic remains, that the whole earth has passed at the same time successively through the Primary, Secondary, and Tertiary Ages. The limits of this essay do not admit of the further discussion of this subject; nor, indeed, is it necessary, as the question has been thoroughly argued by Herbert Spencer in his "Illogical Geology." The disputes of the Neptunists and Plutonists ought to be a warning to Geologists not to apply generalizations, drawn from limited data, to the whole earth. In the present state of Geology we should receive all conclusions with great caution, being prepared at any moment to have them modified or even disproved by future research. Notwithstanding the difficulty of obtaining fossils, the injuries they often have received in being removed from the rocks, that many are lost or destroyed through the ignorance of the workmen who are often the first to find them, together with the fact that the chance of plants and animals being preserved is very small, remembering how the remains of an animal, dying at the present day, are picked to pieces, get separated, and are often finally destroyed,—yet the museums in different parts of the world contain numerous organic remains on which is based the science of extinct plants and animals, or Paleontology, the conclusions of which science are important proofs of the truth of the theory of the evolution of the higher forms of life from the lower. The opponents of the transmutation of species argued fifty years ago, If the higher forms have descended from the lower, where are the missing links? Paleontology has answered that objection by supplying the missing links, such as the intermediate forms which bind together the Rhinoceros and the Horse, the Hippopotamus and the Pig, the Whale and the Seal, the Reptiles and Birds, the Ganoid fishes and Batrachia, etc. Not only are the fossils invaluable, therefore, to the Evolutionist without reference to their age, but the order in which they have appeared, and their relative age so far as it is possible to determine it, are in perfect harmony with the conclusions we have drawn from the structure of living plants and animals. Remembering the uncertainty attached to the absolute and relative age of rocks, let us examine the Primary, Secondary, and Tertiary Ages through which North America has probably successively passed, without reference to the relation these Ages bear in time to the corresponding parts of Europe, etc. Geologists subdivide the Primary, Secondary, and Tertiary Ages into periods (epochs) more or less characterized by their fossils.

AGE OF MOLLUSCA AND ALGÆ.

Passing from the Azoic rocks, in the northern part of the State of New York, through the Potsdam region, to Trenton Falls, southwardly to the Helderberg Mountains near Albany, and eastwardly to Niagara, the immense number of fossil shells, particularly Brachiopods (Fig. 145), attracts the attention of the traveler. The Brachiopods of the present seas are few and far between, whereas the sea of that most ancient period was characterized by shells of this order; the remains of other Mollusca are found, but much less abundantly as compared with those of Brachiopods. The seas of this period must have swarmed with Crinoids, from the great number of them found petrified, their broken stems being known as Lily Stones (Fig. 146) and St. Cuthbert beads. The young of the Comatula, long supposed to be a distinct animal, the Pentacrinus (Fig. 42), is the only known representative of the Crinoids at the present time. With the Crinoids are also found abundantly

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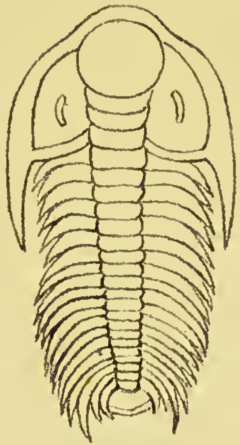

TRILOBITE

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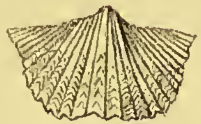

BRACHIOPOD

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CRINOID LILY STONE

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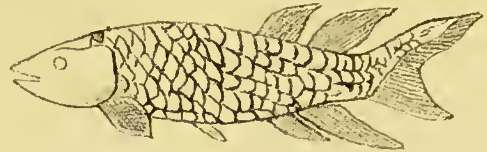

GANOID FISH

Star-fish. Associated with Brachiopods, etc., in great profusion, and in an admirable state of preservation, are the characteristic Trilobites (Fig. 144), an extinct order of Crustacea, to which the nearest approach at the present time is seen in minute Crustaceans like Cypris, favorite objects with the Microscopist, or like the larva of Limulus. In some genera of Trilobites, the different stages of their existence have been very well followed out, the fossils having been found perfect and in great profusion. The rocks furnish evidence of the existence of worms at this period, though, from the delicate nature of their bodies, their remains are few and obscure. Certain impressions or casts found in these rocks, known as Graptolites, are supposed to have been made by animals allied to the Sertularia of the present day, while the Niagara limestone consists almost entirely of Coral. The period characterized by the profusion of the remains of Brachiopods, Crinoids, and Trilobites is known as the Silurian, called after that of England and Wales, which derived its name from the ancient tribe of Silures, once inhabiting those parts. The plants of this period are Fucoidæ, or brown sea-weed. What conclusions can be drawn from the life of the Silurian period in favor of the theory of the higher forms having descended from the lower? We have seen that the animals of this period were aquatic. Now, animals living in the water are more simply and lowly organized than those living on land. An animal subjected to the ever-changing conditions of a land-existence needs a more complex organization to fulfill its requirements than one living in the comparatively unchanging sea. If the Development theory be true, the water-animals, then, should have preceded the land-animals, the water-plants the land-plants. Such has been the order of their appearance, according to the testimony of the rocks. In the chapter on Zoology we gave reasons for supposing that the Crinoids and Star-fish were the oldest of the Echinodermata, the Brachiopoda of Mollusca, the Entomostraca of Crustacea, and that the Worms preceded the Insects, etc. We have just seen that the life of the Silurian, the most ancient period except the Azoic, was characterized by these very orders, which are the most simply organized of the respective divisions of the animal kingdom, while the Fucoidæ, or brown sea-weed, found fossil in rocks of this period, belong to the Algæ, the simplest division of the vegetal kingdom. Geological evidence confirms, therefore, not only in a general way, but to an extent in detail not to be hoped for from the nature of the subject, the view of the development of the animal and vegetal kingdoms deduced from their structure. The Silurian period is sometimes called the Age of Mollusca and Algæ.

AGE OF FISHES.

Passing from the Silurian period to the Devonian, so called from the rocks of this formation having been first studied in Devonshire, England, we notice that while the first half of the Devonian agrees in its main features with the latter half of the Silurian, the latter half of the Devonian, often called the Old Red Sandstone, offers evidence of a progress in life, since its rocks contain the remains* of fish, together with a few Ferns, Lycopods, and Conifers. The remains of these plants are, however, only rarely found in the Devonian ; the flora of this period, as well as that of the Silurian, being more generally characterized by the presence of Algæ. The Fishes found in the Devonian period are Sharks and Ganoids (Fig. 147). The Sharks belong to the order of Cestraphori, or weapon-bearers, so named from their dorsal fin being armed with a long spine; these spines

* Fish-remains found in the Silurian of England.

are found fossil in great numbers; the teeth are in the form of plates, giving the appearance of a pavement. The only Shark at the present day having such teeth is the Cestracion, or Port Jackson Shark, confined to the Australian and China seas. The Ganoids, so called from their shining plates or scales, must have abounded in the Devonian seas, from the numerous fossil genera and species that have been described. The only living examples of Ganoids at the present time are the Sturgeons, Gar-pike, Amia of North America, and the Polypterus of the Nile. In the chapter on Zoology we argued, from their structure, that the Sharks and Ganoids were not so highly organized as the Teliosts, or bony fish of the present day, and concluded that therefore the Sharks and Ganoids had preceded the Teliosts in their appearance on the earth. This view is confirmed by what we have just seen, that the fishes that first appeared were Sharks and Ganoids. Further, we noticed that the Ganoids, while intermediate in many respects between the Sharks and Teliosts, have many striking affinities with the Batrachia and Reptilia. The fact of the Ganoids appearing before the Bony Fish and Batrachia is a striking confirmation of the truth of the view proposed, that the Ganoids were the common stock from which the stems of the Teliosts and Batrachia diverged. Calling attention to the fact of the Silurian period, or Age of Mollusca, preceding the Devonian period, or Age of Fishes, being in harmony with the view of the higher forms of life coming from the lower, we pass on to the Carboniferous period.

AGE OF ACROGENS AND BATRACHIA.

Pennsylvania, the great coal State, was principally formed during the Carboniferous period, often called the Age of Acrogens or Summit-growers, from eight-tenths of its plants belonging to that order of the vegetal kingdom.

Some years ago it was estimated, by Brown, that of the one thousand species of plants found in the rocks of the Primary Age, especially of the Carboniferous period, not less than eight hundred and seventy-two were Fern-like, the remaining species including about seventy-seven Coniferæ and Cycadæ, forty Thallophytes, mostly Algæ, and about twenty undetermined plants. We see from this estimate that the Fern-like plants were the characteristic feature of the Carboniferous period, and must have flourished in a much greater profusion than at the present day, the Tree-ferns of tropical climates, even, giving one no idea of the luxuriance of their growth in those ancient days. Indeed, whole orders have passed away: the Calamites and Asterophyllites, resembling the Horse-tails, having no living representatives, while the Sigillariæ and Lepidodendrons have degenerated into the Club-moss of our forests. As commonly known, the Lycopod of the woods is a delicate moss-like plant: that of the Sunda Islands is often twenty-five feet high. The Lepidodendrons of the Carboniferous period, closely allied to living Club-moss, attained, however, a height of from forty to sixty feet, while their diameter at the roots was as much as twelve to fifteen feet. The Sigillariæ are similar in many respects to the Lepidodendrons, often as high, though more slender. The general aspect of the Carboniferous period was that of a great Fern forest and a jungle of gigantic Club-mosses, with some Coniferæ and Cycadæ; these, however, but rarely seen, comparatively speaking. The gradual decomposition of these plants resulted in the formation of the vast coal-fields so characteristic of this period. In the marshes of these forests first appeared the Batrachia (Frogs, etc.), together with the Centipedes, the May-fly, Locust, and Beetle orders among Insects. We see, therefore, that the tree of the development of life, as proposed in the chapters on Botany and Zoology, is in perfect harmony with what we know of the Carboniferous fossils. The gorgeous Ferns, in great variety, the Lycopod-like plants, having attained the full maturity of their luxuriant growth after this period, give way to the Cycadæ and Coniferæ. The Ganoid fishes die out, their posterity, the Batrachia, having appeared, soon to be replaced, however, by the Reptilia, while the Insects are still represented by the lowest orders just mentioned. Following the Carboniferous rocks of the West in this country, and closely resembling the Carboniferous period in its general features, we meet the Permian, called after the ancient kingdom of Permia in Russia. It is interesting to the Evolutionist as furnishing the remains of the simplest reptiles, the Proterosaurus having been found in the Permian rocks of Germany. By looking at the tree of the development of the Reptilia, it will be seen that the Proterosaurus is regarded as the common ancestor of that group. The Silurian, Devonian, Carboniferous, and Permian periods, taken together, constitute the Primary Age, or age of most ancient beings.

AGE OF CYCADÆ AND REPTILIA.

The Secondary, like the Primary Age, is subdivided into three periods, the Triassic, Jurassic, and Cretaceous. These three periods, while differing considerably in minor respects, agree essentially in their plants and animals, being principally represented by Cycadæ and Reptilia.

TRIASSIC PERIOD.

This period derives its name from the formation in Germany being composed of three kinds of rock; the name, however, is one of only local application, the period being often called in England and America the New Red Sandstone, as distinguished from the Old Red, or Devonian. The absence of Lepidodendrons and Sigillariæ in this period, so striking a feature of the Carboniferous, is to be noticed as an important fact for the Evolutionist, the Cycadæ and Coniferæ completely replacing them. Among the Batrachia of the Trias are to be noticed the immense Labyrinthodons, the skull in one species measuring three feet long by two wide; remains of these animals have been found near Gwynedd, in the Triassic of Pennsylvania. The Connecticut Sandstone is famous for its tracks, supposed to have been made by large Reptiles, of which more than fifty species have been described. During this period the Birds first appeared, and, from their tracks left in the sandstone, they are thought to have resembled the Running-birds of the present day, though much larger, the Brontozoon (Fig. 148) of the Connecticut valley being four times as large as the Ostrich. The existence of such large birds may be doubted by those who are not familiar with fossils. Those, however, who have seen the gigantic Dinornis of the British Museum are quite satisfied with Prof. Owen's statement, that they are "equal to the formation of tridactyle impressions as large as those of the Connecticut Sandstones." (Pal., p. 331.) In the Triassic the remains of Mammals are first found. The fossil remains Microlestes and Dromatherium (Fig. 149) are usually regarded as Marsupials, or pouch-bearing Mammalia. The Dromatherium, according to Prof. Owen, "would appear to find its nearest analogue in the Myrmecobius," a little Marsupial living at the present day in Australia. These fossil Mammals have been supposed by some authors to be Monotremata, though that order have no teeth, as in the Duck-bill, etc. This perhaps, however, was not the primitive condition of the order, the first Monotremata having teeth, which their descendants have lost through adaptation to their peculiar mode of life. Whether this view be or be not confirmed by future research, the important fact to be noticed is that in either case the Mammals which first appeared on the earth were

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FOOT TRACKS OF BRONTOZOON

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JAW OF DROMATHERIUM

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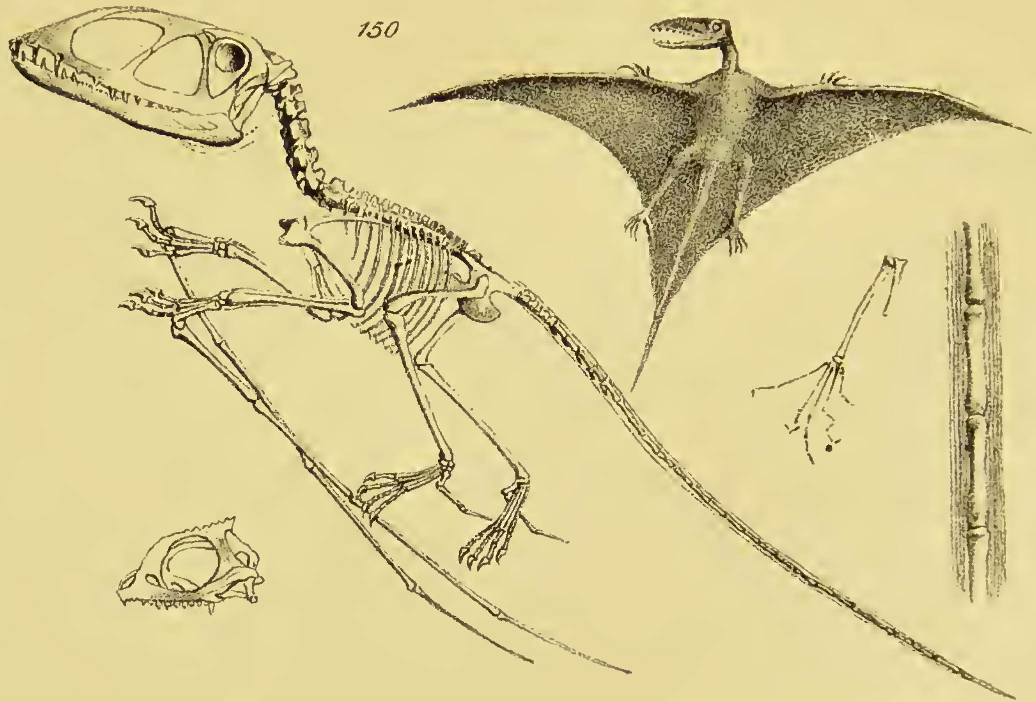


the lowest of the order. The existence of such large birds as the Brontozoon, at this period, is in harmony with the view of the Reptiles being the progenitors through the Ostrich family of the Birds, while the fact of both Birds and Mammals appearing about the same time confirms the theory that they are the diverging stem of a common stock, the Reptilia.

JURASSIC PERIOD.

This period is called after the Jura Mountains of Switzerland, and is remarkable for the variety of its Reptiles, which were of great size. Conspicuous were the "terrible reptiles," or Dinosauria, of which the carnivorous Megalosaurus and herbivorous Iguanodon were upwards of thirty feet long. Very curious flying Reptiles existed in the Jurassic period, such as the Pterodactyle and Dimorphodon (Fig. 150). Equally characteristic were the Ichthyosauri (Fig. 58) and Plesiosauri, upwards of thirty feet long, whose organization united reptilian with batrachian and piscine characters. Their fin- or paddle-like extremities would indicate that they had diverged from the stem of Fishes rather than from that of the Batrachia. Their structure, however, is so peculiar as to make it extremely difficult to determine their exact position in the animal kingdom. Crocodiles and Turtles appear now for the first time, together with Sharks of the cutting-teeth kind, like the modern gray Shark (Notidanus), which will soon replace the Cestracions, so striking a feature of the ancient formations, while the Insects are represented by the high order of Hymenoptera. The Compsognathus (delicate jaw), a very bird-like Reptile, and the Archeopteryx (ancient bird), a reptile-like Bird, both Jurassic fossils, are extremely interesting to the Evolutionist, as almost bridging over the gap between existing reptiles and birds. The Mammals of this period are still of the Marsupial order.

