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AN

INTRODUCTION TO THE STUDY

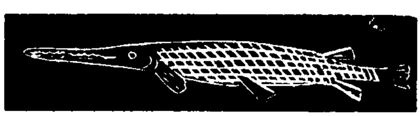
OF

NATURAL HISTORY,

IN A SERIES OF LECTURES DELIVERED IN THE HALL OF THE COLLEGE OF PHYSICIANS AND SURGEONS, NEW YORK.

BY PROFESSOR AGASSIZ.

ILLUSTRATED WITH NUMEROUS ENGRAVINGS.



ALSO,

A BIOGRAPHICAL NOTICE OF THE AUTHOR.

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PREFACE.

In accordance with the request of the Faculty of the College of Physicians and Surgeons, Professor Agassiz delivered, in the Hall of that institution, during the months of October and November of the present year, a series of twelve Lectures on the various orders of animals. The celebrity of the Lecturer and the intrinsic interest and importance of the subject, attracted very large and attentive auditories. Indeed, the degree of attention excited by these admirable discourses manifested, in a very striking manner, the greatly increasing interest with which the popular mind is now directing itself to the investigation of scientific subjects.

Full reports of these Lectures were given in the columns of the "New York Tribune," and abundant evidence was afforded of the high appreciation with which they were received by the public. They are now collected together; and having been carefully prepared for this publication in a permanent form, it is believed that they will prove acceptable to all who take an interest in the study of a department of Science which is daily becoming invested with fresh attractions. The young beginner and the more advanced student of Natural History will both derive essential aid from the study of these discourses; as, while teaching first principles in an eminently lucid and comprehensive style, the Lecturer communicates also the results of the most recent and elaborate investigations in the latest discovered fields of philosophical inquiry.

The Lectures, with the exception of one or two, were reported by Dr. Houston, Stenographer to the Senate of the United States, and he has succeeded in giving them with literal accuracy, so as to preserve the characteristic style of the Lecturer. The few Lectures not reported by that gentleman, were subjected to a careful revision. Of the engravings it is only necessary to say that they were rapidly sketched from the black-board during the delivery of the Lectures, by Mr. Brydges, with perfect accuracy, and will be found to contribute essentially to the elucidation of the subjects discussed in the Lectures. Very many of the illustrations are altogether original, and cannot be met with in any of the treatises on Natural History heretofore published.

New-York, December 10, 1847.

BIOGRAPHICAL NOTICE OF PROF. AGASSIZ.

Louis Agassiz was born on the 28th of May, 1807, in a village of the Canton of Fribourg, Switzerland, called Mottier. His father was a clergyman, a profession to which his progenitors for five generations had been devoted. He received the first rudiments of scholastic education at the Gymnasium of Bienne, where he passed several years, principally in studying the ancient languages. His passion for Natural History appeared during this period, and his vacations at home were employed in making collections. His father having removed to a parish on the Lake of Neufchatel, he made fishes an object of especial study. He went with the fishermen on their excursions, and often, with a line in his hand, passed whole days on the Lake. He soon discovered how defective Natural History was in this department, and resolved to make good the deficiency.

Having completed his studies at school, his father wished him to become a clergyman, but his natural bent was too strong to be resisted. He accordingly commenced the study of Medicine, as being most nearly connected with his favorite pursuits. At the Academy of Zurich he received great assistance in his Zoölogical investigations from the well-known Professor Schinz. Afterward he studied Anatomy at Heidelberg, under the celebrated Tiedemann, until, attracted by the remarkable body of savans collected at Munich, he resorted thither to continue his studies. Here he passed four years, rather as an associate in the private studies of the Professors of the University than as a student under their instruction. He also collected around him a knot of young men of kindred spirit with himself, for the discussion of scientific subjects, and into this assembly, which was called the "Little Academy," even the Professors were drawn.

At this time Agassiz made his first appearance as an author, and in the most honorable manner. Martius, one of the Professors at Munich, was occupied in preparing his great work on the Natural History of Brazil. To Agassiz he confided the department of Ichthyology; this portion formed a folio volume, in Latin, with plates, and at once established the reputation of the young Naturalist.

His parents, who had long been dissatisfied with the devotion of their son to Natural History, which withdrew him almost wholly from his medical studies, now cut off the allowance on which he had depended for a living. In this emergency he fell back upon his own resources. He exhibited to the bookseller Cotta the material he had collected for a work upon Fresh-water Fishes, and obtained from him the means of completing that work. At the same time he returned to Medicine, in order to regain the favor of his parents, and with so much success that he shortly after obtained the degree of Doctor. Subsequent to this he passed another examination, and received the degree of Doctor of Philosophy.

Having been restored to his former relations with his parents, he received from them permission to visit Vienna in order to complete his medical studies. He did not, however, neglect his favorite pursuits, but, as before, occupied a great part of his time with Ichthyology, and especially with the department of Fossils. On his return home, he obtained from a neighboring clergyman the means of visiting Paris. There he became intimate with Cuvier, who even resigned to him a work on Fishes which he had long designed, and for which he had made extensive preparations—so high was his estimate of the gifts and learning of the young man. He remained with Cuvier until his death in 1832, when he returned to Switzerland and became Professor of Natural History in the College of Neufchatel.

Before he had passed the age of thirty-four, Agassiz had been made a member of every scientific academy in Europe. Many universities invited him to become one among their Professors; and the cities of Edinburgh and Dublin, in both of which he received the degree of LL.D. enrolled him in the number of their citizens. His personal influence induced several persons of distinction to engage in the study of Natural History; among others, Sir Philip Egerton and Lord Enniskillen, whose collections are known to all paleontologists.

The reputation and influence of M. Agassiz have rendered the little town of Neufchatel a nursery of Science, resorted to from all parts of Europe; and on his recommendation a young pupil of his, Dr.

Tschudi, who has since become known by his work on Peru, was dispatched on a voyage round the world, to collect objects of Natural History.

In order to confirm the Glacial Theory which has made his name so famous, M. Agassiz, after having visited in succession most of the glaciers, fixed his headquarters at the glacier of the Aars, whither he went with his friends to pass his summer vacation for *eight years consecutively*; at first with no shelter except a large boulder lying on the middle of the glacier, which soon became famous under the name of the *Hotel des Neufchatelois*. Here he prosecuted the long series of researches which have since obtained so much celebrity in the scientific world.