CRETACEOUS PERIOD.

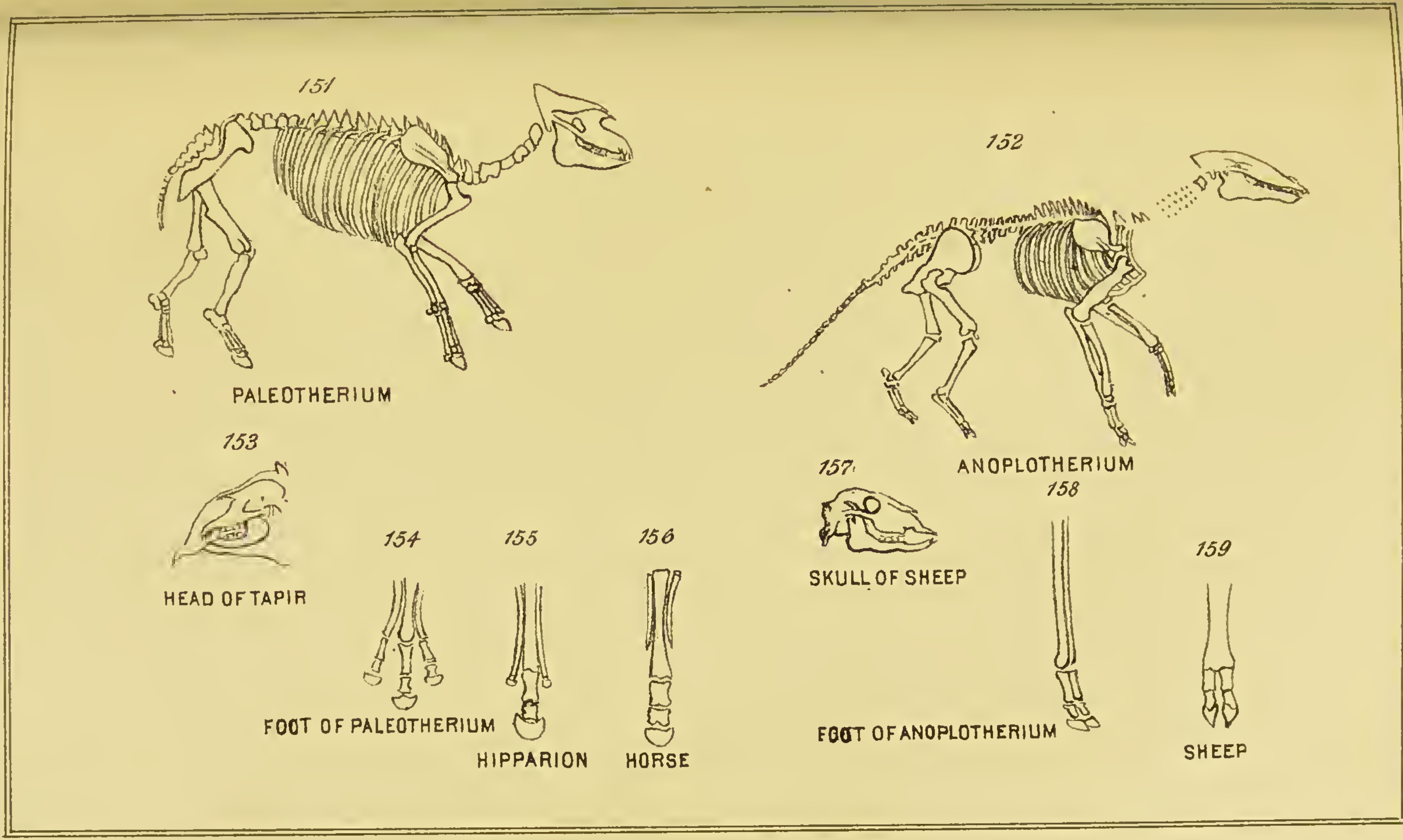
This name is given to rocks occurring in various parts of the world, which contain well-marked and characteristic forms of animal and vegetal life, though the rocks themselves may be composed of very different minerals. Thus, the chalk-cliffs of England are so striking as to give her the name of Albion, while up to the present time no chalk has been found in America. The formation in New Jersey, etc., supposed to correspond to the Cretaceous of England, consists principally of marl, much used for fertilizing purposes. The apparently simple and generally unobserved phenomena of one's fireside are often really so complex that lives have been spent in investigating, volumes written in explaining them. The burning of a candle forms the subject of an interesting little book by the late Prof. Faraday; while Prof. Huxley observes, "The man who should know the true history of the bit of chalk which every carpenter carries about in his breeches-pocket, though ignorant of all other history, is likely to have a better conception of this wonderful universe, and of a man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of Nature." It would be superfluous to attempt to show the justice of this profound remark, as those who care to follow the reasonings by which such a conclusion is reached can find them in the essay on a "Piece of Chalk," from which the above quotation is taken. While the Reptiles of the Cretaceous period still include huge creatures like the Hadrosaurus and Mososaurus, the Fishes and Plants are becoming more modern in their appearance, Bony Fishes first appearing in this period, among which are to be mentioned the Herring, Salmon, etc., and the vegetal kingdom being represented by modern trees, like the Palms, Oaks, and Poplars, accompanied by a marked decline in the Cycadæ. With the

Cretaceous period we leave the Secondary Age, and pass on to the Tertiary.

AGE OF PALMS, EXOGENS, AND MAMMALS.

The Tertiary Age is subdivided into the Eocene, Miocene, and Pliocene periods. These names were chosen to express the result of a comparison made between the shells found in the rocks of the Tertiary formation and those living at the present day, the object in view being to determine whether many living shells are found petrified in the Tertiary rocks. Thus, in Sicily, of one hundred petrified shells, from seventy to ninety are found in existing seas; hence the name Pliocene, or most recent, was given to rocks containing such a large proportion of living shells. Those parts of the Tertiary formation known as Miocene, or less recent, have from forty to fifty per cent., while only the dawn of recent shells is expressed by the term Eocene. The subdivision of the Tertiary Age into these three periods, originally based on the proportion between the fossil and living shells, was afterward applied to Tertiary plants and animals generally, it being supposed that a proportion similar to that of fossil and living shells existed between Tertiary plants and animals and those of the present day. These periods often, however, pass so gradually into one another, the lines of demarkation not being very well defined, that this classification is not always applicable. The Tertiary Age, notwithstanding the minor differences of its periods, is essentially an age of Mammals, Palms, and Exogens. There is no necessity of describing the details of its animal and vegetal life, since Asia and Africa, with their Hippopotami, Rhinoceroses, Elephants, Lions, and Tigers, living amidst the characteristic tropical plants, give one an excellent idea of what America, Great Britain, etc. were during their Tertiary Ages. To the Evolutionist the

Paleotherium (Fig. 151) and Anoplotherium (Fig. 152), living during the early part of this age, are extremely interesting, being regarded as the progenitors of the odd- and equal-toed Mammalia. The conclusions of Cuvier as to the nature of the Paleotherium, based only on fragmentary remains, were perfectly confirmed by the discovery of an almost entire skeleton. Since that time many allied forms have been described, principally by Prof. Owen, some of which, uniting the Rhinoceros, Tapir, and Horse, make the group of odd-toed, while others, associated with the Hog, Hippopotamus, etc., form that of the equal-toed. Prof. Leidy has described many kinds of horses found fossil in the western part of the United States, etc. (these discoveries are confirmed by those of Owen and Rutimeyer), which represent the transient stages through which the modern horse passes, so that the descent of the Horse from some paleotheroid form is completely made out. As regards the Flora of the Tertiary Age, as compared with that of the Cretaceous and Modern periods, according to Brown, the Apetalæ (Fig. 133) were greatly in excess during the Cretaceous period, the Diapetalæ were represented by a few species, while the Gamopetalæ (Fig. 131) had not appeared. In the Tertiary Age the Diapetalæ exceed the Apetalæ, the Gamopetalæ being comparatively well represented; while at the present day the great number of Gamopetalous genera seems to indicate that this order of plants is increasing most rapidly. These facts are very significant when compared with what is said of the structure of these plants. The age following the Tertiary, that in which we live, is known as the Age of Man, whose early condition, etc. will be treated of in the chapter on Anthropology. Repeating that great caution must be exercised in accepting the generalization of Geologists as to the relative and absolute age of rocks, a *résumé* of their fossil remains seems to exhibit the following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PALEOTHERIUM
152
ANOPLOTHERIUM
153
HEAD OF TAPIR
154
FOOT OF PALEOTHERIUM
155
HIPPARION
156
HORSE
157
SKULL OF SHEEP
158
FOOT OF ANOPLOTHERIUM
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SHEEP

progress of the higher forms of life from the lower. The Brachiopods, the lowest of Mollusca, the Crinoids and Star-fish, the lowest of Echinodermata, and the Trilobites, among the lowest of Crustacea, abounded in the Paleozoic Age. The Crinoids and Brachiopods lived on through Secondary time, playing, however, an inferior *rôle*, and now have almost passed away, a few Brachiopods only and one Crinoid living at the present day. The Age of Mollusca, we have seen, was followed by an Age of Fishes, thus exhibiting a progress in the animal life of the globe. The fact of these fishes being Sharks and Ganoids is very significant: the important point to be noticed is, that whatever view be taken of the rank of the Ganoids among fish, they preceded the Teliosts and Batrachia, and that the Sharks with pavement teeth came before those with cutting teeth. The next two periods offer a further progress in the life of the globe, since we find the Batrachia (Frogs, Labyrinthodons) appearing in the Carboniferous, followed by the Reptiles (Proterosaurus) in the Permian, while the Insects are represented by the lower orders, of which the Neuroptera (May-flies) were very abundant in the Carboniferous. In the Secondary Age the Reptiles reach their climax, while the Bony Fishes, Mammals, and Birds are just appearing. The gradual unfolding of the vegetal kingdom during the Primary and Secondary Ages is as marked as that of the animal kingdom. An Age of Algæ was followed by an Age of Acrogens; these gave way to Cycadæ and Coniferæ; the Cycadæ, in their turn dying out, were replaced by the Palms of the Tertiary, associated with which are the Forest trees, among which the great Mammals lived, and the flowering plants offered then as now a resting-place for butterflies, which first appeared in this age.

Modern Geologists do not believe that life, since it first appeared, has ever been extinct all over the globe at the same time. The earth has, no doubt, from time to time experienced great changes, its life being more or less destroyed by the effects of earthquakes, volcanoes, etc. These catastrophes were, however, local in their effects, as at the present day. If living plants and animals be compared with those whose remains have been preserved in the rocks, we see that, while many species and genera have passed away, comparatively few orders have become extinct, — that is, there are very few fossils which have not their modern representatives. Further, where the rocks overlie or follow each other, plants and animals appear in the later formation which did not pre-exist in the earlier, and usually exhibit a more complex structure. So that the "persistent types of life" seem to have been more or less modified from time to time. These general conclusions are in perfect harmony with the doctrine of the gradual development of the higher forms of life from the lower. We turn now to Embryology, which confirms, in the most remarkable way, the tree of life deduced from the structure and fossil remains of the animal and vegetal kingdoms.

CLASSIFICATION OF ROCKS ACCORDING TO THEIR ORGANIC REMAINS.

TIME.	PERIOD.	AGE.
Primary.	Silurian.	Mollusca, Algæ.
	Devonian.	Fishes.
	Carboniferous.	Batrachia, Acrogens.
Secondary.	Triassic. Jurassic. Cretaceous.	Reptiles, Cycadæ.
Tertiary.	Eocene. Miocene. Pliocene.	Mammals, Palms, Exogens.
Quaternary.	Modern.	Man.


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EGG
BLASTODERMIC VESICLE
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Primitive Trace
Area Opaca
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EMBRYOLOGY.

THE study of the transitional stages through which plants and animals pass from the early to the mature condition is not only of immense importance to the Physiologist, but equally so to the Zoologist, Botanist, and Geologist. Notwithstanding that some knowledge, at least, of Embryology is demanded in the study of Biology, the subject is comparatively little cultivated, owing, probably, to the limited means of obtaining material, and the difficult manipulation required in this kind of work. Nevertheless, since 1759, the year in which Wolff published his "Theoria Generationis," there have appeared from time to time Embryologists like Von Baer, Schleiden, Schwann, Coste, Remak, Rathke, etc., who, after overcoming the difficulties inherent to the nature of their studies, left treatises which will always be models of scientific work and philosophic thought. Our prescribed limits only permit of briefly calling attention to some of the conclusions of Embryology, pointing out the manner in which they confirm the theory of the evolution of life as deduced from the structure and petrified remains of the vegetal and animal kingdoms. Those who are ignorant of the early stages of plants and animals will hardly believe that beings so different as sea-weed, oaks, star-fishes, mollusca, guinea-pigs, rabbits, dogs, and men begin their life in the same way; yet Fig. 160 represents equally well the cell, or primitive stage, of any of the plants or animals just mentioned. Confining ourselves for the present to the animal kingdom, let us examine the cell, or the egg, of a mammal,—that of a rabbit (Fig. 160), guinea-pig, or man, for example. The egg of a mammal, about the $\frac{1}{120}$ of an inch in diameter, when magnified, is seen to consist of a cell-wall or Vitelline membrane (Fig. 160), inclosing cell-contents, or the Vitellus, in which is found the nucleus (Fig. 160, *n*), or Germinal vesicle, with its nucleolus, or Germinal spot. Let us observe what takes place, supposing the conditions to be favorable to the development of the egg. According to some observers, the Germinal vesicle and spot disappear; equally good observers, however, state that the Germinal vesicle and spot divide into two. While there is some doubt as to the disappearance of the Germinal vesicle and spot, all observers agree that the Vitellus, or cell-contents, divide into two segments (Fig. 161), and that each segment has its nucleus and nucleolus. As the segments are the halves of the Vitellus, probably the nuclei and nucleoli are formed through the division of the Germinal vesicle and spot. However this may be, the Vitellus divides into two segments, each segment having a nucleus with its nucleolus. These two segments subdivide into four balls (Fig. 162), the four into eight (Fig. 163), the eight into sixteen (Fig. 164), and so on. Through this process of cell-division, or segmentation, as it is called, the Vitellus is divided into a number of little balls, and assumes the shape of a mulberry. Finally, the superficial balls of the mulberry are transformed into cells, and so arrange themselves as to present the appearance of a mosaic pavement (Fig. 165); as the deeper balls become cells, they pass to the surface and increase the thickness of this mosaic-like membrane. In this manner the Vitellus is converted into a vesicle; within this vesicle there shortly appears a second vesicle; these two vesicles are usually called the Germinal layers, or the External and Internal blastodermic membranes. If the

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CHICKEN EGG
WITHOUT SHELL

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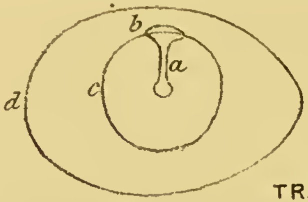

CHICKEN EGG WITH SHELL

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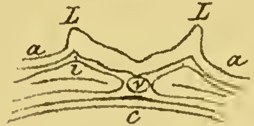
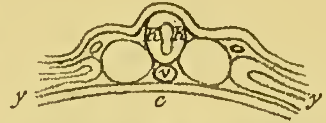