Occupied with these investigations and with his regular duties. Prof. Agassiz remained at Neufchatel until his visit to this country. This visit was undertaken at the double instance of the King of Prussia, who charged him with a scientific exploration of America, and of the Lowell Institute in Boston, before which he was invited to deliver a Course of Lectures Since his arrival he has been offered a Professorship of Zoölogy and Geology in Harvard College which he has accepted on condition of being released from his engagement with the King of Prussia.

Professor Agassiz is personally a man of very striking and prepossessing appearance. He is tall, and formed with as much strength as elegance, with a rather florid complexion and dark hair. In his manner and bearing there is a singular grace and benignity.

His principal work is on Fossil Fishes, in five folio volumes, with an atlas of plates. It is dedicated to Alexander von Humboldt, and has a very high and extensive reputation. He has also written on the Fossil Echinodemata of Switzerland, on Fossil Molluscs, on the Fresh-water Fishes of Central Europe, on the Glaciers, and on other subjects.

The rapidity with which these works have appeared, and the research and learning which they all display, would be inexplicable had no other hand than that of their distinguished author been concerned in their production In 1837, M. Agassiz associated with himself a young Naturalist, M. Desor, with whose valuable assistance his labors have since been prosecuted. By this means much more has been accomplished for Science and the world than could have been done by any single individual, however highly endowed.

THE ANIMAL KINGDOM.

INTRODUCTORY LECTURE.

Natural History—Its Study and the Lights in which it may and should be viewed....Man may expect fully to understand Nature....Man's Body similar to the Bodies of Animals—The Cause....The Varied Types of Nature—Astonishing Variety of Animals—difficulty of at first perceiving any order in them....The Star-Fish....The Corals.....The Jelly-fish.....Clams, Worms, Spiders, Crocodiles, Bats—Their great apparent Dissimilarity and yet many of them of the same type—The Lobster, the Spider and the Butterfly—The Cuttle-fish, the Snail and the Clam all allied—The Coral and the Jelly-fish....Soft Animals and their Power of Contraction....The respective Nervous Systems of the different Types of Animals....Origin of the applied terms, *Articulata, Vertebrata, Radiata* and *Mollusca*.... The different Sets of Organs in these different Animals.

Dr. A. H. STEVENS introduced the lecturer to the assemblage in a few complimentary remarks.

Prof. AGASSIZ then presented himself to the audience, and, in a singularly agreeable voice and marked foreign accent, delivered the following Lecture:

LADIES AND GENTLEMEN: Having to address you in a foreign tongue, I must first apologize for the deficiency of my language. Happily, however, Natural History has an interest entirely apart from the form in which the subject is presented to the student. The investigation of objects of Natural History does not need the aid of rhetoric to invest it with attractive charms; and the mind may trace these phenomena even without putting them into a definite form, and, therefore, the mode of expression employed in conveying the results of such inquiries is not so important as it would be in a literary work. I shall do all in my power to make up for the deficiency of my power of language, by the interest directly derived from the subject itself.—(Applause.)

Natural History may be studied in very different points of view. Some may consider it as a source of information for useful purposes. The wealth of States depends frequently on the knowledge acquired by individuals of the structure of the soil. The working of mines has become an actual business since Geology as a science has given us the key to the investigation of the deeper regions under the surface of the ground. Many trades depend on the knowledge of certain phenomena of Nature. Even Navigation is the result of scientific investigation and discovery; and, at this time particularly, the vastly increased facilities of frequent intercourse between nations have been the result of the recent progress of natural science—of physical science especially. Thus, though viewed in this strictly utilitarian aspect a sufficient inducement may be furnished for the study of Nature and of the objects of Natural History in particular, the subject is yet to be regarded from a more elevated point of view. It is not enough for a philosophical mind to know the natural phenomena. It may be enough to know some isolated phenomena in order to derive important aid in the arts, but to the philosopher such superficial acquaintance with Nature is not sufficient. He wants to understand Nature. He is not satisfied with the knowledge of isolated phenomena.

When I say that the philosopher desires to understand Nature, I will perhaps better explain my meaning by an example. When we enter on the study of an author we may begin at a very low stage. With one of the classic Poets of antiquity, for example, we may begin by translating sentence by sentence, with great difficulty, and in this way we may go through the most beautiful language of ancient poetry. But would it by any means follow because we have thus spelled over the pages of Homer, that we understand him? Another and a higher sort of mental process is requisite to enable us to know, to understand, that sublime author. It is only when we have become acquainted with the condition of human society in that age—the rivalry which existed between the nations of Asia and Greece—and the mythology of that remote time, that our sympathies approach the level of the poet's work and our hearts own the influence of the poet's spirit.

So it is with the study of Nature. We may know by their name a great many animals. We may be able to indicate with accuracy the characteristic differences between the various tribes of animals. We may be able to distinguish the trees in our forests and the plants cultivated in our gardens; nay, we may know any isolated plant that flourishes upon the surface of our globe, and yet we may after all know nothing of the plan of creation. There is a higher point of view from which we attain a deeper insight into that plan.—We must understand the connection between the various parts of Creation, and, rising higher still, direct our contemplations to the Author of all, who has formed the whole and subjected it to all those modifications extending through long ages which Geology has revealed, from the remotest epoch up to the period when Man was created and introduced upon the surface of the globe with the animals and plants which we now behold.

Understand, then, that the study and knowledge of Nature consist in something more than acquaintance with the isolated beings which exist upon the surface of our globe. We must understand the connections existing between these beings, and the relations which they sustain to the Creator of them all.

But the question may be asked, is it possible for Man to acquire more than a superficial insight into natural phenomena? This question has been answered in many different ways. Some have maintained that all we can expect to come at is an artificial classification, agreeing in a greater or less degree with the natural phenomena; that a real insight into all the varied departments of Nature by man is unattainable. But if we view the progress of natural science, and observe the investigations made in every succeeding generation in the matter of isolated phenomena—if we bear in mind how many things which appear isolated have been combined into one and the same point of view, we are furnished with a strong ground of hope that it will be given unto Man to attain that insight into Nature.