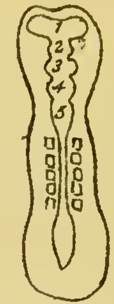
TRANSVERSE SECTION THROUGH
CHICKEN 24 HOURS OLD

176



TRANSVERSE SECTION THROUGH
CHICKEN 48 HOURS OLD

177



GUITAR SHAPED FORM
OF EMBRYO

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TURTLE

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MAN

egg in a slightly more advanced stage be now examined from a horizontal point of view, there will be seen a light oval space, the area pellucida, surrounded by a dark space, the area opaca (Fig. 166); within the area pellucida will be noticed an oval body, the Primitive trace, so called from indicating the position of the embryo, the furrow in the Primitive trace being known as the Primitive groove. A little later the Primitive trace and area pellucida become guitar-shaped (Fig. 167), and if a longitudinal section of the egg be examined (Fig. 168) it will be seen to consist of the External and Internal blastodermic membranes, and a third membrane lying between these two. The partial fusion of these membranes makes the Primitive trace. While these three membranes are consolidating into the Primitive trace, the Middle membrane splits into two layers: the Upper terminates in the External blastodermic membrane, the Lower grows gradually around the Internal blastodermic membrane, finally inclosing it. The embryo at this period is a guitar-shaped body (Fig. 177), consisting simply of three membranes lying over one another, narrowly bound together. The question may be asked by some of our readers, What relation does so minute a structure as the egg of a mammal bear to that of a bird? Does the development of a rabbit resemble that of the chick? The egg of a chicken (Fig. 174), as all the world knows, is composed of a shell inclosing a semi-liquid substance, in which is suspended a yolk. If a freshly-laid egg be carefully examined, however, supposing the conditions to have been favorable to development, there will be found lying on the top of the yolk a delicate sheath (Fig. 174, *b*), which is composed of two membranes; while the yolk itself, if laid open, exhibits in its interior a whitish body (Fig. 174, *a*), which, narrowing into a thread, runs upwards towards the membrane composing the sheath. This whitish substance is called the white yolk, as distinguished from the yellow yolk surrounding it. We have tried to explain how, by a continued process of cell-division, the contents of the egg of a mammal assume a mulberry-shaped form, and the gradual conversion of this mulberry into the External and Internal blastodermic membranes. If the yolk of the chicken be examined before it is surrounded by the semi-fluid substance (Fig. 173) and shell, there will be found lying on the top of the yellow yolk a membrane (Fig. 173, *b*) in which may be seen the Germinal vesicle and Germinal spot; by a process of cell-division, known as partial segmentation, this membrane is transformed into a heap of balls which gradually assume the form of the two membranes which, we have stated, are found lying upon the yellow yolk of the freshly-laid egg. In the course of development a third membrane appears between these two. The partial fusion of these membranes makes the Primitive trace, which passes from the oval to the guitar-shaped form (Fig. 177). The Middle membrane splits into two layers (Fig. 175), the Upper uniting with the External blastodermic membrane, the Lower bending down on the Internal blastodermic membrane (Fig. 176, *c*). The Middle and Internal blastodermic membranes now grow gradually downward around the yellow yolk, and finally inclose it. At this stage the embryo chick corresponds to Fig. 177, representing the embryo of a mammal. We see, therefore, that the development of the chick and the mammal is the same, while the difference between their eggs is not an essential one,—the nutriment for the mammalian egg being furnished from time to time, while that for the bird's egg is supplied at once in the form of yolk. A homely illustration of this difference is that of a man who receives his yearly food from day to day, and of one who receives his yearly food at once. The only part of the chicken's egg which corresponds to the mammal's egg is the membrane with its Germinal vesicle and Germinal spot, lying upon the yellow yolk of the unlaid egg.* Whatever view be taken of the relations of the eggs of the Vertebrata, the important point to be noticed is that the embryo of a fish, batrachian, reptile, bird, or mammal, including man at an early stage of life, is a guitar-shaped body (Figs. 177, 167), consisting of three membranes lying over one another, and narrowly bound together (Fig. 168); and if we were ignorant of the animal whose egg had been transformed into such a body, it would be very often impossible to say what would result from its development. These membranes are called blastodermic, or tissue germinating from the organs of the future animal growing in them.†

The skin and central nervous system are developed in the External, or upper membrane; the osseous, muscular, vascular, reproductive, and urinary systems, the walls of the alimentary canal, and its appendages, are produced in the Middle membrane; while the epithelium, which lines the alimentary canal and its appendages, the lungs, liver, etc., is derived from the Internal or lower membrane.

In speaking of the Primitive trace, at page 127, we called attention to the furrow known as the Primitive groove. As development proceeds, this furrow deepens, and it the

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* We have called attention to the distinction of white and yellow yolk, as the white yolk, or part of it, is supposed by Peremesko to form the Middle layer of the chick; his view being that the balls of the white yolk, by an amœbiform movement, pass up and between the External and Internal blastodermic membranes, coalesce, and so form the Middle membrane.

† By many Physiologists the embryo is stated as consisting of two layers, the External and Internal germinal layers, or blastodermic membrane, from which the future animal is developed. The view of the embryo consisting of three germinal layers was distinctly enunciated by Remak as long ago as 1852, "Comptes Rendus," tome xxxv., and even earlier. Since that time Remak's views have been confirmed by Rathke, Kölliker, Stricker, Waldeyer, Klein, and others. We, therefore, give in the text what may be called the German theory of Embryology.

embryo be viewed in transverse section (Fig. 175), this deepening is seen to be produced through the rising up of the External blastodermic membrane (Fig. 175, *a*) in two heaps, called Laminæ Dorsales (Fig. 175, *L*), which, growing towards each other, finally coalesce, thus converting the Primitive groove into a tube (Fig. 176, *K*). This tube is the rudimentary central nervous system. Directly underneath this tube, in the Middle membrane, however, is seen a cylindrical rod of cells, the Chorda Dorsalis (Fig. 176, *v*), in which are developed the bodies of the vertebræ (segments of spine). By looking at Figs. 169 to 172 (Dog or Man), we see how, by a continually constructing process, the upper portion of the Internal blastodermic membrane (Fig. 169, *I*), with that part of the Middle membrane lying upon it, is gradually pinched off from the lower (Fig. 169, *a*), until, finally, only a narrow pedicle connects the two. The upper pinched-off portion is the primitive alimentary canal (Fig. 170, *I*), the lower the umbilical vesicle, or yolk-bag. The umbilical vesicle (Figs. 169 to 172, *a*), in the course of development, passes away, the time of its disappearance varying in different animals: thus, in the Trout it is retained till the sixtieth day. By referring to Figs. 169, 172, it will be seen that the alimentary canal and umbilical vesicle are composed of two layers. The inner layer, or the Internal blastodermic membrane, develops the epithelium of the mucous membrane; the outer layer, or the lower half of the Middle membrane, makes the wall of the alimentary canal. This is a very important distinction, since the lower lungs, etc., which first appear as buds sprouting from the alimentary canal, exhibit the same structure. In the Batrachia (Frog), and some Fishes, however, the whole of the Internal blastodermic membrane, with that part of the Middle membrane lying upon it, is used up in the formation of the alimentary canal, which is developed in a different manner from that of the dog or man; there is, therefore, no umbilical vesicle or yolk-bag. The gelatinous mass which surrounds the egg of the Frog furnishes the nutriment for the embryo. The development of the Reptile, Bird, and Mammal offers a striking contrast as compared with that of the Fish and Batrachian in the formation of the Amnion and Allantois. The External blastodermic membrane, at that point where the upper part of the Middle membrane unites with it, rises up into two folds (Fig. 169, *d*). These folds grow towards each other, arching over the embryo, and finally unite (Fig. 170). The inner fold then separates from the outer, and forms the Amnion (Fig. 171, *d*), while the outer fold recedes from the Amnion until it reaches the Vitelline membrane, with which it unites. These united membranes are known as the Chorion (Fig. 171, *Ch*). The Amnion becomes filled with the Amniotic fluid, in which the embryo is suspended. During the formation of the Amnion there buds out from the posterior portion of the embryo a sac (Figs. 169 to 172), which, in expanding, finally comes in contact with the Chorion. This sac is called the Allantois, and serves in Birds and Reptiles as a respiratory organ, the porosity of the egg-shell allowing the oxygen to pass in and the carbonic acid to pass out. In the Mammals, through the Allantois, the embryo is put in communication with the mother. We have now explained as briefly as possible the development of a vertebrate.

In the hatching process the Chorion, Allantois, and Amnion break, they being only temporary structures. It will be seen, therefore, that the animal is formed of but a portion of the three blastodermic membranes. Beginning alike in the form of a cell or egg, the Invertebrata and Vertebrata grow for some time in the same manner. As development advances, characteristic structures appear in the embryo, and the division, class, or order to which the future animal will belong becomes evident. Figs. 178 to 181, representing the embryo Turtle, Chicken, Dog, and Man, illustrate the resemblance of vertebrate animals at an early stage of their existence. Not only, however, does man at such a period resemble a Turtle, and is undistinguishable from a Dog, but the transitory stages of his internal organization are also more or less represented as permanent structures in the lower animals. This generalization, which is one of the most important in Biology, may be expressed in the statement, that the structures which are transitory in the higher animals are retained permanently in the lower. Thus, for example, the spine of the higher animals is composed of a number of bony segments or vertebræ. These are represented in the embryo, however, by a cylindrical rod of cells, the Chorda Dorsalis, and by a few quadrate masses lying on each side of the central nervous system. The Chorda Dorsalis, which is only the rudimentary condition of the bodies of the vertebræ, is retained permanently, however, in the Amphioxus and Myxinoid fishes. The Chorda Dorsalis, until recently, was supposed to characterize the Vertebrata, and as it is a very important structure, its apparent absence in the Invertebrata (animals without a backbone) was often urged as an insuperable objection to the view of the higher forms of life having come from the lower. The free-swimming embryos of the Ascidian worms, however, according to Kowalebsky and others, exhibit, in their organization, a Chorda Dorsalis (Fig. 38 *a*, *C*) and a Central nervous system, which develop in the same manner as that observed in the Amphioxus, the simplest of fishes. The importance of this discovery cannot be exaggerated, as the embryo Ascidian furnishes the transition from the Invertebrata to the Vertebrata. We have seen that the Central nervous system is formed through the conversion of the Primitive groove into a tube. The tube is originally pointed at both ends, and this rudimentary condition is retained permanently in the spinal marrow of the Amphioxus (Fig.

40),—the fish without skull or brain. In all other Vertebrata, however, the anterior part of the spinal marrow, in the course of development, expands into a vesicle, which subdivides into three; the anterior of these three vesicles divides into two, and the posterior into two, the middle remains undivided; thus five vesicles (Fig. 177, 1, 2, 3, 4, 5) are formed out of the swelling of the anterior portion of the spinal marrow. These vesicles are called, translating their German names literally, the Fore brain, Between brain, Middle brain, Hind brain, and Hindmost brain, the different parts of the brain being developed from them. The brain of adult man, although highly complex in its organization, is nevertheless represented, at an early period of life, by five vesicles, being undistinguishable from those of an embryo dog, rabbit, bird, or fish. In fishes like the Myxine and Lamprey the brain remains in this undeveloped condition, thus exhibiting permanently the stages of the brain that are transitory in the higher animals. Every one knows that in breathing the air passes through the windpipe to the lungs, and that the food goes to the stomach through a separate and distinct tube. If, however, a Garpike be examined, its lung-like air-bladder is seen to communicate with the alimentary canal by a tube, the air-duct. This arrangement represents perfectly the rudimentary condition of the lungs in the human being, or in the embryo of the higher animal, as in these the lungs are developed as buds from the alimentary canal, the pedicle by which they are attached to it becoming later the windpipe, which corresponds to the air-duct of the Gar. The organs of Respiration naturally suggest those of Circulation. The successive stages through which the heart and blood-vessels of mammals pass in the course of development are more or less well represented by the vascular apparatus of the fish, batrachian, reptile, and bird. The termination of the Digestive, Reproductive, and Urinary apparatus in a Cloaca, exhibited in the embryo of man, is a permanent arrangement in the Sloth, Monotremata, Birds, and Reptiles. Finally, the development of the Skull and Extremities illustrates the same principle of the lower forms of life, representing the undeveloped stages of the higher. Has the Biologist any theory to offer as an explanation of these facts? One may reasonably ask, Why do the flipper of the seal, the foot of the turtle, the wing of the bird, the hoof of the horse, the claw of the lion, the hand of man, etc., develop from a bud? Why are these structures, used for such different purposes, constructed on essentially the same plan? Is there any explanation of the fact that man and the lower animals are undistinguishable in the early stages of their existence, and that the transitory phases through which man passes in the course of development are more or less permanently represented in the lower animals,—that is, that man is not absolutely at any time a Reptile or Dog, etc., but at a certain period exhibits an organization which is undistinguishable from that which later becomes a Turtle or Dog, etc.? It seems to us that the theory of the higher animals having descended from the lower explains perfectly all these facts. We will try to illustrate this view by noticing the effects supposed to be produced on the posterity of a family by their dispersion. After the lapse of ages, subjected to different conditions of soil, food, and climate, the races descending from this family would differ so greatly as regards their appearance, language, and customs that an Ethnologist might doubt if indeed they had come from one stock. If, however, he compared young individuals of these races, and found they resembled one another, and at an extremely early period of life were even undistinguishable, and, further, that sometimes individuals appeared that differed greatly from the race from which they descended, resembling rather a remote, often more barbarous, one; and, finally, that the individuals of a barbarous race, when subjected to more favorable conditions, in becoming more civilized, begin to resemble those more advanced,—considering these facts together, the view might be suggested to the Ethnologist that the different races had come from one stock. An important fact to be remembered in reference to the origin of races is that peculiarities which appear in the parent reappear in the offspring at the same age in which the parent was affected. Thus, the parent at a certain age develops a disease: his child grows up apparently healthy; suddenly the same disease appears in the child, and at the same age at which the parent was affected. Though the causes of peculiarities appearing in the parent, and the inheriting of them by the offspring, are still unknown, or very obscure, nevertheless we know it to be a fact that peculiarities—good or bad—affecting a parent may, and often do, reappear in the offspring in the manner just illustrated. Suppose, now, in a remote past, two animals, the descendants of the same parent, grew for some time alike, but that gradually they began to differ, acquiring certain peculiarities. These, if transmitted to posterity, would appear at the same age in which they were acquired by the parents. This hypothetical case illustrates what we suppose to have been the development of the Bird and Mammal from a common ancestor, the Reptile. This reptilian ancestor had two descendants; one acquired the peculiarities of the Bird, the other those of the Mammal: the Bird and Mammal of the present day ought, therefore, to develop in a reptilian manner until they attain the age at which their progenitors acquired the characteristic of the Bird and Mammal; from that time their development ought to be different. Our brief *résumé* of development shows that the facts perfectly confirm such a theory. By the same reasoning we conclude that the Reptiles and Batrachia have diverged from a form like that of the Lepidosiren, or Mud-fish, the Bony fish and Lepidosiren from the Ganoids, the Fish and Ascidians from some Sac-worm, the Echinodermata and Articulata from the Articulated Worms; finally, that the animal and vegetal kingdoms are the diverging stems of an intermediate kingdom, arising through spontaneous generation, or whose origin is unknown. This theory of the gradual descent of the higher animals from the lower explains perfectly why the phases exhibited in the development of man should be more or less permanently represented by lower animals, or, as John Hunter expressed it, "If we were to take a series of animals from the most imperfect to the perfect, we should probably find an imperfect animal corresponding with some stage of the most perfect." This view of nature throws light on the presence of rudimentary organs, such as the wings of birds and insects who never fly, the eyes of fish who, living in dark caves, never see, and the teeth of young birds and of certain whales who, when adult, do not have a tooth in their head. In the lung-breathing Vertebrata a right and left lung are usually present; the organization of the snakes and snake-like lizards exhibits the peculiarity of only one lung being developed, the other being rudimentary. Of the egg-sacs, or ovaries, of most birds, only the left is developed, the right being without function. Assuming the theory of the transmutation of species to be true, these rudimentary organs have a meaning, as indicating the ancestry of the animals exhibiting them. Important to the Evolutionist are, therefore, such structures as the plica semilunaris of the human eye, the representative of the third eyelid of lower animals, the external muscles of the human ear, the coccygeal bones composing the short tail of man, the vermiform appendix, etc. The monstrosities of the animal and vegetal kingdom are explainable from this point of view, the monstrosity usually consisting in the excessive development or deficiency of one or more organs, the abnormal in one animal being normal in another. Occasionally we find animals so badly organized as to make it incredible that they should have appeared on the earth as such originally. In speaking of the Sloth, Cuvier observes, "One finds them so little related to ordinary animals, the general laws of living organizations apply so little to them, the different parts of their body seem to be so much in contradiction with the rules of co-existence that we find established in the whole animal kingdom, that one could really believe that they are the remains of another order of things." Cuvier then continues by saying that in most forms the disadvantages are compensated by advantages, "but in the Sloth each singularity of organization seems to result only in feebleness and imperfection, and the inconveniences belonging to the animal are not compensated by any advantage."*

The only explanation, at present, of the existence of such a wretched animal as the Sloth is that it is the degenerated representative of some extinct animal who lived at the same time as the Megatherium, which it resembles in the form of its head. The limbs and backbone of the Megatherium are, however, represented by the Great Ant-eater. The Sloths and Great Ant-eater are confined to South America, and it is there that the Megatherium remains have been found in great abundance.