There is another reason why Man may expect fully to understand Nature. We feel in ourselves that we are not mere matter. We have a soul. We have an intelligence. We have feelings by which we are in connection with each other. These feelings—that intelligence—carry us beyond the limits of our globe. We thus rise to the notion of a God. We have that within ourselves which assures us of a participation in the Divine Nature; and it is a peculiar characteristic of Man to be able to rise in that way above material Nature, and to understand intellectual existences. The possibility of obtaining an insight into Nature is thus strengthened by the analogy between the Human and Divine Natures. On that principle, Man being made in the image of God, it is possible for his intelligence to comprehend the doings of God in Nature. Hence by a constant intercourse with these works—by a Natural Religion—by a constant study of these works of Creation, we may come to understand the views, the objects of the Creator in doing these works—in introducing these phenomena as realities into existence. We may, in one word, come to a full understanding of Nature from the very reason that we have an immortal soul.

Again, our body is so similar to the bodies of animals. The organization of our body discovers intimate relations with their physical condition. We pass from the lower type of animals so gradually to the higher, until we find Man, with his superior organization. Thus on one hand we see that owing to the intellectual nature of Man he has peculiar relations with the Author of all things, while on the other hand, from his physical nature he has a root in the soil—a material foundation, and hence both the intellectual and the material world is laid open to his contemplation, affording substantial grounds for the belief that he is competent to attain a full understanding of the works of creation and the plan of God when bringing the world into existence.

That all this creation has not been the result of one creative act, we know from geological observation. This globe—the animals which exist upon it now—have not been brought into existence at one moment. We have learned from geological observation that a long series of epochs have succeeded each other, and that during every epoch animals and plants, organic beings of various types, were successively living and died away. to make room for others, till the surface of the globe was occupied by the animals and plants which now exist with Man as their head.

The most superficial knowledge of those phenomena soon gave rise to the notion that the introduction of Man has been the object of the creation of this globe, and the position which Man now occupies upon the surface of this globe is such that this notion appears to us quite natural. I think it may be shown by actual demonstration, as far as physical phenomena can be demonstrated, that the view of the Creator in forming the globe—in allowing it to undergo these successive changes which Geology has discovered, and in introducing gradually all these different types of animals which have passed away, was, after all, to introduce Man upon the surface of our globe, and to bring him into connection with the other organized beings and with the soil in connection with which he does now exist.

There is one reason to believe that this is so. That reason is this: We see from every point of view in which we may regard the Animal Kingdom—and I shall from this moment limit all my remarks to the Animal Kingdom, in order not to trespass beyond the bounds properly set to this discourse—we see that Man possesses the most complex and most perfect structure. Even his position is remarkable and significant. Man's erect position in standing or walking shows that he is placed at the head of creation. All the lower animals have a horizontal position. The fishes move horizontally. Gradually as we ascend in the scale of animated beings we behold them raising their heads a little. Snakes have no feet, but they are able to elevate the head; and if we proceed farther we find successive types in which the position becomes an oblique one, until the head is raised more perpendicularly. But to Man alone is given the most important position—the vertical position, which allows him to make use of his hand and fingers and to raise his eye directly toward the heavens. In this very position—in this material construction of his body, we have an evidence of the superiority of man. But in every respect, if we consider his structure, we see that Man stands at the summit of animal being—and that it is just so to regard Man as at the head of Creation, will be one object of these Lectures.

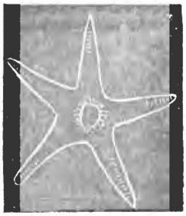
Again, if we consider the construction of animals upon the surface of our globe, we will find that the lower types have been first created—that they belong to the most ancient rocks—that the deepest rocks contain none of the higher animals, and that gradually some more perfect types were introduced till at last Man was created, and it may be shown geologically, by actual investigation and without the slightest reference to any historical or sacred tradition, that Man has been created the last.

Again, if it cannot be shown from this point of view that the introduction of man was actually the object of the Creator, it may be at least shown that Man was the last and most perfect work that proceeded from His almighty hand. But that it was actually the object of the Creator to introduce Man at the head of the Animal Kingdom can, I hope, be shown by combining the knowledge we have acquired with regard to his physical structure, and his relations with the different other classes of animals and with the surface of the globe at large. At no time do we find in geological epochs a species spread all over the surface of our globe. Every type of animal—every variety of animal, occupies in the geological epochs only a small portion of the surface of the globe. This fact holds true in all geological times. Before the animals now living were created—when races entirely different from them existed, every species was circumscribed within narrow limits, and in no case occupied the whole surface of the globe. No one of the species of former epochs was superior to the whole type of its time. At no geological epoch do we find one species standing preëminent above others. But at this present epoch, we find not only that Man stands preëminent above all other species, but that he occupies the whole surface of our globe; and in this respect he appears to be of a superior organization and endowed with privileges which no type ever enjoyed before him.

But I will not dwell on those general questions without some more precise foundation. I shall at once proceed to call your attention to the varied types which exist in Nature, so as to have actual facts upon which to reason. I desire that the statements with which I set out may be regarded as the results of investigation and not as matter of mere speculative opinion.

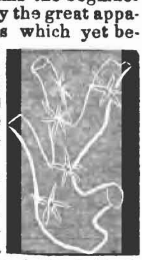
There is an astonishing variety of animals upon the surface of our globe. This variety is such that it is very difficult for the student who for the first time directs his attention to the subject, to perceive any order. It is impossible at first to perceive the intimate affinities and the near relations which subsist between all these varied formations.

I have here some diagrams giving outlines of a few of these formations. I just name the subjects before passing to their characteristics. Here we have the common star-fish of the Mediterranean Sea. Here we have one of those jelly-fish so common in temperate and warm latitudes. This is a species common in the Atlantic—one of the species whose substance is more or less phosphorescent. Here is a coral of the Red Sea—a very common species. Here is a cuttle-fish, common on the western shores of France. Here



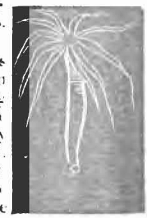
are different species of snakes, some from the East Indies and one from Central America. Here is a clam very common on the south-west shores of Africa—not the common species. Here is the common lobster. Here is a worm, of that species having colored blood. Here is a spider. Here are several skeletons of vertebrated animals—an hyena—an ostrich—a crocodile—an enlarged skeleton of the bat. I do not mention two of these animals, because although represented so perfectly, they are not now in existence. They are nowhere to be found on the surface of the globe; but these representations have been made from preparations most skillfully completed by attaching together isolated bones collected in the neighborhood of Paris, and arranged into a complete animal by the wonderful attainments of Cuvier in comparative anatomy. Thus these long extinct species of animals are as well known to us as if we had perfect specimens of them in our museums.

Now, on looking at these diagrams the beginner in Natural History will be struck by the great apparent dissimilarity between animals which yet belong to the same family. Thus, how little apparent resemblance between the star-fish and the coral! Then again, the cuttle-fish, the snail and the clam appear to have little in common, and yet the affinity between them is so close that they appear to the naturalist as members of one and the same family. And again, the worm, the lobster, the spider and the butterfly belong to one and the same tribe.



The common earth-worm is more intimately allied to the crab or the butterfly than to a snail or slug. One might think that the leech and the slug were of a very similar class. Not so. Mere external appearance alone conveys an idea of identity. There is by no means any actual relation between them. The animals represented in the other diagrams constitute a fourth great division all ultimately allied. The fish and the bat—the crocodile and the ostrich, belong to one great type; and the characters by which they may be defined are not artificial characters. They are not distinctions introduced by Man in order to facilitate his understanding of those subjects and to make his classification easy. This intimate relation between them is a natural one, derived from their internal character.

It is very obvious that here in this star-fish, the star-like rays constitute the prominent characteristic. The rays proceed from the centre.—The same character is perceived in the coral and jelly-fish. Here you perceive a similar radiated arrangement of the parts. The common characteristic of this order of animals is this radiated arrangement from the common centre, the mouth.—The star-fish has at the lower surface an opening through which the food is introduced: precisely the same arrangement is seen in the jelly-fish, which has a quadrangular mouth; so, also, in the case of the polyp, surrounded by these fringes or tentaculæ. In consequence of this peculiarity these animals have been denomnated *Radiated* animals.



The next type contains animals which have very soft bodies and have the power of contracting themselves very much. If you see a snail contract itself and entirely disappear at the bottom of its shell, and again, if you see it grow out enlarging and expanding itself so as to have apparently twice the size of the shell itself, you will consider that this is a faculty which no other type of animals possesses in such a degree. No bird can swell its body to twice or three times its natural size. No quadruped can do that; no insect can do it. It is only in these animals that we see so considerable expansion and contraction. Again, the movements of this type are very sluggish. No one of them can jump or run; they can only creep upon the soil by successive contractions of the body. A few can swim, but when swimming they are moved in a peculiar mode by means of those appendages round the head. Even these have the power of contraction in a degree which no other type of animal possesses, and even here [pointing to the cuttle-fish] the locomotion is owing to this contraction.

The whole body of this class is covered by a dense mucosity, and this mucosity makes these animals very unpleasant to the touch; and it is a peculiarity of this substance to contain a great deal of mucus, which, to some, has a very agreeable taste, so that a great many of this type are among the eatable animals. Nevertheless, a great majority of them please only in consequence of the beauty and value of their covering. For instance, shells, for many centuries, have been one of the subjects of greatest attention among naturalists, and extensive collections of these coverings have been made everywhere, while the animals themselves have been much neglected; and we do not possess in our collections the soft parts of these animals, which would enable us to know them perhaps better than we do by their shells. In fact, when we attempt to classify them from the shell, it is not more reasonable than if we should attempt to form a correct notion of the character of a people by looking at their coats! (Laughter.)

The softness of this class of animals is one of their main characteristics, and they are all symmetrical. They have a right and left hand side, an anterior and a posterior extremity, an upper and a lower side. From the softness of their bodies these animals have been called *Mollusca*.

[Here the learned Professor demonstrated the nervous system of this type by several diagrams on the board which he explained to his audience.]

In the next type, we find together the lobster and the butterfly! Nothing seem more dissimilar than the worm and lobster, and yet the structure is the same. The body of each is formed of rings, each moving on the anterior and posterior ring. The rings may vary in hardness. All do not possess rings so hard as those of the lobster. Some lobsters even have soft shells. Some animals of this class have coverings as soft as the coverings of the butterfly. If we examine the body of any insect, the

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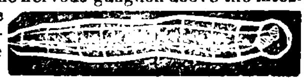
spider, the butterfly or the grasshopper, we find that it is divided into such a series of rings, each movable on those anterior and posterior to it. Even in the worm—the leech—we have such rings, only in them they are very soft. Thus we have already one character by which we can combine the worm with the crab or with the spider. Between the spider and the insect with wings there is scarcely any difference but that constituted by the existence of wings. The wings are appendages of no great importance when considered with reference to the general organization of these animals.

But the more striking and important difference between these two types is again to be seen in the nervous system: and it is a matter of no little importance that the greatest difference between animals should be perceived in the nervous system —in the system which presides over the most important functions of animals, and by which their faculties are exhibited. That again has the most striking character; and always the same arrangement of it, and the same relations to the other organs are manifested whatever may be the external form of the animal.

Now the nervous systems of the worm, spider and crab are so similar that no difference will be perceived except by those who have paid some attention to these subjects. [Here the learned gentleman illustrated the nervous system of this type by diagrams on the board.] In the worm it will be seen there is one nervous ganglion above the intestine, and all the others below—as many active centres of ner-



vous influence as there are rings. This affords an explanation of the well-known fact that many of these animals may be cut into pieces and yet retain the power of regenerating the portions removed from the diffusion of the nervous influence through these different parts of the animal.

These details may appear very anatomical, and have little reference to the knowledge of animals in general, but I hope it will be seen that without such a foundation it is impossible to come to an understanding of the Animal Kingdom—without which we cannot arrive at a knowledge of our own nature. The material, physical condition of our own existence can by no means be understood without a distinct and accurate idea of the structure of the inferior animals. There is really no inherent difficulty in these subjects. Children might just as easily be instructed in this department of natural science as in those subjects which usually occupy the first years of tuition. (Applause)

The type of animals to which I have just directed your attention is called, from the peculiarity pointed out, the *Articulata.*

The fourth type contains those animals which have this bony frame in their interior. Though only the hard portions are represented in the diagrams, yet all have recognized the ostrich and the crocodile. These animals possess what is called a 'backbone'—a continuous column of bones from the head to the tail. Under this column is a large cavity in which the organs of respiration and the intestines are contained. On the anterior part of the body is the mouth—the opening of the intestinal tube; and the nose, the beginning of the respiratory organs. Yet this is not the only cavity in the body of this order of animals. We have in them the head, the cavity in which the brain is contained. We have beside all along the bony column a cavity in which is contained a substance called the spinal marrow, forming another nervous centre. We have in fact two cavities of the body—one above and the other below.