The development of the flower through the gradual metamorphosis of the leaf is a beautiful illustration of the evolution of different forms from a common type. In the words of Prof. Gray, "The leaves of the stem, the leaves or petals of the flower, and even the stamens and pistils, are all forms of a common type, only differing in their special development; and it may be added that, in an early stage of development, they all appear nearly alike.

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* Cuvier, "Ossemens fossiles."

That which, under the ordinary laws of vegetation, would have developed as a leafy branch, here develops as a flower; its several organs appearing under forms some of them slightly and others extremely different in aspect and in office from the foliage. But they all have a common nature and a common origin, or, in other words, are homologous parts. When, therefore, the floral organs are called modified or metamorphosed leaves, it is not to be supposed that a petal has ever actually been a green leaf, and has subsequently assumed a more delicate texture and hue, or that stamens and pistils have previously existed in the state of foliage, but only that what is fundamentally one and the same organ develops, in the progressive evolution of the plant, under each or any of these various forms." The visceral arches of the Vertebrata are among the many illustrations of this idea offered by the animal kingdom. The visceral arches (Figs. 178 to 181, *c*) consist of thickenings or papillæ situated behind the primitive eye, and below the primitive ear. They are present in the early stages of all Vertebrata, and are much modified in the course of development. The branchial arches supporting the gills in Fishes represent best their primitive condition, while in remaining Vertebrata they are used partly in the formation of the lower jaws, partly in the formation of the organs of hearing.

The subject of Embryology is as intimately related to Geology as to that of Anatomy, for the changes through which plants and animals pass in the course of development are essentially the same changes through which life in general has passed from its first appearance to the present time, for not only are the transitory stages of the higher animals permanently represented by the lower, but they are also permanently represented by the fossils. In other words, the development of the most complex plant, and of the most highly-organized animal, is an epitomized history of vegetal and animal life in general. Let us illustrate by a few examples. We stated in the chapter on Zoology that the Horse, Tapir, and Rhinoceros formed a natural group, they being connected through intermediate forms, the series beginning with the Paleotherium (Fig. 151). In the chapter on Geology we called attention to the fact that the Paleotherium appeared before the Horse, etc. The embryo Horse, however, in his three toes and the structure of his teeth, represents the Paleotherium (Fig. 154), while the transitory stages through which the Horse passes from the Paleotheroid condition to its adult state are permanently retained in the Anchitherium and Hipparion. (Fig. 155). In Ruminating animals, like the Gazelle, Sheep, and Ox, the upper jaw is without incisor and canine teeth (Fig. 157); these exist, however, in a rudimentary condition in the embryos of these animals. The embryos also exhibit two distinct metacarpal and metatarsal (Fig. 158) bones, which, in the course of development, fuse into the so-called cannon-bone of the fore and hind leg (Fig. 159). Now, in the early part of the Tertiary period there lived animals like the Dichobune, Dichodon, and Anoplotherium (Fig. 152), whose adult organization represents very well the transitory stage of the hollow-horned Ruminants, the Anoplotherium having well-developed canine and incisor teeth, and retaining the condition of two distinct metacarpal and metatarsal bones (Fig. 158). The stages through which one of our hollow-horned Ruminants passes give thus a picture of the transitional stages through which the Ruminant order in general has passed. The molar teeth of these animals, as well as those of the Rhinoceros, Horse, etc., are very interesting from the Evolution point of view. The type of tooth characteristic of the Paleotherium runs, more or less modified, through the Rhinoceros, Tapir (Fig. 153), and Horse, while that of the Anoplotherium can be traced through the Hog, Hippopotamus, Sheep, Deer, etc.;

but in still earlier forms, like Coryphodon, Pliolophus, and Lophiodon, we find teeth combining the characteristics of the Paleotherium and Anoplotherium. So that just as the Rhinoceros and Horse are specialized forms of the Paleotherium, the Pig and Sheep of the Anoplotherium, so the Paleotherium and Anoplotherium are specialized forms of the Coryphodon. Accepting the theory of the specialized higher forms of life having descended from a more general lower form, we have an explanation of the harmony offered by the anatomy, embryology, and petrified remains of these animals. But the theory of Evolution explains not only the most important facts in reference to this particular order of animals, but we hope to have shown that it is equally applicable to the whole vegetal and animal kingdom. The question now naturally arises, Are there any natural causes sufficient to effect the development of the animal and vegetal kingdoms out of a monad?

To that subject we now turn.

NATURAL SELECTION.

In his introduction, Mr. Darwin tells us that "when on board H. M. S. Beagle as naturalist, I was much struck with certain facts in the distribution of the organic beings inhabiting South America, and in the geological relations of the present to the past inhabitants of that continent. These facts seemed to throw some light on the origin of species." In the chapter on Geographical Distribution, he says that "neither the similarity nor the dissimilarity of the inhabitants of various regions can be accounted for by their climatal and other physical conditions." Thus, the plants and animals of South America, between latitudes 25° and 55°, are very different from those of Australia and South Africa; and yet the physical conditions of these three countries, within these limits, are very similar, while, notwithstanding the great differences of the physical conditions north of 25° and south of 35°, the plants and animals of these parts of South America are very similar. The existence of lofty mountain-chains, great deserts, etc. acts as a barrier to the free dispersion of plants and animals, and, therefore, is of great importance in reference to Geographical Distribution; thus, the life of opposite mountain-chains is often quite different. This is equally true of the ocean life on opposite sides of a continent: thus, the marine animals of the north side of the Isthmus of Panama are very different from those of the south side, whereas similar fishes are found in as remote waters as the Pacific and Indian oceans,—there being no obstacle to their free dispersion. The relation of the living animals to those found fossil in the same countries is very significant in this respect, the Apteryx of New Zealand representing the gigantic Dinornis, the Armadillo and Sloth the extinct Glyptodon and Megatherium. Further, in reference to Geographical Distribution, the fact of the plants and animals of islands being like those of the nearest island or mainland is as important to the Geologist as to the Botanist and Zoologist. Thus, Mr. Wallace explains the similarity of the plants and animals of Sumatra, Java, Borneo, etc. to those of southern Asia by supposing that these islands once formed part of that continent, being connected with it by Malacca; while the Celebes, Moluccas, New Guinea, resembling in their flora and fauna Australia, are regarded as forming with it another continent, the islands of Bali and Lombok indicating the limits of these ancient continents. Mr. Wallace says, in crossing over the straits separating these islands, "we may pass in two hours from one great division of the earth to another, differing as essentially in their animal life as Europe does from America." The study of South America and the Malay Archipelago suggested to Messrs. Darwin and Wallace their explanation of the Geographical Distribution of plants and animals through what Mr. Darwin calls Natural Selection, which may be expressed as follows:

Plants and animals struggle for existence. The immediate descendants are never absolutely like their parents; while remote posterity often differs considerably from them.

Those plants and animals whose modified organization gives them an advantage over those not so favored survive, or are naturally selected, and transmit their modifications to posterity.

Let us examine these statements, and try to explain how the conclusion follows.

STRUGGLE FOR EXISTENCE.

Every one knows that the life of an individual plant or animal depends on a proper supply of food, is affected by changes of climate, and is constantly endangered by disease and enemies; few are, however, aware of the extent to which individual life is dependent on the existence of some other kind of life, and of the extremely complex nature of the struggle for existence. Thus, according to Prof. Haeckel, "There are small oceanic islands whose inhabitants live essentially on a species of Palm. The fructification of these Palms is effected principally through Insects, who carry the pollen from the male to the female Palm. The existence of these useful Insects is endangered through Insect-feeding birds, who in turn are pursued by Rapacious birds. But the Rapacious birds often succumb under the attacks of a small parasitic Mite, which develops by millions in their feathery coats. These small, dangerous Parasites can be killed through parasitic Fungi. Fungi, Rapacious birds, and Insects in this case would favor, Bird-mites and Insect-feeding birds, on the contrary, would endanger, the growth of the Palms, and consequently of men." Thus the existence of entire populations may be indirectly dependent on the presence of a highly insignificant plant or animal form. If one considers the millions of eggs laid by fishes, and that a pair of elephants, the slowest of breeders, would reproduce in five hundred years fifteen millions, the importance of the struggle for existence in checking over-population will be appreciated. According to Mr. Darwin, the red clover never produces seed if the humble-bees be prevented from visiting it. For the bee, in sucking the honey out of the flower, brings the pollen in contact with the pistil, and by this means the clover is fertilized. Now, it is well known that the bees are destroyed by the field-mice, and that the number of mice depends on the number of cats; hence, if the cats were destroyed the field-mice would increase and destroy the bees, in which case the clover would produce no seed, and the cattle would soon be deprived of a most important article of food. The same author calls attention to the fact of cattle determining the existence of trees: "Here there are extensive heaths, with a few clumps of old Scotch firs, on the distant hill-tops: within the last ten years large spaces have been inclosed, and self-sown firs are now springing up in multitudes, so close together that all cannot live. When I ascertained that these young trees had not been sown or planted, I was so much surprised at their numbers that I went to several points of view whence I could examine hundreds of acres of the uninclosed heath, and, literally, I could not see a single Scotch fir, except the old planted clumps. But on looking closely between the stems of the heath, I found a multitude of seedlings and little trees, which had been perpetually browsed down by the cattle. In one square yard, at a point some hundred yards distant from one of the old clumps, I counted thirty-two little trees; and one of them, with twenty-six rings of growth, had, during many years, tried to raise its head above the stems of the heath, and had failed. No wonder that, as soon as the land was inclosed, it became thickly clothed with vigorously growing young firs. Yet the heath was so extremely barren, and so extensive, that no one would ever have imagined that cattle would have so closely and effectually searched it for food. Here we see that cattle absolutely determine the existence of Scotch fir. But in several parts of the world insects determine the existence of cattle. Perhaps Paraguay offers the most curious instance of this; for here neither cattle nor horses nor dogs have ever run wild, though they swarm southward and northward in a feral state; and Azara and Rengger have shown that this is caused by the greater number in Paraguay of a certain fly which lays its eggs in the navels of these animals when first born," the new-born dying in consequence of these inroads. As illustrating the struggle for existence, Prof. Haeckel calls attention to the effect of placing goats or pigs on one of the isolated oceanic islands uninhabited by man. These animals ran wild, and meeting no enemies, and finding at first plenty of food, increased in such surprising numbers that they killed the other animals and plants. Thus, in the course of time, the whole island was nearly depopulated, the goats or pigs even dying out for want of food. In some cases dogs were let loose, after the island had been overrun by goats or pigs. The dogs, finding an abundance of food at first, increased so rapidly that their very numbers made food so scarce that they finally died out.

Many other interesting examples of the struggle for existence might be mentioned; those just noticed suffice, however, to call attention to the important relation existing, in this respect, between plants and animals. We turn now to a consideration of the facts of Inheritance and Variation.

INHERITANCE.

Not only does the offspring resemble the parent in the manner of its growth, in the form of its body and general appearance, but, as is well known, mental peculiarities are also inherited, the development of particular talents for music, painting, etc. being conspicuous in certain families: thus, the Bach family have numbered twenty distinguished musicians, the family of Weber upwards of forty. Less pleasant peculiarities, as those of diseases of all kinds, are well known to reappear in posterity both at the same time and in the same place as they first appeared in the parent. In a word, generally speaking, "Like begets like." This expression, however, is not absolutely correct, since the members of every family differ more or less in the color of their eyes and hair, in their complexion, dispositions, etc. The same species of trees differ as regards the size of their stem, number of their branches, leaves, flavor of their fruit, etc. Let us examine now, a little in detail, some of these variations, and attempt to indicate their probable causes.

VARIATIONS.

The quantity and quality of the food are known to modify animals and plants. Thus, what a marked difference is produced in the habit of our domestic animals, who are fed daily, and of wild ones, whose means of subsistence are so precarious! The quality of the food modifies, as well as the quantity, the tissues: thus, richly azotized food develops little fat, poorly azotized food, on the contrary, a great deal. The farmer requiring fine wool supplies his sheep with different food from that which he gives wishing to obtain good meat. Notice the effects of a rice diet as seen on the Chinese, and of a beef one on the English. Climate is an important element in the production of variations: thus, plants growing in dry, warm, and sunny places offer a very different aspect from those of moist, cool, and shady spots. Plants that at the sea-side exhibit thick, fleshy leaves, in hot, dry places develop haired ones. The crowding of trees has the effect of making the stem tall, while it diminishes the foliage; whereas the foliage of the isolated tree expands, the stem being comparatively short. We see, therefore, that the social state, so to speak, is of importance in modifying forms. The use and disuse of organs produce most marked effects: thus, the wings of the domestic duck are lighter than those of the wild one, whereas the legs of the domestic duck are heavier; the difference being caused undoubtedly by the different habits of these animals. The rudimentary condition of the muscles moving the external ear, in domestic animals, is no doubt due to their disuse; domestic animals not being, like wild ones, continually on the watch for prey or enemies. Gymnasts illustrate well the effect of using the muscles, sedentary persons of their disuse. The development of the mental faculties by their use is well seen in the domesticated Dog and Horse as compared with these animals when in a wild condition; while their degeneration through want of use has been noticed in the domesticated Rabbit, whose senses are not so keen as those of the wild one. Parasites are interesting in this respect: thus, the young of many parasites lead a free, active life, exhibiting often a complex organization. In the course of time, however, in adopting a parasitic mode of life they lose many organs, or retain them only in a rudimentary condition. The greater development of the bones, muscles, and nerves of the right hand as compared with the left, is due, no doubt, originally to greater use. This variation, like many others, has been inherited by posterity, since the new-born child offers the same difference in its hands. The thickened skin on the soles of the feet and the palms of the hand (seen also in the new-born child) has no doubt been acquired in the same way. The eye which is most used in microscopy becomes near-sighted, the other eye far-sighted. It must be borne in mind, also, that variations beget variations; the different organs of a plant or animal being so correlated that it is impossible to modify one organ without sooner or later some other organ becoming affected: thus, the increased flow of blood to a part, through continual and violent muscular action, may finally produce hypertrophy of the heart. There are many variations, however, arising through the correlation of organs, which cannot be so readily explained: thus, certain Pigs and Dogs, who lose their hair when taken to warmer climates, have their teeth affected.

The Edentata are so called from the peculiar character of their teeth; but the skin-covering of many of them, like the Armadillo and Pangolin, is equally remarkable. Short and compressed heads accompany short limbs, as seen in Pigs and Cattle. The horned animals are without incisor and canine teeth, as seen in the Ruminants, etc.; while those that have these teeth (like Pigs and the Musk-deer) never exhibit horns. With the long legs of Wading-birds (Heron and Stork) are associated long beaks. Dark-skinned, dark-haired, and brown-eyed Europeans are less susceptible to tropical diseases, and therefore more easily acclimatized, than those with light skin, blond hair, and blue eyes. These examples illustrate the important principle of one variation entailing another through the correlation of organs. The different modifications that we have mentioned are variations appearing in the parent, and often transmitted to the offspring. But there are also variations which first appear in the posterity, such as monstrosities, the difference of the sexes, etc. Of these variations it is often difficult to say whether they are produced by causes acting directly on the parents, or directly on posterity, or indirectly through the parents on posterity. While the causes of many variations as well as their transmission to posterity are obscure or unknown, it seems very probable that changes in Nutrition are the causes of all variations, the term Nutrition including the effects of Food, Climate, Social Relations, Use and Disuse, Correlation of Organs, etc.; while the facts of Inheritance are to be explained by the laws of Generation, of which as yet few are known. No doubt at some future day Nutrition and Generation will be shown to be simply physical and chemical phenomena. However that may be, the important fact is that "all organic individuals become in the course of their life, through adaptation to different conditions of existence, unlike one another, although the individuals of one and the same species remain mostly very similar."

SURVIVAL OF THE FITTEST.