This type of animals has received the name of the *Vertebrata.*

So we have four great tribes of animals characterized by peculiar external appearances as well as by internal differences, of which the nervous system presents as distinct characteristics as any other. Thus, the location and arrangement of the nervous system in the *vertebrated* animals present an essential difference from the other types. In the *Radiata* and *Mollusca* and *Articulata* there is but one cavity in which the nervous system as well as the organs of respiration, of circulation and of digestion are contained; while in the *vertebrated* animals the two sets of organs, those which preside over the functions of the will and those which preside over the functions which maintain the body in its natural system, are distributed in two different cavities; the more important being in the upper and the other in the lower.

In the next Lecture I shall proceed to show that notwithstanding this great variety of form in the Animal Kingdom—notwithstanding the great difference in external appearances—these animals—all of them in their types—are constructed on one and the same identical plan. (Applause.)

LECTURE II.

Infinite Wisdom displayed in the Animal Creation....The Structure of Radiated Animals....General Division of this Type....The Polyps....Their Mode of Subsistence and Digestion....Mode of Reproduction....Have the Polyps a Nervous System?....Coral Reefs.

CLASSIFICATION OF THE RADIATA.

I..POLYPI	(Many tentacles.)
1. *Actinoidæ*	(Ray.)
2. *Hydroidæ*	(Hydra-like.)
II..ACALEPHÆ	(Nettle skin.)
1. *Siphonipheræ*	(Siphon-bearing.)
2. *Discopheræ*	(Disc-bearing.)
3. *Ctenopheræ*	(Having the fins of a crab.)
III..ECHINODERMATÆ	(Skin with spines.)
1. *Asteroidæ*	(Star-like.)
2. *Echinidæ*	(Sea-eggs.)
3. *Holothuridæ*	(Worm-like.)

LADIES AND GENTLEMEN: In beginning these Lectures I endeavored to show that the student of Natural History should aim at a higher object than the mere knowledge of isolated phenomena—that even the study of an accurate classification is not the highest point to which our effort can arrive. There is a more elevated view of the study of Nature than that, which we should always keep in sight when we enter on such a field of investigation. It is to consider Nature as a development of the thoughts of the Creator. Regarded in that aspect every object at once assumes a greater importance, and becomes invested with new and superior value in our eyes.

There was another point which I touched, but on it I shall not now dwell, as I shall repeatedly have occasion to show that it is the true view in which we should prosecute these studies—and that was, that there is a plan, a general plan, in the works of Creation. We will be able to show that even isolated classes are made according to one precise plan; yea, that we must refer at once the creation of these things to the understanding of a higher Power, a greater Wisdom, than man's power or man's wisdom.

After these preliminary remarks, I proceed to show that the Animal Kingdom is constructed according to four different modifications of the arrangement of the parts.

What naturalists intend when they speak of what they call "types" of the Animal Kingdom may be easily understood by comparison. We all know that architects construct our dwellings according to plans conceived by them before the erection of the edifice; and if we take a general view of the works of domestic architecture we shall see that they all agree in one respect. They are spaces circumscribed by walls, covered by a roof, and are designed to afford shelter, comfort, and even all the luxuries of life. All these structures, from the humblest hut to the proudest palace, agree in this general object, and we may say that they are all constructed according to one plan, though it may be subjected to endless variety of modification.

Again, those who have studied and practiced music know very well that they can, from a fundamental harmony, produce a great many variations, and yet among these variations they will very readily recognize the principal tune. Well, in Nature we will readily discover one fundamental harmony throughout the works of Creation, and we will soon perceive that the variations of the different types can all be reduced to that general principle. Nay, we can go farther and recognize in these four types a fundamental idea which is common to all. The fundamental tune in the Animal Kingdom is life, while the endless varieties are the thoughts of the Creator diversified in an infinite degree, and all in such a way as altogether transcends the intelligence or even the fancy of Man. Thus, in whatever way we regard this subject, our contemplations must always at last fix on the great Architect of the Universe.

These four plans are, as I mentioned; first, the *Vertebrata*, to which Man belongs, and the higher animals as we call them, the mammalia, birds, reptiles and fishes. They all agree in one respect—that they have an internal frame of bones surrounded by flesh, and that under this covering of hard and soft parts there are cavities containing the viscera—the different organs by which we digest our food, and breathe, and by which the blood is circulated; and another cavity above that containing the organs of the higher functions of animal life, the brain and spinal marrow, the organs of sense, the nerves. This type has an arrangement of parts which may be expressed by a very simple formula; and as chemists have adopted formulæ to express the composition of inorganic bodies, we may adopt formulæ to express the general structure of organized beings. A figure, then, like the numeral 8 would express the general arrangement of parts in all vertebrated animals. The centre of the two bodies being the body of the vertebral column; the upper arch, or cavity, representing the cavity containing the brain, and forming the upper region of the animal, and this lower cavity containing the viscera—all surrounded by fleshy parts from which some appendages in the higher animals proceed to form the limbs. I shall have occasion to show how the arms and legs all conform to the different arrangements of the *Vertebrata*. We can trace these modifications from the lower type of fishes, where the arms continue attached in continuous form—or snakes, where there are no external legs, nevertheless there are some such organs of locomotion connected with the walls of the body. All these analogies may be traced and be actually shown by direct demonstration.

The next type is that of the *Articulata*: then there is the *Mollusca*, the third; and the *Radiata*, the fourth type. All these three types agree in one respect, that their organs are contained in one and the same cavity. There is but one cavity. But the nervous system, as I showed, differs in its general arrangement, and all differ in another essential point—in the mode in which they are formed.—When speaking of the formation of animals within the egg, I shall have occasion to show how fundamental are these differences. They are such that the germ of an articulated animal is formed just reversely to that of the *Mollusca*. These differences in the formation of the animal have been traced in so many animals from the egg up to the period of full growth, that there can be no doubt on the subject, and there can be no doubt that the peculiarity in the location of the nervous centre in the lower portion of the body of the *Articulata* has reference to the mode of formation of the germ and development of the raw individual.

These facts may be very readily observed in the eggs of the crab and the spider. It is more difficult to investigate this in the eggs of insects, because they are not so transparent. In them the delicate process of the formation of the new individual is not easily traced. But in the crab it is very easy to observe it. I need hardly say that this is one of the most interesting and wonderful things in the study of the Animal Kingdom.

In the first type, all the parts branch as it were in all directions and form a radiated animal; and in these different rays we see sacs of the alimentary canal, so there is no anterior and posterior region, owing to the general adaptation of the parts to the general arrangement. Perhaps the differences which are notorious between the form of types may not be easily comprehended now, but I hope when entering into more details with reference to the structure of the various types to make this part of the subject better understood.

My object in this recapitulation was to show that this division of the Animal Kingdom was really based on this intimate structure—on the very foundation of the plan according to which they have been constructed; and that this division has not been adopted merely for external differences perceived between the various types of the Animal Kingdom.

I shall now proceed to demonstrate the structure of the *radiated* animals.

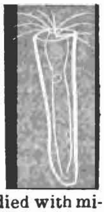
My object in beginning with the lowest type of animals is to show how wonderfully organized are those beings even which occupy the most inferior condition of existence. Their organization is indeed so simple that for a long time they were considered as wanting in internal structure. But more minute investigation has shown that even the lowest of the radiated animals have a structure infinitely more complicated than was at first supposed. They all agree in one respect—they have all a radiated form.

I have here before me one of those animals which show this radiated appearance most distinctly. It is a star fish, of the common species, found living on the American shores of the Atlantic. All radiated animals have not this radiated appearance so distinctly marked; but in most of them it can be readily perceived when they are subjected to sufficient observation. In some it is traced with difficulty, owing to the very minute size of the animal. There are a great many of the radiated animals whose entire length is scarcely a line or even less than that; but there are others again, such as the star-fish, whose size is so considerable as to amount to one or two feet diameter.

The whole type of radiated animals may be divided into three classes: the polyps, containing the coral; the jelly-fishes, and the star-fishes.

In their external appearance these classes do not differ very much. [Here the lecturer directed the attention of his auditors to several illustrations of the various classes of radiated animals.] But in their internal structure they differ widely. All polyps have one single cavity in which all the organs are contained; and all these organs consist only of a large stomach and some groups of eggs arranged around the stomach. By means of their tentacles they seize on their prey. In the centre is the mouth. Here is the general substance of the body, formed of fleshy material, its walls being vertical lines. This animal is very soft in its substance. It is fleshy, and when touched contracts suddenly. It closes its tentacles entirely when touched; its mouth is also contracted in that case, and assumes a spherical form, showing no trace whatever of the beautiful external appearance which you see represented in the drawing. The vertical folds which are here scarcely perceived become marked and distinct.

If such an animal be cut vertically, you will see that it contains one large cavity, with a wide opening below. Through that opening you enter another cavity. The walls of these cavities are folds which are the partitions running to the periphery. Some of these folds will not run to the stomach, and form only subdivisions of the principal partitions. Between the two cavities there is, as I have said, a wide opening. This structure is common to all polyps. The organization of this class is now pretty well known, though it has not been long studied with minute attention. This augmented knowledge of polyps is owing to the efforts of the naturalists of the Exploring Expedition of this country under Captain Wilkes. (Applause.) Valuable contributions to this department of Natural History have also been made by Mr. Dana. His work must always be a standard authority. (Applause.)



On entering into some more minute details of these animals, it will be seen that this organization is very interesting. We can here trace the animal functions in their lowest condition. How do these animals live? The food is seized by these tentacles. The whole surface of the tentacles is covered with microscopic vibratory cilia—little, soft, projecting hairs, so minute as to be discernible only under a microscope of very considerable power. Unless you apply two hundred and fifty diameters—which is a very considerable power—you can scarcely perceive these little cilia. But under such a magnifying power you see the entire surface of these tentacles covered, as it were, with hairs, and these hairs are in constant, incessant motion in different directions. A continuous current of water is thus maintained by these minute appendages. Here again, in the opening, these vibratory cilia are constantly in motion; and in the internal cavity there are also seen vibratory cilia moving constantly. They are not under the control of the nerves—not under the control of the will. They move incessantly. From the moment the animal escapes from the egg, and even when within the egg, they are in motion. During the whole period of life these cilia do not cease to move. They act by day and night. During the rest of the animal, as well as during the more active periods of its existence, these unwearied organs are at work.

Now, it is owing to the action of these cilia that minute portions of organic matter are introduced into the animal's mouth. A considerable space of several inches in diameter is swept by these tentaculæ. All the little particles—imperceptible to the eye—of animal matter, of decomposed vegetable matter, shells, and so on, are thus brought into the mouth, and thus food is supplied to the animal incapable of moving or running after other prey.—This is the mode in which Nature has provided for the sustenance of these animals.

But beside this mode of alimentation, these animals can contract their tentacles and seize upon large prey. Polyps of a few inches in diameter will seize a fish, surrounding it with their tentacles and introducing it into their mouth, after which it is digested very rapidly. Now this mode of alimentation is performed in a very interesting way. The tentacle of such a polyp is a very complicated structure. I had an opportunity lately to study its microscopic structure, and I have found that each tentacle, examined under considerable microscopic power, is a tube whose walls are formed of longitudinal muscular fibres—fibres similar in structure to the muscles of the higher animals. By their contraction these fibres can shorten the tentacle in all directions; or if excited only on one side they will curve it on that side. Then, again, there are other circular fibres around the whole tube, and these pull the tentacle in succession, so as to elongate it to them in four times its usual length. Thus the animal is enabled to seize upon larger prey.