Every one is aware that favorite breeds of cattle, many beautiful flowers, particular kinds of horses, such as the dray-horse, race-horse, etc., are not found in a wild state, but that these forms have been gradually produced. Let us examine the means by which this end has been accomplished. Suppose, for example, a gardener wishes so to modify some particular white flower that in time it will exhibit a striking scarlet color. He looks carefully among the particular flowers until he finds one which offers a trace of red; he plants the seeds of this flower, and from their posterity he selects the reddest flowers. Continuing to select the reddest flowers, and planting their seeds alone, finally the gardener succeeds in obtaining one of a scarlet color. The success of the gardener's operation depends upon the fact of there appearing, among the flowers which are usually white, one exhibiting a faint red color, and upon the fact of posterity inheriting from their parents a variation which they transmit in turn to their offspring, this variation becoming more marked as it is transmitted from generation to generation. An equally good illustration of this principle is the often-quoted instance of Seth Wright, the Massachusetts farmer, who, noticing that one of his rams, with a long body and short bandy legs, could not jump over the fences, concluded that it would be a good thing to breed with this ram alone, and to his great satisfaction soon obtained a race of sheep characterized by the peculiarity of a long body and short bandy legs. Indeed, although the subject of inheritance is still theoretically obscure, practically it is so well understood that Sir John Sebright "can produce in three years a given feather, but that he requires six years in order to obtain a particular kind of head and beak." Now we know that variations appear among wild animals, and that these variations are transmitted to their posterity. Is there then also a selection in nature which brings about the same results as that produced by man's selection? Suppose, for example, a number of plants are growing in a dry place, it is evident that those plants whose leaves are most thickly haired will be favored in the struggle for water, since the hairs are useful in taking up moisture. These plants will therefore survive and reproduce their kind, while those whose leaves are deficient in hairs will die out. But in the next generation some of the plants will be characterized by still thicker hairs; these will therefore be preserved and procreate; but in the course of generations plants are produced through this Natural Selection which differ very considerably from the parent stock, not only in the hairing of the leaves, but in other peculiarities, as one variation sooner or later entails another. Thus the moisture taken up by the hairs furnishes a large amount of nutriment, but if the nutriment is increased the flowering organs diminish; but this effect in the struggle for existence will bring about other variations, and so on indefinitely. "The wingless condition of so many Madeira beetles is mainly due to the action of natural selection, but combined probably with disuse. For during many successive generations, each individual beetle which flew least, either from its wings having been ever so little less perfectly developed, or from indolent habit, will have had the best chance of surviving from not being blown out to sea; and, on the other hand, those beetles which most readily took to flight would oftenest have been blown to sea, and thus have been destroyed." Through the Survival of the Fittest, by Natural Selection, we see why animals resemble in color, etc. their surroundings or the places they live in. Thus, the Plant-lice and many insects are green, like the leaves they live upon. The Jumping Mouse, Fox, Lion, and Gazelle are yellow or yellowish-brown, like the sands of the desert they frequent. The Polar Bear, living on ice and snow, is white or gray; but as the summer advances and the snow passes away, leaving the dark ground exposed to view, the Bear changes his skin to a brown or black, assuming again, as winter returns, its whitish hue. Mr. Darwin explains these striking facts by showing that the harmonizing of the color of an animal with its surroundings is useful to it. For those animals being unobserved are favored in the struggle for existence, seizing more easily their prey, or escaping from their enemies more readily, than those not so favored. Mr. Wallace, speaking of the butterfly Kallima parapleta, says, "At length I was fortunate enough to see the exact spot where the butterfly settled, and, though I lost sight of it for some time, I at length discovered that it was close before my eyes, but that in its position it so closely resembled a dead leaf attached to a twig as almost certainly to deceive the eye even when gazing full upon it." In reference to this subject, Prof. Haeckel notices the Helmichthys, fishes whose bodies are so transparent that one can read a book through them. The Carinaria among the Mollusca, the Salpa among the Worms, many of the Jelly-fishes, are either bluish or colorless as the water they live in. The transparent glass-like color of these animals who live on the surface of the open sea is evidently of service to them in catching the objects of their prey or avoiding their enemies. Suppose now the remote ancestor of one of these animals to have been slightly transparent, a little more so than the individuals of the same species, it would have been favored in the struggle for existence, and would have survived. Transmitting this useful peculiarity, its posterity would be still more transparent. Finally, in the course of generations, almost perfectly transparent animals would be produced. Prof. Cope observes, "The gray sand hue so well adapted for concealment is universal, with few variations, in the reptiles of the Tartar and Arabian deserts, the Great Sahara, and the sands of Arizona and California. There is also a tendency to produce spiny forms in such places; witness the Stellios and Uromastix and Cerastes of the Sahara, the Phrysonomas and Horned Rattlesnake of Southwestern America. The vegetation of every order, we are also informed, is in these situations extremely liable to produce spines and thorns."

Every one is aware of the great difference in size and color exhibited by the male and female of birds, butterflies, etc., of male animals being armed with weapons, like the horns of deer, the cock's comb, etc. Mr. Darwin supposes these organs to have arisen through what he calls Sexual Selection. Thus, at breeding-time the number of male deer exceeds that of the female; hence there is invariably a fight, and the deer with the biggest horns gets the better of his rivals: naturally their posterity will be characterized by large horns. This process, continued through generations, finally results in the production of the antlers of the male deer. But, as Mr. Herbert Spencer observes, large horns require large muscles to move the head, large muscles must be supplied with sufficient nutriment, which is brought to them by large arteries, which necessitates a powerful heart, and so on indefinitely. The voice of the singing birds is supposed to have arisen in the same way, for of the male birds those who sing best are chosen by the females for their mates. The voice is therefore continually improved from generation to generation. The male Crickets, Grasshoppers, Katydids are equally remarkable for the noise they can make. The incessant "Katydid she didn't" is produced by one wing being played on by the other wing, like a fiddle and bow. "All observers agree that the sounds serve either to call or excite the mute females;" and Mr. Darwin quotes Mr. Bates as stating that the male of the European field-cricket "has been observed to place itself in the evening at the entrance of its burrow, and stridulate until a female approaches, when the louder notes are succeeded by a more subdued tone, whilst the successful musician caresses with his antennæ the mate he has won." Ornaments of the male animal, like the cock's comb, the peacock's tail, the gorgeous plumage of the paradise bird, the brilliant color of the male butterfly, are made use of, like the weapons and musical tones just mentioned, in obtaining the female. The old Spartan principle of killing the deformed and sickly, which resulted in the production of a magnificent race of men, is the action of Sexual Selection applied to man. Necessarily the offspring will exhibit marked improvement in beauty of form, development of talent, and powers of defense, if the fathers are always selected from those who approach nearest the standard of excellence.

Having illustrated now, we hope sufficiently well, the selection brought about by man and nature, let us see how they differ and in what they agree. Man selects knowingly, with an object; making use of variations, he modifies for his own advantage. Nature eliminates blindly, without an object, the organisms surviving being better fitted for existence through some advantage. Thus the Massachusetts farmer knowingly made use of the variation of a long body and short bandy legs, exhibited by one of his rams, to produce a particular race of sheep. But suppose the conditions of existence had been such that the short-legged sheep had some advantage over the long-legged ones in the struggle for existence, the favored ones would have survived, and nature blindly would have done in the long run what the farmer did in a few generations. A similar case would be that of a farmer who, having black and white pigs, wanted black pigs only. To attain this object he would knowingly separate the pigs, and breed from the black pigs alone. But if the farmer lived in Florida, and would turn his pigs in the woods, nature would blindly bring about the same result, since the white pigs would soon die, it being well known that pigs eat "the paint roots (Lachnanthes), which color their bones pink, and which cause the hoofs of all but the black varieties to drop off:" hence the squatters say "we select the black members of a litter for raising, as they alone have a good chance of living." Suppose man to be heartless enough to abolish all hospitals, almshouses, etc., soon nature would eliminate, as Sparta got rid of, the sickly and deformed, the result being the survival of the fittest. We have seen that there is a most complex struggle for existence, that while like begets like, plants and animals vary in their organization; it follows, necessarily, that those organisms whose variations give them an advantage in the struggle for existence will survive, or be naturally selected, while those not so favored will die out. We see, therefore, that Natural Selection neither implies the existence of a Natural Selector nor is the Survival of the Fittest effected by chance. The facts of Inheritance are to be explained by the laws of Generation, those of Variation by Nutrition. The Struggle for Existence is caused by the number of individuals that are born being out of all proportion to the size of the earth they live in. The ever-changing conditions of Nature have the effect of eliminating the conservative kinds of life, while the plastic organisms survive and transmit their peculiarities to posterity. These variations become more marked from generation to generation, until finally, in the course of ages, there result very different forms of plant and animal life.

A good illustration of this whole subject is the history of the Siredon and Amblystoma. The Siredon lichenoides (Fig. 65) is a perennial gill-breathing Batrachian reproducing Siredons; the Amblystoma mavortium (Fig. 66) breathes by lungs and reproduces Amblystomas. These forms were naturally supposed to be distinct kinds of Batrachians ; but the experiments of Prof. Marsh and Prof. Dumeril have demonstrated that changing the conditions of existence has the effect of metamorphosing the Siredon into an Amblystoma. The importance of these experiments may be appreciated by supposing that Tadpoles reproduced Tadpoles in Nebraska or Mexico, and Frogs reproduced Frogs in New Haven or Paris, and that anatomists regarded the Tadpole as an entirely distinct Batrachian from the Frog; but removing the Tadpoles to New Haven or Paris, and changing the conditions of existence, the Tadpole turned into a Frog: our hypothetical case is exactly that of the Siredon and Amblystoma. As Professors Marsh and Dumeril developed a lung-breather, the Amblystoma, from a gill-breather, the Siredon, so we believe nature to have developed the lung-breathing Frogs from gill-breathing tadpole-like animals. Thus, in remote time, the conditions of existence changing, some of these tadpole-like animals changed into Frogs, while others remained unmodified and reproduced tadpole-like animals. But as the development of the individual Frog is the epitomized history of the race to which it belongs, the developing Tadpole, or the transitional stages of the Frog, are permanently represented by animals like the Salamander and Proteus.

An important consequence of the Struggle for Existence is the Division of Labor so characteristic of man, the higher animals, and plants. Savages supporting themselves by hunting and fishing, while often acting in concert, are, however, not dependent upon one another, so that the sudden death of even many individuals does not cause any inconvenience to the rest of the tribe. But in the civilized state, where the crowding together of people diminishes the means of subsistence and increases the number of rivals, the Struggle for Existence soon differentiates the population into growers of corn, hewers of wood, and carriers of water, as every one cannot work at the same trade, and the dependence of one upon another becomes very great. This is immediately seen if we consider the confusion that would arise in a city if the butchers and bakers were suddenly to die. But the community in general is not only differentiated by the Struggle for Existence into divers interests, but, sooner or later, the individuals are affected in the same way. For the individual whose organization is most specialized and whose functions are many is better fitted to maintain himself against the changing conditions of life than one whose organization is more simple. But we have seen that one variation entails another, and that the peculiarities of the parents are transmitted to their offspring: hence in the course of generations the organization becomes extremely complex. Thus the Division of Labor is carried out to such an extent in the organization of the human body that it requires volumes to describe the anatomy of man. The Division of Labor, or a complex organization, does not necessarily follow from the Struggle for Existence; for there are animals who, when young, lead a free active life, and have quite a complex organization, but, growing older, they adopt a parasitic mode of life, and then lose many of their organs through disuse. Prof. Haeckel aptly observes, "The traveler lightens his journey who throws away his pack." So of many parasites: the one who first gets rid of any useless muscles or nerves will have the best chance of surviving; complex conditions of existence bring about, sooner or later, complex organization, while simple structures are the result of simple conditions of existence. Supposing this view of Nature to be correct, the plants and animals that first appeared on the earth ought to have been simply and lowly organized, the later ones highly complex. In our chapter on Geology we have shown that such is the case,—that there has been a progress from the lower to the higher forms of life, accompanied at the same time by retrograding metamorphoses, as seen in parasites, etc.

While Natural Selection is generally admitted to be a sufficient cause for the production of unimportant variations, it is often objected that important structures, such as the skeleton, could never be modified by such a process. Mr. Darwin, however, has shown that the skeleton is as susceptible to modification as any other part of the organization. Thus, the different kinds of pigeons, supposed unanimously by "fanciers" to have descended from different ancestors, but which are now known to be the posterity of the Rock Pigeon, offer great variations in their skeleton, as in the number of their vertebræ and ribs, in the character of the breast-bone, merry-thought, lower jaw, and bones of the face. All zoologists admit that the various kinds of rabbits have descended from a common stock; and yet the greatest difference is seen in the size, shape, and form of the skull, in the character of the backbone, etc. But not only have the changing of conditions and the domestication of animals modified the skeleton, which is regarded by anatomists as one of the most constant of characters, but the viscera and all other parts of the organization have been affected. We do not regard, therefore, the objection of Natural Selection not being a sufficient cause of change as of any weight. The fact of Hybrids often not breeding is regarded by many as an important objection. The case of the mule not breeding is usually referred to. This objection does not seem to us to amount to much, as it is well known that the Porto Santo rabbit, which is the offspring of the European rabbits placed on that island in 1419, will not breed now with the posterity of its European ancestor. Further, it does not follow, because mules are unreproductive, that all other hybrids have been, and will be. Thus, the Lepus Darwinii, originally resulting from the crossing of the Rabbit and Hare, now reproduces its kind, the animal being half Hare half Rabbit. According to Prof. Haeckel, the pairing of the male Goat and female Sheep is very common in Chili, their progeny being fertile; while the Ram and female Goat rarely pair, and then without offspring. It is well known that some animals when confined in menageries, etc. will not breed. We see, therefore, upon what slight differences reproduction depends.

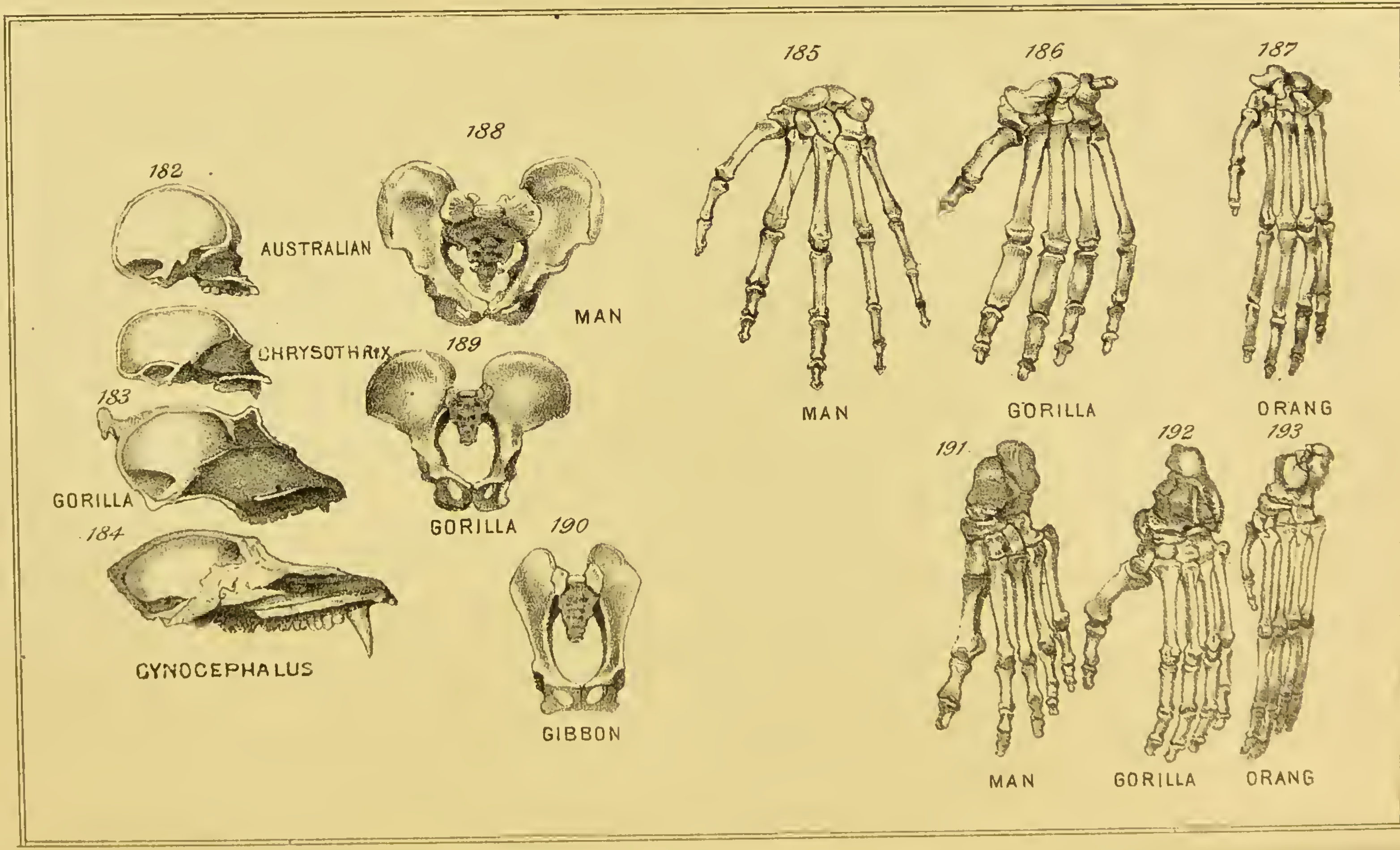
The absence of links between the different forms of plants and animals is often urged as an objection to the theory of the Evolution of Life. The not finding of links is due very often to not looking for them in the right place. Thus, a pigeon-fancier, not finding a link between the Carrier and Pouter, might have argued some years ago that they had descended from the primitive Carrier and Pouter, of whose origin he knew nothing. But it is well known now that these pigeons are the posterity of a common ancestor, the Rock Pigeon. Hence the transitional forms are between the Rock Pigeon and the Carrier, between the Rock and the Pouter. We have tried to show that the Struggle for Existence produces a divergence of character, so that in the course of time the posterity differs greatly from the parent stock. Now, if the intermediate animals die out, forms are left which have little in common with existing animals. In this manner may be explained the existence of such isolated unique forms as the Elephant, Sloth, Giraffe, so readily distinguished by their striking peculiarities. The Capuchins, among the South American monkeys, on the contrary, exhibit such a number of varieties, species, and genera that it is almost impossible to classify them, the transitional forms being so numerous. Many have argued that too much time is required in the development of the animal and vegetal kingdoms through the Survival of the Fittest. Physical and Geological science cannot at present assign any definite age to the Earth; and, from the rate at which deposits are formed at the present day, millions and millions of years would have passed away in the formation of the Aqueous Rocks. So that, while admitting the looseness of the data, we feel that we are less likely to err in assuming an amount of time practically unlimited for the development of life than if we attempt to fix a definite limit. It is often asked, How could the instincts of animals and man arise through a process like Natural Selection? The manner in which the young uneducated Pointer acquired the instinct of pointing explains the origin of all instincts. The original Pointer was taught to point, and in the course of generations, this peculiarity being inherited, the pointing became instinctive. All of our ideas have arisen in the same way, mind being the impressions of the brain derived from the external world through the medium of the senses. If there really be what metaphysicians call "*a priori* ideas," originally they have been derived *a posteriori;* that is, these ideas were originally derived by the parent organism, and later inherited by posterity. Finally, to many persons, complex structures like the eye and ear are insuperable objections to the theory of Natural Selection, it seeming incredible to those who are unacquainted with Comparative Anatomy that such organs could have arisen through the Survival of the Fittest caused by the action of a blind, objectless, working Nature. The eye is usually studied in a most developed state, as in man, for example; but the visual organ of some of the lower animals is only a pigment spot, more or less sensitive to the rays of light, but incapable of forming the image of an external object. As we ascend in the scale of life, we notice there is added to this pigment spot a sensitive nerve, and as we gradually progress there appears the lens, a light-refracting organ, which, collecting the rays of light in a focus, delineates the image of an external object. Still more highly organized animals exhibit additional media of service in transmitting the light, a complex retina for receiving the image, and special arrangements for the accommodation of the eye to distances. By glancing, therefore, at different animals, we see the eye in different stages of perfection. But the gradual development of the eye of man offers a series of transitional stages, which are permanently represented by the eyes of the lower animals. Now, if the eye has gradually been perfected through the Survival of the Fittest, we understand why the transitional stages in the development of the eye of man have permanent representatives in the eyes of the lower animals; but if the eye has been created for the purpose of seeing, we neither understand why such an extraordinary method is adopted in its formation nor why it is not a perfect optical instrument. The same reasoning will apply to the human ear as well as to the eye, they both beginning as depressions in the skin, which later, closing, form the primitive eye and ear vesicles.

RESUME.

We tried to show in the chapters on Zoology, Botany, Geology, and Embryology, that the structure of plants and animals, their petrified remains, and their manner of development, are explained by supposing that life has evolved, that there has been a gradual development of the higher forms of life from the lower, accompanied here and there by a retrograding metamorphosis. In the early part of this chapter we called attention to the facts of Geographical Distribution not being consistent with a theory that supposed plants and animals had been created for special localities, but that they could be explained by supposing that life migrated from place to place, being more or less modified from time to time by the new conditions of existence, natural barriers being often the cause of the great difference exhibited by plants and animals living under similar conditions. The conclusion of an Evolution of Life, arrived at by a comparison of many biological generalizations, we then tried to show was the necessary consequence following from the Struggle for Existence combined with the effects of Inheritance and Variation: the resultant of these three forces being what Mr. Darwin calls Natural Selection. It must be remembered that Natural Selection does not explain the facts of Inheritance and Variation, but follows from them and the Struggle for Existence. The facts of Inheritance and Variation seem to depend upon Generation and Nutrition, which are chemical and physical phenomena still involved in much obscurity. Before leaving the subject, it seems proper to mention, as it does not appear to be generally understood, that the theory of the Evolution of Life may be accepted as true, and yet Natural Selection not be considered as a sufficient explanation. Suppose, now that the attention of naturalists has been drawn to the theory of Evolution, that most careful observations are made in reference to this subject, and that all biologists become convinced in time that plants and animals gradually change, the flora and fauna of a remote future differing very considerably from those of the present day,—the theory of the Evolution of Life might be demonstrated, and yet it might be shown that Natural Selection did not entirely produce it, or indeed the cause might still remain unknown. Let us repeat, then, that whatever may be thought of the causes advanced, as sufficient to bring about a development of life, the theory of Evolution remains the only explanation of the most important generalization of the comparative anatomy of plants and animals, their Paleontology, Embryology, and Geographical Distribution.

ANTHROPOLOGY.

IF it be admitted that the different kinds of existing animals are the modified descendants of pre-existing animals, then it follows necessarily that if man is an animal he must have descended from some pre-existing animal. Supposing the theory of the Evolution of Life to be true, the important question to be decided is not whether there are any transitional forms or links between man and this or that kind of animal,—though of course the discovery of such links would be weighty additional evidence,—but whether man is an animal, whether the difference between man and the members of the animal kingdom is one of kind or only of degree. Since man has a backbone, he is a vertebrate, and, as he is suckled when young, he is a mammal. Thus far naturalists are agreed as to man's place in Nature. The question, however, of determining the particular order of mammals to which man belongs, has given rise to much discussion. Linnæus united in one group the half Monkeys (Lemurs), the Bats, the true Monkeys, and Man, calling them Primates. Blumenbach, however, joined the true Monkeys with the half Monkeys, calling them Quadrumana, or the four-handed order, while he regarded Man as the representative of a distinct order, the Bimana, or two-handed; the term four-handed was adopted by Blumenbach from the older writers. This classification was accepted by Cuvier and most contemporary anatomists, though always regarded as incorrect by Geoffroy St. Hilaire, who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AUSTRALIAN
CHRYSOTHRIX
183
GORILLA
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CYNOCEPHALUS
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MAN
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GORILLA
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GIBBON
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MAN
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GORILLA
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ORANG
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MAN
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GORILLA
193
ORANG

considered the higher apes to be more nearly allied to man than to the lower monkeys. The untenability of Blumenbach's classification becomes at once evident, on reflecting that no one would argue that the Chinese boatmen and Bengalese artisans are four-handed because they can row and weave with their feet. We would only say these people use their feet as hands. No one regards the hands of the Colopus and Ateles as feet because in these monkeys the thumb is so rudimentary (or absent) that its opposability to the hand is impossible. We see, therefore, that if the mobility of the thumb or big toe be accepted as a test of an extremity being a hand or a foot, we should have to admit the existence of four-handed people, and of monkeys having feet where their hands usually are, and *vice versa*. Prof. Huxley has, however, shown that there is as much difference anatomically between the foot and hand of the monkeys as between the foot and hand of man. The essential difference of a hand, as compared with a foot, consists in the characteristic arrangement of the bones in the two members, and the presence or absence of certain muscles. Accepting this test as the correct one, monkeys as well as men are two-handed and two-footed. Prof. Huxley has also demonstrated "that the structural differences which separate Man from the Gorilla and the Chimpanzee are not so great as those which separate the Gorilla from the lower Apes." This is at once seen on comparing Figs. 182 to 193, representing the skull, teeth, hand, pelvis, and foot of a Man, of a Gorilla, and of some other monkey. While it is admitted that there are gaps between Man and the Gorilla, between the Gorilla and the Orang, between the Orang and lower monkeys, the differences, however, are not sufficiently great to admit of making distinct orders: hence Man and the Gorilla, etc. must be considered as members of the order of Monkeys.

We concluded our chapter on Zoology by noticing the half monkeys, represented by the Galeopithecus, Cheiromys, and Lemurs, stating of this group that the Loris seemed to furnish the transition to the true monkeys. Let us now consider these a little. The true monkeys are usually divided into the Catarhines, or the monkeys of the Old World, including the Gorilla, Chimpanzee, Orang, Gibbon, Magots, Macaques, Baboons, etc., and the Platyrhines, or those of the New World (confined to South America), among which are found the Howlers, Spiders, Capuchins, and Marmosets. The terms Catarhine and Platyrhine refer to the nostrils, which in the Catarhine look downward, but in the Platyrhine are flattened. In the peculiarity of the downward nostrils Man agrees with the Catarhine monkeys. Further, all Catarhines have thirty-two teeth, which is also the dental formula of Man; whereas the Platyrhines have thirty-six, the Marmosets excepted, in which the third true molar is rudimentary. These little monkeys offer also the peculiarity of having claws on their fingers and toes. We see, therefore, of the two groups of monkeys that Man, from the position of his nostrils and the number of his teeth, belongs to the Catarhine.

Having briefly called attention to some of the peculiarities of the human skeleton, etc., as compared with that of the Gorilla and other monkeys, let us now compare the brain and mental powers of Man with those of the lower animals. While no one understands how the physical impression of an external object conveyed to the brain through the senses gives rise to an idea, or becomes thought, every one admits that without the brain there can be no thought; and by a comparison of the mental powers in different kinds of animals, we conclude that the relative perfection of mind depends on the relative perfection of brain. Thus, in Bees and Ants, which have long been famous for their intelligence, the nervous system is more highly developed than in any other members of the Articulata. In speaking of

Ants, Mr. Darwin says they "communicate information to each other, and several unite for the same work, or games of play. They recognize their fellow-ants after months of absence. They build great edifices, keep them clean, close the doors in the evening, and post sentries. They make roads, and even tunnels under rivers. They collect food for the community, and when an object too large for entrance is brought to the nest they enlarge the door, and afterwards build it up again. They go out to battle in regular bands, and freely sacrifice their lives for the common weal. They emigrate in accordance with a preconcerted plan. They capture slaves. They keep aphides as milch cows. They move the eggs of their aphides, as well as their own eggs and cocoons, into warm parts of the nest, in order that they may be quickly hatched; and endless similar facts could be given." It is incredible to suppose that animals could accomplish such feats without mind of some kind.

The brain of the Fish is small compared to the spinal cord of which it is the continuation, and the parts of which it is composed are so arranged that no one part obscures the other. In Reptiles the brain is larger, and the Cerebral Hemispheres, the seat of the higher mental activities, slightly predominate over the other parts of the brain. This peculiarity becomes more marked in the Birds; while the Cerebral Hemispheres of the lower mammalia, like the Ornithorhynchus and the Opossum, quite overlap parts perfectly visible in the Fish. Ascending through the orders of the Mammalia, the Cerebral Hemispheres continue to overlap the other parts of the brain, until finally in the higher Apes and Man they entirely cover the Cerebellum, Medulla Oblongata, etc. By comparing the mental powers of the different Vertebrata, we see that the gradual development of the brain is accompanied by a corresponding development of mind. The low grade of intelligence of the

Fish depends on its low cerebral organization, the mental activity of the Dog is due to its comparatively highly complex brain. Every sportsman can give numerous illustrations of dogs reasoning. Mr. Darwin quotes Colonel Hutchinson as his authority for the following example: "Mr. Colquhoun winged two wild ducks, which fell on the opposite side of a stream; his retriever tried to bring over both at once, but could not succeed. She then, though never before known to ruffle a feather, deliberately killed one, brought over the other, and returned for the dead bird." The every-day fact of a dog hiding a bone implies Prudence, Anticipation, and Memory. According to Mr. Darwin, the muleteers in South America say, "I will not give you the mule whose step is easiest, but *la mas racional*, the one that reasons best." Those who are familiar with the habits of Monkeys are always impressed by their intelligence. Buchner, quoting many reliable authorities, says of the Orangs, living tame on board ship, that they will wear clothes, uncork bottles, assist the sailors in fixing the sails and unloading cargoes, will sew with them, dust the furniture, and even light the fire and help cook. It seems impossible that these Apes could learn through imitation, or be taught so much, without having reasoning powers. That the Orang should be so intelligent is not at all extraordinary when we remember that his brain is so much like that of Man. A glance at the brain of the Orang, the Hottentot Venus, and Gauss the mathematician (Figs. 194, 195, 196) demonstrates that the brain of the Hottentot was more like the Orang's than that of the mathematician. According to Vulpian, "the real differences which exist between the brain of Man and that of the superior monkeys are very small. One must not have any illusions in this respect. Man is much nearer the Anthropoid Apes in the anatomical character of his brain than these are, not only to other mammals, but even to certain quadrumana, like

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PROFILE VIEW OF THE BRAIN OF THE ORANG OUTANG

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PROFILE VIEW OF THE BRAIN OF THE HOTTENTOT VENUS

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PROFILE VIEW OF THE BRAIN OF GAUSS

the Guenons and Macaques." Prof. Huxley calls attention to the differences between the cranial capacity of different races of mankind being far greater than between the lowest Man and the highest Ape. Thus, the highest human skull measured by Morton, containing one hundred and fourteen cubic inches, compared with the lowest, containing only sixty-three cubic inches, gives us a difference of fifty-one cubic inches; while a Gorilla's skull, containing thirty-four and a half inches, compared with the lowest human skull just mentioned, gives us a difference of only twenty-nine and a half cubic inches.

Let us consider now briefly the habits and mental powers of some of the barbarous races of mankind. Among these probably stand lowest the Australians and the inhabitants of the adjoining islands, the Bushmen, the Hottentots, and some of the Negro races. The languages of these races are among the poorest known, they having no abstract words, like animal, plant, color, sound, each animal and each plant being designated by a particular name. The mind of these people is so little developed that there are no abstract ideas of which such abstract words are the corresponding expression. As quoted by Buchner, De la Gironnière says of the Ayetas of the Philippine Islands, "that they gave him the impression of being a great family of monkeys: their voice recalled the short cry of these animals, and their movements strengthened the analogy." According to Buchner, "the language of the savages of Borneo is rather a kind of warbling or croaking than a truly human mode of expression;" and Sir Emerson Tennent relates of the Veddahs of Ceylon "that they communicate among themselves almost entirely by means of signs, grimaces, guttural sounds, resembling generally very little, true words, or true language." Some of these races, as the Australians, for example, cannot count over four or five. Many barbarous tribes live in trees, eating fruits, roots, worms, flies, etc.; they herd together, having no idea of marriage or family life. As quoted by Buchner, Krapf, the missionary, in speaking of one of the Abyssinian tribes, says, "The Dokos are human pygmies; they are not more than four feet high; their skin is of an olive-brown. Wanderers in the woods, they live like animals, without habitations, without sacred trees, etc. They go naked, nourishing themselves by roots, fruits, mice, serpents, ants, honey; they climb trees like monkeys. Without chief, without law, without arms, without marriage, they have no family, and mate by chance like animals; they also multiply rapidly. The mother, after a very short lactation, abandons her child to itself. They neither hunt, nor cultivate, nor sow, and they never have known the use of fire. They have thick lips, a flattened nose, little eyes, long hair, hands and feet with great nails, with which they dig the soil." Lallemand, in speaking of the Botocudos, a tribe of Brazil, says, "I am sadly convinced that there are monkeys with two hands." The Negritoes, a race inhabiting the Philippine Islands, are regarded by those who live in Manilla as monkeys. According to Büchner, "the toes of these savages, who live partly in grottoes, partly on trees, are very mobile, and more separated than ours, especially the great toe. They use them in maintaining themselves on branches and cords as with fingers." As we would naturally expect, the unanimous testimony of those who have lived among these races is that all attempts at civilizing such beasts have utterly failed. As these statements may appear somewhat exaggerated to those who are not familiar with the results of ethnological research, we content ourselves with referring such to the works of Lyell, Lubbock, Rolle, Haeckel, and Büchner, on Man. Büchner quotes no less than twenty-five well-known writers, including missionaries, naturalists, philologists, travelers, as entirely confirming his statements respecting the low mental state of

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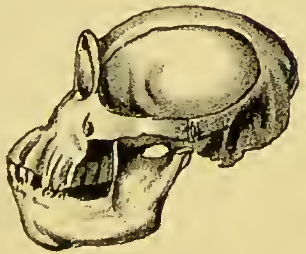

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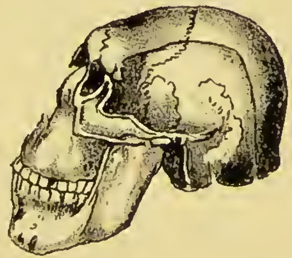

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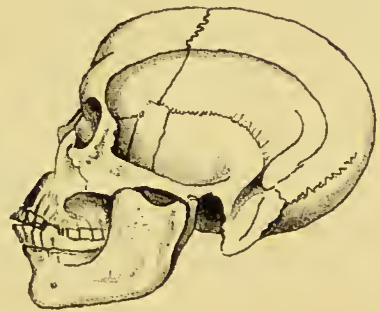

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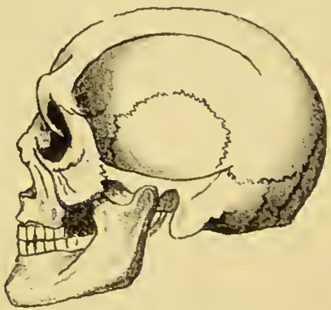

savages. If we now compare the mental powers of the higher animals, such as those of the Horse, Dog, Elephant, Monkeys, with those of such savages as we have mentioned, and these with the most cultivated of men, we come to the conclusion that the difference is certainly much less between the higher animals and the lower races of mankind than between these and men like Shakspeare, Newton, Hunter, Voltaire, La Place, Cuvier, Goethe, Gauss, Müller.