Such is the manner in which the food is introduced into the internal cavity. This cavity is a simple sac, and even a sac which is open at both ends. But then the ends may be contracted and shut at the animal's pleasure. When the whole animal is contracted, both these openings of the stomach are shut, and when the animal has filled its stomach with food the lower opening of the stomach is closed. But as soon as the food is within that cavity it comes in contact with some secretion, probably similar to the bile or the salivary fluid of higher animals. At all events, it is subjected to the influence of some agent the character of which has not yet been ascertained, but should be ascertained, as the animal is very common on the shores of this Continent. Digestion is rapid in these animals. Even shells are speedily assimilated, the hard parts being rejected by the mouth, and the juices produced under the influence of the walls of the stomach are diffused into the lower cavity. The food is introduced into the stomach with a certain quantity of water, so that the food is from the beginning mixed with a quantity of water, but the moment the food has been digested in the stomach, it passes into this lower cavity, and is there mixed with a greater quantity of water.—Now this digested food begins to move in the whole cavity, and to move between all these partitions; and the motion is produced in a way similar to that of the tentacles. These partitions have the whole of their surface covered with vibratory cilia, so that the water containing the alimentary substance is constantly moving between them. The refuse of the water escapes through the tentacles. We have here the digestive function, as it were, combined or mixed with a kind of circulation. There is indeed no blood in these animals—no vessels—no respiration proper. There is only one large cavity divided into two sacs, the upper one digesting the food, and then we have this digested food mixed with water, and this fluid again diffused throughout a great many smaller cavities in contact with the walls of the animal. These walls absorb the fluid like a

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sponge, and the alimentary portions remain within the body of the animal, while the superfluous water escapes through the tentacles. Of course the contact of the water produces a kind of respiration. There is undoubtedly a change of substance constantly produced between the external water and the internal fluid.

The eggs, which are very numerous in these animals, are hung in bunches as numerous as the partitions. There are polyps in which there are twenty and in some a greater number of bunches of eggs hung around the lower opening of the stomach or on the internal wall of these partitions. When the eggs are ripe they escape either through the stomach and mouth, or between the partitions through the tentacles. In the course of this Summer I have witnessed repeatedly this operation in one of those polyps which are common on these shores. They may very often be found on the piles of the wharves all along the shores of the Atlantic. In some of them I have witnessed the process from the earliest stage. When the young animals escape from the egg, they have the same shape as the old one, but with this difference, that they have only five or ten tentacles arranged in such a way (making a diagram on the board); afterward they have five additional tentacles, and so go on increasing till these appendages become almost innumerable. I have found that these tentacles are uniformly multiples of five.

The mouth appears to be circular, but when carefully examined it is found to have an elongated appearance. In fact, the mouth is rather oblong, and in the young animal that form is quite apparent.—You will perceive that in the young animal one of the tentacles is just parallel with the straight line of the mouth, and the four others are arranged in two pairs laterally. This point is important, as I shall show that there we have the first indication of bilateral symmetry with the anterior region well defined.

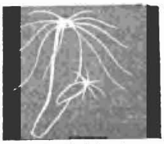
No nerves have been observed in these animals. Nevertheless, we cannot doubt that they feel.—Light acts upon them. They contract under strong light. They also contract under the influence of darkness. In mild light they expand completely. Some, indeed, can expand in the strongest light.—This shows certainly that the sensation of light is perceptible to them.

In some of the polyps I have observed dark specks, corresponding in number with the tentacles. We may be allowed to conjecture that the specks are eyes, and if so there can be no doubt that there are nerves. In fact, in the star-fish the nerves have been seen. They have been traced up to these colored specks.

This is about all that can be said of the structure of the polyps. Their external form is very various. I will mention some of them in order to show the variety of types among them. All those which have numerous tentacles, and the internal cavities with bunches of eggs hanging from the walls of the lower cavity, have been named sea-anemones.—Some are entirely soft. Others have, inside, a hard framework formed of limestone—of carbonate of lime—and in this framework one can see the same radiated appearance which we can see in the type, which is entirely soft.

You see in this specimen an illustration of the remarks just now made. It is not correct to regard these corals as the shells in which these animals cover themselves. The hard parts are found within the animal and form a portion of their internal structure. There are a great many of them in which the hard parts are deposited within like network. [Here the lecturer pointed to specimens in illustration.]

The polyps do not all multiply only by eggs, though all will lay eggs and multiply in that manner. Some produce buds on their surface. and these buds will grow and remain attached to the main body, and in that manner the buds will become branched. Perhaps a little polyp attached to a rock assumes such a form. After a certain time we see a small bud, which enlarges in the same form, and grows and pushes out its tentacles in the same manner as the first individual. Thus from this branch a new individual will be formed and remain connected with the parent stem. In that manner we have compound animals, and that is the case with most of corals where a great may individuals are united in one and the same stem, while others remain single.



The importance of these animals is very great, from the well-known coral reefs. Beside, these animals act in a very extensive manner in modifying the shades of the ocean's depth. They contribute in the formation of islands and in enlarging continents, by increasing the amount of hard substances deposited on the surface of the earth. We know from geological researches that whole mountain ranges have been formed by the agency of this minute animal. But this is not the place in which to speak of this geological phenomenon. I allude to it at present only for the purpose of showing the importance of the functions performed by this little animal in Nature. There are some polyps which produce eggs and buds, but it is only some of the latter which can in their turn produce eggs. A great many of the animals classified in the *Infusoria* are only eggs of polyps and other lower animals swimming freely by the agency of their vibratory cilia, which cover [the surface of the egg-shell. The seeds of plants are in the same way covered by cilia, and, moving freely in the water, are also often classed with the *infusoria*. There are plants called *Confervæ*, divided by partitions in the manner which I have described, and the seeds are covered with vibratory cilia, moving so freely in the water that they cannot be distinguished from the lower animals. They are so minute that an examination of their internal structure is a matter of very great difficulty. If we could only ascertain whether they have a stomach, their position among organized beings would be very easily fixed. But as they are so minute that the highest microscopic power discloses only these vibratory cilia, and as there are animals which have been discovered to possess a stomach very closely resembling them in external appearance, it is very difficult indeed to determine whether they belong to the animal or vegetable kingdoms.

Locomotion, as such, is not a distinctive character of animal life. It is only the wilful motion under the action of nerves which is characteristic of the Animal Kingdom. But vibratory motion, produced by these minute hairs covering the surface of minute animals and plants, is common to organized beings in general, and is found as well in the vegetable as in the animal kingdom.