We hope now to have shown that the difference between Man and the other members of the animal kingdom is not one of kind, but only one of degree. Notwithstanding the great differences exhibited by the races of mankind in color, hair, skin, skull, teeth, mental and moral powers, every one admits that the civilized have descended from the barbarous races; the Australian of the present day, for example, representing pretty well the ancient Briton. But we hope to have shown that the difference between a Newton and an Australian is much greater than that between an Australian and the higher Apes. It follows, therefore, that if a Newton could be developed from an ancient Briton, or his living representative an Australian, an Australian could be developed from an Ape.

We began this chapter by stating that supposing the theory of the Evolution of Life to be true, the animal descent of man was a necessary consequence, and therefore the absence or presence of transitional forms was comparatively unimportant. In trying, however, to show that man differs from animals only in degree, not in kind, we hope to have made out a series of transitional forms, beginning with the lower monkeys and ascending from them, through the higher apes and the lower races of mankind, to the higher. Thus, the skulls of the Chimpanzee, Idiot, Negro, and Calmuck, offer a series of ascending forms. By comparing Figs. 197, 198, 199, 200, it will be seen that the receding forehead, which is a striking feature in the skulls of Negroes and of the lower races, is still more marked in the Idiot and Chimpanzee. This type of skull is known as the long head, or dolichocephalic; that of the Calmuck, in which the forehead is developed, as the short head, or brachycephalic. Further, in the Negro the teeth are not set straight (orthognathous) as in the Calmuck, but the teeth of the upper jaw make an acute angle with those of the lower jaw (prognathous). The receding of the forehead and the angular arrangement of the teeth are accompanied by a receding of the lower jaw (see Figs. 201, 203, 204), and great development of jaws. In these peculiarities, the lower races resemble the apes, and differ from the higher races of mankind. The beastly and ferocious appearance of some savages and apes is principally due to this excessive development of the jaws. The large size of the canine teeth is also a striking feature in the skull of apes; but, as Prof. Haeckel observes, in comparing many human skulls, one always notices that the canine teeth project in some more than others; and Mr. Darwin aptly says, "he who rejects with scorn the belief that the shape of his own canines, and their occasional great development in other men, are due to our early progenitors having been provided with these formidable weapons, will probably reveal, by sneering, the line of his descent; for, though he no longer intends, nor has the power, to use these teeth as weapons, he will unconsciously retract his 'snarling muscles' (thus named by Sir C. Bell) so as to expose them ready for action, like a dog prepared to fight." The different size of the molar teeth, according to Buchner, is also important: in civilized men, of the three last teeth or molars the first is the largest, whereas in the Chimpanzee the last is the largest; the lower races of mankind are intermediate in this respect, the three molars being equally developed. Now, it is an interesting fact that, in the milk teeth, the last molar is the largest, as in the Chimpanzee, illustrating the law which we have had

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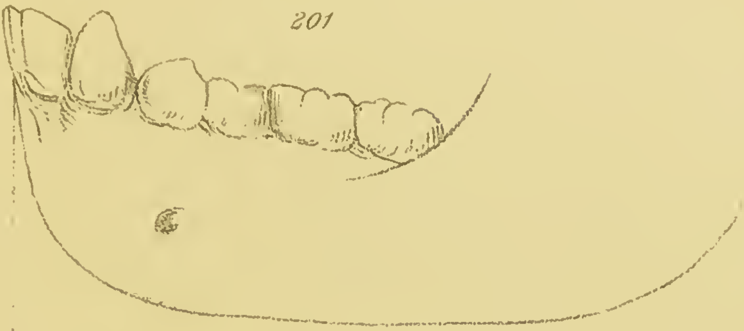

JAW OF CHIMPANZEE

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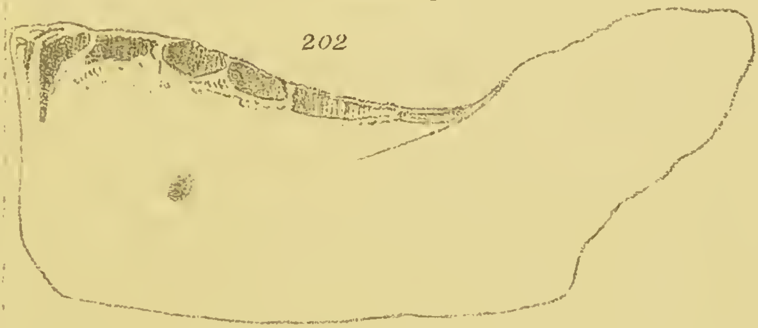

JAW OF LA NAULETTE

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JAW OF MELANESIAN

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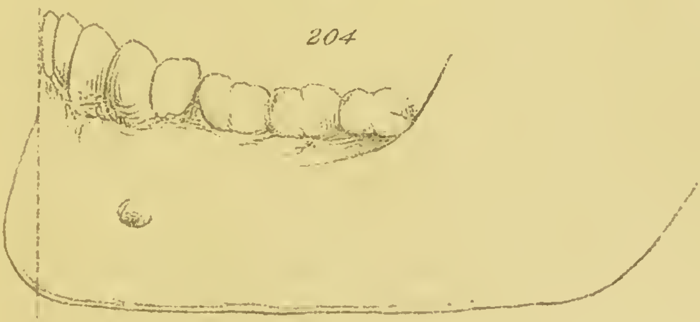

JAW OF MODERN PARISIAN

occasion so often to mention, that the lower animals retain permanently forms that are only transitory in the higher.

We see further examples of this principle in the receding of the forehead and jaws, which are only exhibited by the skulls of the higher races in their embryonic or undeveloped condition, in the learning of the child to walk, and in the development of speech. The erect position of man is often regarded as an objection to his having descended from a lower animal. But as it is evidently an advantage for man to use his hands for grasping, etc., but his feet to stand and walk upon, we can understand how, through the Struggle for Existence, etc., this division of labor was brought about. The view of the erect position having been gradually assumed by man is confirmed by such facts as the creeping on all-fours of the baby and the shuffling unsteady gait of the young child. The baby, at the first month, uses its foot like a hand, and it is well known that some savage people retain the mobility of the big toe, using it as a thumb and the other toes as fingers; further, the unsteady sidelong step of the child learning to walk is seen in the semi-erect gait sometimes assumed by the Gibbon and Gorilla. The young Chimpanzee, walking along hand-in-hand with his keeper, resembles so strongly a little negro learning to walk, that it is impossible not to recognize their distant cousinship. In a word, the transitory stages through which an individual man passes in learning to walk represent the stages through which man in general has passed in assuming the erect position, the transitory stages being permanently retained in the lower animals.

It is admitted by all that articulate speech is peculiar to Man. The possession of this faculty, however, does not seem to be inconsistent with the view of his animal descent. It is well known that animals communicate their ideas by means of touch, sounds, etc.: thus, the Dog barks in different ways, expressive of pain, anger, joy, despair, entreaty.

Cows, cats, pigeons, chickens, give vent to their feelings by sounds. Language, or the expression of one's thoughts, is therefore common to man and the lower animals. Let us see now what light is thrown on the origin of articulate speech, or the peculiar language of Man, by comparing its development in the child with the languages of different races. It must be remembered that intelligent speech depends as much on the development of the brain as of the vocal organs, for Parrots and Ravens can talk. Naturally, then, words are wanting if there are no ideas to give rise to them. Hence the poorness of the languages of savage races, and the simple talk of the child. Further, one hears few verbs, prepositions, or conjunctions, in listening to the prattle of young children: their expressions are almost entirely composed of nouns and adjectives,—thus, "sugar good," "toy nice," and so on. The language of savage nations is equally simple, often not rivaling even that of the children of the civilized. Hence celebrated philologists, like Grimm, Schleicher, Bleek, regard language as progressive, considering the most ancient languages as much more simple than the modern ones. They maintain that language is not an art, but a natural growth arising from the necessity felt by man of having some means of communicating his ideas. According to Schleicher, the most simply constructed languages have been slowly developed out of the natural cries that Man has in common with animals. He considers that, in the lapse of ages, languages experience great modifications, some, indeed, altogether dying out, others becoming so changed that their origin cannot be certainly determined; that, comparatively speaking, language is a recently acquired faculty depending on development of brain and vocal organs; primitive Man having no language excepting the natural cries inherited from his Ape ancestors. Accepting this theory, we have an explanation of the fact that the roots in the languages of the lowest races of mankind resemble the

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NEANDERTHAL CRANIUM

sounds made by monkeys. Indeed, according to some authorities, the language of the Papuans is much more like that of the Monkeys than that of Shakspeare. Philological facts like those here only briefly mentioned lead us to the conclusion that the development of language in an individual of the higher races is the history of the development of language in general. It is sometimes said that the faculty of speech entirely separates Man from the Monkeys. But this difference, like all others, is only one of degree, not one of kind. The vocal organs are well developed in Apes, the Gibbons shouting to each other as they swing through the woods. To take Mr. Darwin's example, one might as well argue that the Crow is not a bird, because it croaks, whereas the Nightingale sings.

Having mentioned some of the peculiarities of the structure and development of man in reference to his animal descent, let us now call attention to the importance of certain human remains in this respect. Through modern discoveries made in France, Belgium, Germany, etc., the remains of races of men have been brought to light, which without doubt have long since been extinct. Now, it is a very significant fact that the skulls of these primitive races exhibit a very low type of organization. According to Prof. Schaffhausen, "the form of the forehead of the Neanderthal skull (Fig. 205), the dentition and form of the jaw of La Naulette (Fig. 202), the prognathism of some infantile jaws of the stone period of Western Europe, exceed, as regards their animal form, that observed in living savages." Further, according to the same high authority, "these characters must not be considered as accidental exceptions from the normal form, which was the common theory on meeting with such finds; for these peculiarities in the organization of the pre-historic man do not occur as exceptions, but as a rule; and what is decisive is the circumstance that they mostly present a fœtal character, and thus exhibit an early stage of development. They also frequently stand in reciprocal dependence; one character determines the other, according to the law of harmony or coexistence which governs the form of all living bodies. With the flying forehead, we find, as a rule, a projecting jaw, large teeth, a high temporal line, a strongly developed occipital ridge, simple cranial sutures, small cranial capacity." Mr. Carter Blake, in describing the jaw of La Naulette (Fig. 202), so called from being found in the hole of the same name, says, "Its undoubted resemblance to the jaw of a young ape I shall not venture to deny." In speaking of the molar teeth we stated that they were of equal size in the lower races of man, but that the last molar was the largest in the milk teeth of man and in the adult Chimpanzee. In reference to these facts, the jaw of La Naulette is extremely interesting, since its last molar is the largest, agreeing in this respect with that of the Chimpanzee and milk teeth of Man; the tooth also exhibits the remarkable peculiarity of having five roots, as is the case with the last molar of the Gorilla and Orang. Further, in the great size of the canine teeth, and the absence of the chin, the jaw of La Naulette resembles in a marked degree that of the Chimpanzee. An important distinction between the molar and premolar teeth in man is that the molar teeth have three roots, while the premolars have only two; but a very ancient human skull found at Olmutz exhibits, according to Schaffhausen, the peculiarity of the second premolar having three roots, as is the case in the premolars of the Apes. According to the same author, this is also seen in two human skulls belonging to the Göttingen collection. In comparing the human bones and cranium brought from the cave of Neanderthal with other specimens, Prof. Schaffhausen says they "exceed all the rest in those peculiarities of conformation which lead to the conclusion of their belonging to a barbarous and savage race," and at the conclusion of his address on the primitive form of the skull, translated in the Anthropological Review, we find "it follows further that we must place the primitive man lower in the scale than the rudest savage. The Neanderthal skull and the La Naulette jaw present characters of a low organization such as we do not find in any living race."

Want of space prevents us from dwelling further on this subject. Suffice it to say that what is known of the remains of primitive man confirms the view of his animal descent. From the transitory stages through which man passes in his development being more or less permanently retained in the lower animals, from his organization exhibiting in a rudimentary condition structures which are fully developed in the lower animals, from abnormal characters such as certain muscles appearing in man which are usually only present in monkeys, we concluded in our chapter on Embryology that man had descended from some animal form. That this animal form, or the remote ancestor of man, was an ape, we have tried to show in this chapter by comparing the higher apes with the barbarous and the civilized races of men, the result of this comparison being that the barbarous races are more nearly allied to the higher apes than to the civilized man.

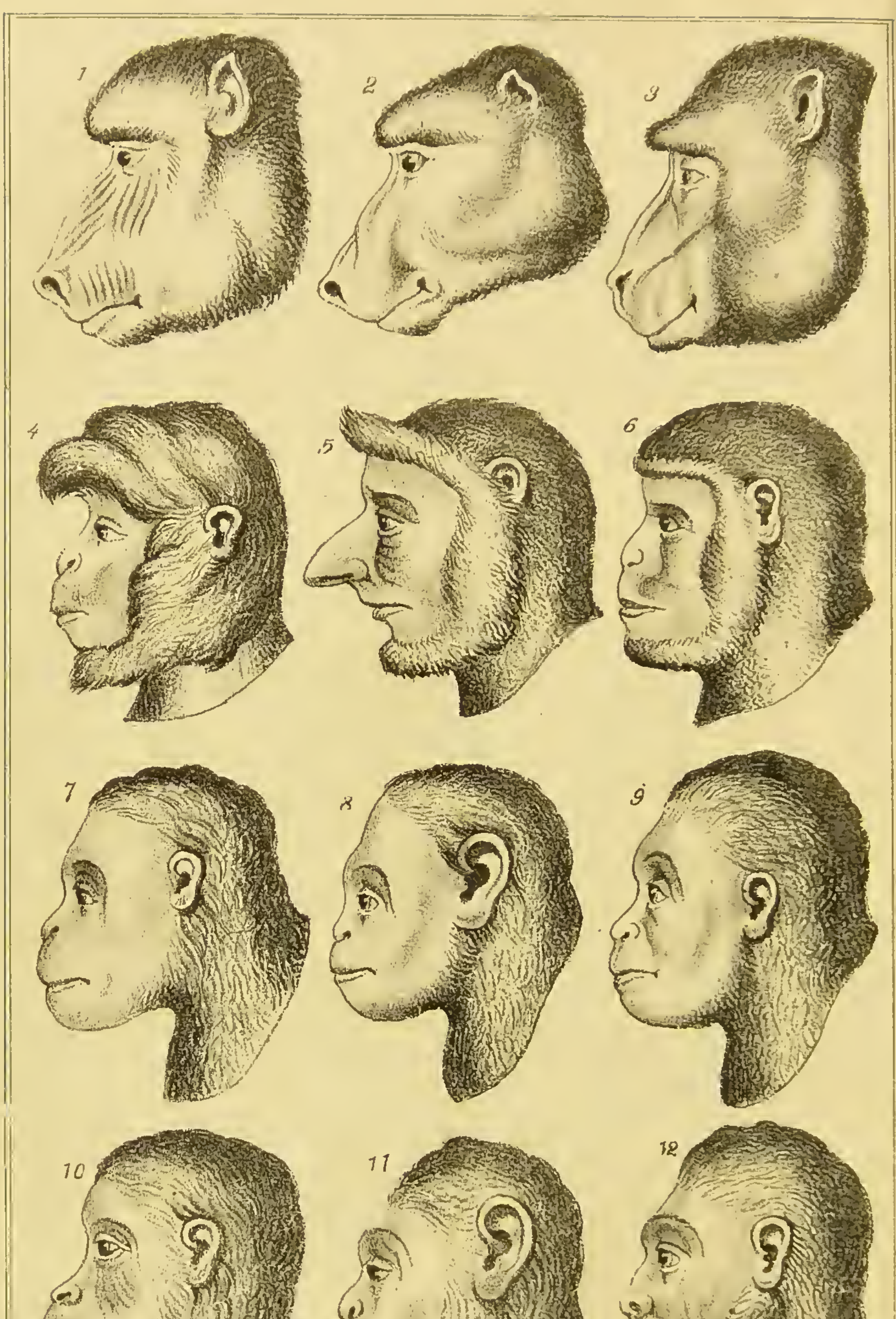
While accepting the theory that man has descended from an ape, it is impossible, however, to designate any particular ape as his remote ancestor. The apes that most resemble man are the Gorilla, Chimpanzee, Orang, and Gibbon, hence called Anthropoid Apes. Their features are very like those of the lower human races. (See plates of faces of men and monkeys.) No evolutionist, however, so far as we are aware, supposes man to have descended from one of these apes. For while each of these apes has something in common with man, each differs from him very considerably. Thus, the Gibbon resembles man in the thorax; the Orang, in the brain; the Chimpanzee, in the

EXPLANATION OF PLATES

OF

FACES OF MONKEYS AND MEN.

			NATIVE COUNTRY.
Fig.	1.	Baboon	Guinea.
"	2.	Pig-faced Baboon	Cape Land.
"	3.	Macaque	Sumatra.
"	4.	Semnopithecus	Java.
"	5.	Nasalis	Borneo.
"	6.	Gibbon	India.
"	7.	Orang, young (female)	Borneo.
"	8.	Orang, old "	Borneo.
"	9.	Chimpanzee, young (female)	Guinea.
"	10.	Chimpanzee, old "	Guinea.
"	11.	Gorilla, young (female)	Guinea.
"	12.	Gorilla, old "	Guinea.
"	13.	Papuan (female)	Van Diemen's Land.
"	14.	Hottentot "	Cape Land.
"	15.	Caffre "	Zulu Coast.
"	16.	Negro "	Soudan.
"	17.	Australian (male)	Victoria Land.
"	18.	Malay (female)	Polynesia.
"	19.	Mongolian (male)	Thibet.
"	20.	Arctic (female)	Kamtchatka.
"	21.	American (male)	Mississippi.
"	22.	Drave "	India.
"	23.	Nubian "	Kordofan.
"	24.	European "	Greece.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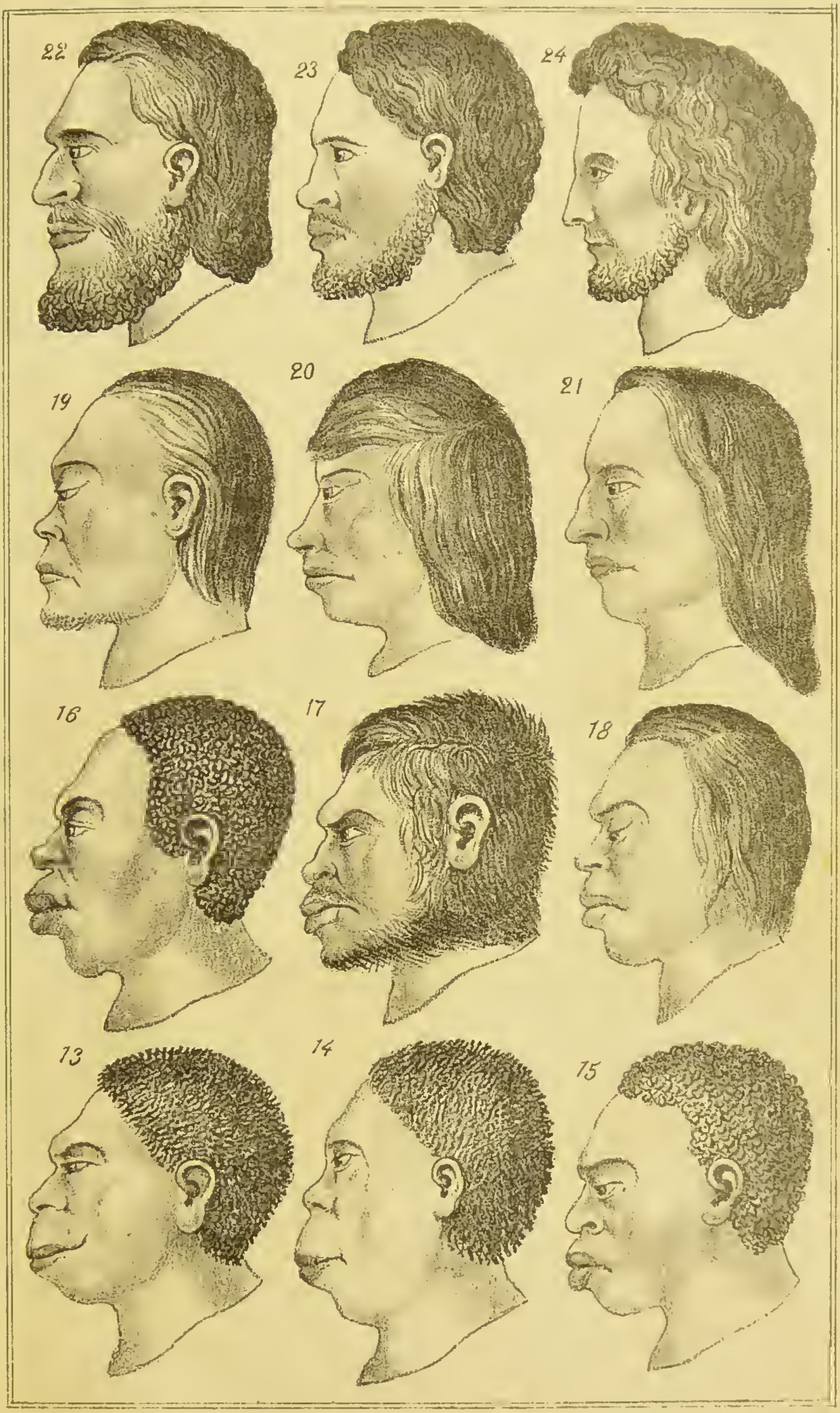
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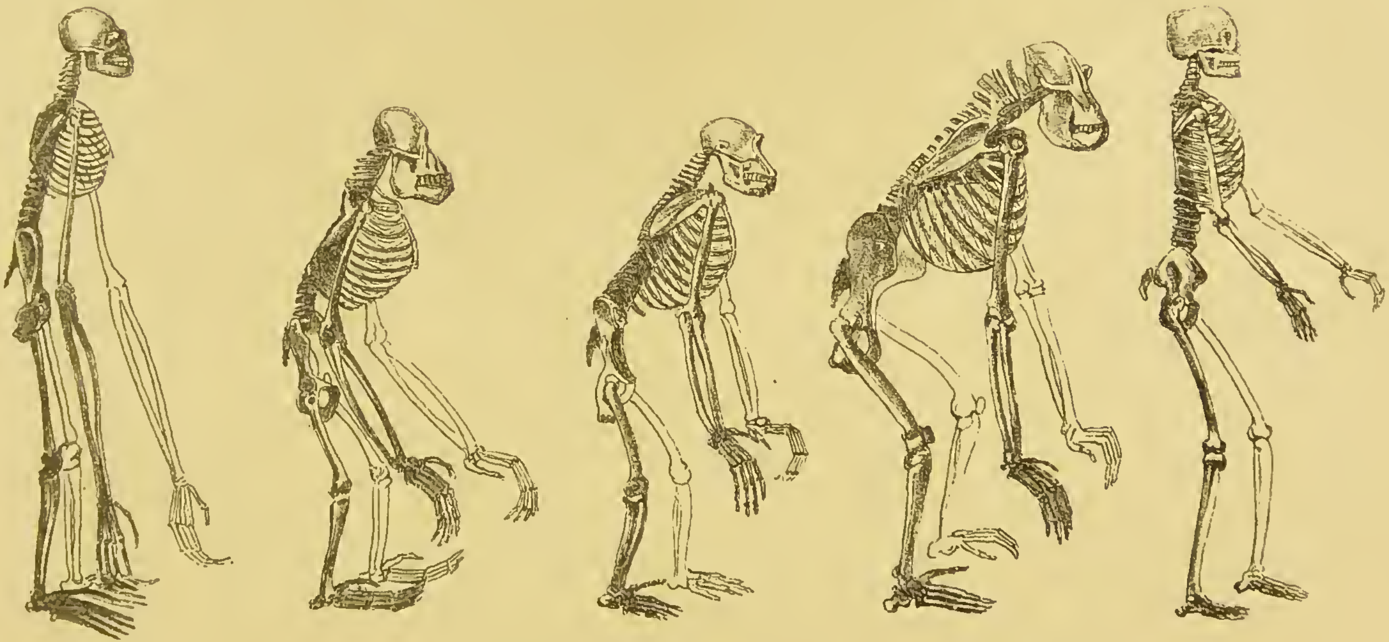

GIBBON ORANG CHIMPANZEE GORILLA MAN

skull; the Gorilla, in the hand and foot. Further, these apes have a rudimentary tail, like that of man. (Figs. 206 to 210.) By comparing the skeletons of man and the apes, the differences will be found to be also very striking. (See Figs. 206, etc.) The more probable theory of the relationship of man to the Anthropoid Apes is that they are very distant cousins, the posterity of a common ancestor of some extinct form whose remains have not as yet been discovered.

The birthplace and antiquity of man, like his genealogy, are still involved in obscurity. Many geologists and naturalists, however, suppose that there once existed a continent where the Indian Ocean now rolls, which stretched from the Sunda Islands to Madagascar. This sunken land is called by Sclater, Lemuria, from the half monkeys, the Lemurs and their allies, being so characteristic of Madagascar and the Indian Archipelago. This view of a land of Lemuria having once existed harmonizes very well with the evidences of Ethnology, Philology, etc., which point to some intermediate spot between Southern Asia and Eastern Africa, like Lemuria, as the birthplace of the human species. As regards the antiquity of man, the data are so imperfect that it is impossible to give an estimate. Some authors think man appeared in the latter period of the Tertiary Age; according to others, still earlier. However this may be, it is certain that immense periods of time must have elapsed since the appearance of man.

Those who are impressed with the poetical idea of a Golden Age, from which man has fallen, no doubt find it difficult to admit that he has descended from an ape. The explorations of the last forty years, however, have proved that so far from there having been a Golden Age, the first age was that of Stone (the implements being made out of stone, hence the name of the age), followed by one

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of Bronze, a further progress being exhibited in the Age of Iron. Ethnologists consider the primitive man to have been lower than the lowest of existing savages, more ape-like even than the extinct human races, whose remains we have briefly noticed. According to philologists, the primitive man was speechless, and the earliest languages babble. All kinds of evidence negative the idea of man having fallen from a high estate, but support the view of his having developed from a lower one. The descent of man is indeed an ascent.

It does not seem out of place to briefly call attention to the probable spreading of the human species over the earth, which, according to Prof. Haeckel, was as follows. Starting in Lemuria (see plate on distribution of races), the posterity of the primitive men diverged towards Africa, Australia, the Indian Archipelago, and Asia; the Hottentots, Caffres, and Negroes being the descendants of those who came to Africa, while the Papuans, Australians, and Malays are equally the posterity of three stems. Diverging from the Malay stem appeared the Drave and Mongolian races. The Draves, peopling India, passed towards Arabia, and divided into the stems of the North African races and Europeans; while the Mongolians, passing through China and spreading over Northern and Eastern Asia, finally crossed over Behring Straits and peopled the Americas. This view of the gradual spreading of the races of men from a common point situated between Asia and Africa seems to be a fair conclusion from what is known of Ethnology and Philology.

While admitting that the different races have descended from a common stock, it does not necessarily follow that the primitive men came from a single pair. Thus, possibly, different apes may have been the ancestors of the Malay and South African races. It is interesting in this respect to observe that the Orang, who is found in the Malay

Archipelago, is of a yellowish color, and is brachycephalic in the form of the skull, like the Malays, whereas the Chimpanzee, found in Africa, is black and dolichocephalic, like the Negroes. At present it seems to us impossible to say which is the more probable, whether the primitive men came from one pair of apes, or many. In either case, however, they had a common origin, since the apes are the posterity of a common ancestor.

The kindred question of the origin of the different languages from one or many roots depends on the period at which the primitive men first acquired language. For if language was acquired by the primitive men before their posterity had dispersed, then the different languages would have had a common origin; whereas if the races had dispersed before their ancestors had acquired a language, then the languages of these races would have arisen independently.

In conclusion, it seems proper to mention that the descent of man from some ape-like form is perfectly consistent with the development of morality. As we noticed in the last chapter, among barbarous tribes there is no dependence of individuals upon each other, the character of the daily life of savages being such as not to offer much chance of their mutually benefiting each other; while the uniting of barbarians, for the purpose of attacking some other tribe, is unfavorable to the development of sympathy and kind feelings towards mankind, since war encourages murder, robbery, and crime of all kinds. We have shown, however, that in the social state the relations of man to man are so complex that no one is independent of his fellowmen. To such an extent is the division of labor carried out in highly civilized countries that even distant nations have many interests in common. This is so true of some countries that war is dreaded and has been avoided by them, every one knowing that the effects would be very injurious to both the victorious and conquered. Notwithstanding that the effect of the social state is the restraining of men's evil passions, nevertheless crimes and outrages are committed even among the most civilized,—simply, in the words of Mr. Spencer, because man "partially retains the characteristics that adapted him for an antecedent state. The respects in which he is not fitted to society are the respects in which he is fitted for his original predatory life. His primitive circumstances required that he should sacrifice the welfare of other beings to his own; his present circumstances require that he should not do so; and in as far as his old attribute still clings to him, in so far is he unfit for the social state. All sins of men against each other, from the cannibalism of the Carib to the crimes and venalities that we see around us, have their causes comprehended under this generalization." The same author then argues that as the gratification of passions increases, whereas the restraining of passions lessens, desire, and that the faculties develop through use, but diminish through disuse, man must improve, as his organization is becoming continually better fitted to his surroundings, "all evil resulting from the non-adaptation of constitution to conditions." We see, therefore, that progressive morality is a necessary consequence of the Evolution of Life.

RESUME.

We conclude, from the general theory of the Evolution of Life, from the facts brought forward in this chapter and in the two preceding ones, that man has descended from an animal; that the remote progenitor of man was an ape, resembling the Gorilla and Chimpanzee; that the birthplace of man was situated somewhere between Southern Asia and Eastern Africa, in Lemuria, if such a continent existed; that myriads of years have rolled by since man appeared on the earth; that the primitive men exhibited a grade of organization lower than the lowest of existing savages; that the different races of men have descended from a common stock; and that the physical, mental, and moral improvement of man is the necessary consequence of the Evolution of Life.

The doctrine of the Evolution of Life has this, then, in its favor: that it is a comprehensive theory of Life,—a theory on which can be based a scientific Ethics and a scientific Politics; and as all happiness depends on duty to one's self (Ethics), and therefore duty to one's neighbor (Politics), it follows that a theory which offers a basis for the development of these social sciences must immeasurably benefit mankind.

> "To thine own self be true;
> And it must follow, as the night the day,
> Thou canst not then be false to any man.
> Farewell; my blessing season this in thee."

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THE END.