Polyps are divided into two great families: the *Actinia*, in which the eggs are arranged in bunches internally, and *Hydroida*, which have tentacles in the same manner as the others, but in which the eggs hang in bunches externally from the lower end of the upper cavity, in graceful forms and sometimes beautifully colored.

The hour is now so far advanced that I cannot enter into the consideration of other classes of radiated animals. I shall take them up in my next Lecture.

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LECTURE III.

Additional Facts Relative to the Structure of the Polyps....The Grand Distinctions between Animals and Plants.... Organization of the Egg....The Acalephæ....Structure of the Jelly-Fish....Phosphorescence of the Ocean in part produced by the Medusæ....Difference between the Polyps and Medusæ....Mode of Growth of this Species.... Discoveries of Sars, Krohn and Chamesso....The Echinodermata....Interesting Field of Investigation Open.... Structure of this Species....Mode of Locomotion....Digestive and Circulatory Apparatus....Evidence of Design in this Department of the Work of Creation.

Ladies and Gentlemen: The last Lecture was occupied in tracing the characteristic features of the polyps—the lowest of the radiated animals. I showed how simple, and nevertheless how beautiful and well adapted the structure of these animals is. We find in them only one organ, and yet we find almost all the functions of animal life. That one organ is the stomach—an ample cavity with two openings, a mouth and a hole at the bottom of the sac emptying into the general cavity of the body; thus the food when digested is mixed with water which constantly fills the general cavity of the body. This mixture of sea-water is constantly set in motion by capillary cilia or hair-like appendages covering the whole surface of the internal cavity as well as the internal cavity of the tentacles, and by the partitions which run from the external wall of the animal toward the centre of that cavity thus filled with water, which is then kept in motion in different currents, some ascending, others descending, so that there is constantly kept up a circulation of the digested food. The walls of the animal are permeable to this liquid—that portion which is nutritive remains in the walls of the animal, while the water which has been the vehicle for this food is pushed out by the contraction of the animal.

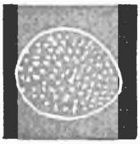
There are two exits for the food, either through the mouth again, or by the small openings in the tentacles. The water which fills the general cavity enters also through the tentacles and the mouth —alternately through one or the other. But as there are muscular fibres similar to the flesh of higher animals which can be elongated by gradual contraction or expansion, this cavity can be alternately shut, so that by the contraction of the mouth the introduction of water may be allowed or prevented. The contents of the stomach may be kept within the cavity by the contraction of the lower opening of the intestinal cavity, and again the tentacles can contract at their end and so prevent the water from escaping; and while the digested food is moving with the water within the cavity, with the tentacles thus contracted, nothing escapes —but after the nutritive portion of the food has been absorbed by the walls of the animal, then the water is allowed to escape through its mouth, as well as the other opening. An agency or influence is undoubtedly exerted upon the surface of the animal by the surrounding water which may be compared to the respiration of animals that live in the water. There is something similar to bronchial respiration in some of the lower animals, especially the Mollusca, where the action of the water acts on the fluids in the animals and produces upon them a change which enables the fluid to become a portion of the living creature. These changes are very complicated and not all fully understood.— There is much room for investigation with reference to the changes which the food undergoes in order that it may become a portion of the living animal. What is more wonderful than what we see every day—a cow grazing and turning the grass into brain, muscles, bone! That is constantly going on; and different animals produce the same changes upon common food, with different organs, but in all the same result. Thus the same food is transformed in one case into the body of the hare; in another into that of the deer; and in another into the body of the elephant. With the same food these animals not only reproduce, but create, as it were, their bodies, under the influence of the primitive material principle which is the cause of their existence.

Another system of organs existing in the polypi are the ovaries, hanging in bunches either in the internal cavity or outside on the tentacles. These two forms have been the foundation of the two great divisions of the polypi, namely, the *Actinoidæ*, the name derived from the Greek word for "ray," and the *Hydroida*, because these animals resemble that one which has been called the hydra —a name reminding you of a fearful animal. Thus these harmless, minute, almost microscopic animals have received that formidable name.

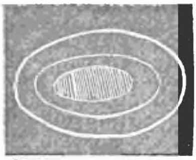
You see here (pointing to a diagram) eggs forming on the outer side. Some are not isolated as in this case. In many instances the eggs hang in bunches —as you have them here, for instance, in another diagram.

I then alluded to other differences in polypi, where some were isolated individuals and others combined; the latter budding on one and the same stem, thus forming three large groups of individuals united by their base. It is a peculiarity of polypi to be fixed on the soil. There are no free swimming animals among them. Some are attached to other bodies at the bottom of the sea. Some are fixed at will or move at will from their location; but there are none among them who swim freely in the water. In this respect many of them have some likeness to plants, and were indeed long mistaken for plants. Even so late as the middle of the eighteenth century, naturalists quarreled about the vegetable or animal nature of polyps. But it is now fully understood that they belong to the Animal Kingdom; while, on the other hand, many organizations which belong truly to the vegetable kingdom have been introduced among the polypi, and must of course be rejected from that class and be again classed among the plants. There is, indeed, some difficulty in distinguishing some of the lower types of plants and animals. I have already alluded to one grand distinction between them. The existence of a stomach is a chief characteristic of an animal, and no being should be introduced into the Animal Kingdom in which a stomach does not exist. But as there is great difficulty in ascertaining in some of the lower animals whether there is an alimentary cavity or not, we must take other characteristics by which they can be distinguished; and we have now a very remarkable test by which we can determine whether an organized being is a plant or an animal. In the mode of respiration we may, by chemical analysis, discover whether an animal or a plant is before us. All animals in respiration assimilate oxygen and reject carbon, while plants assimilate carbon and reject oxygen. There is thus a constant antagonism between the animal and vegetable kingdoms. All animals would die were it not for the breathing of plants, and all plants would perish did animals cease to respire. The antagonism is such that the whole amount of animals living, now consume precisely the amount of oxygen which plants expel during the night, and by this antagonism between the animal and vegetable kingdoms, the constant and unvarying equilibrium of the atmospheric air is maintained. Now when we want to know whether we have before us a microscopic animal or a microscopic plant, all we have to do is to examine the nature of the gas absorbed or expelled in respiration.

Another test may be as certain. That test consists in the examination of the egg. The eggs of all animals, without any exception, from the polypi up to the mammalia, are identical. There is not the slightest difference in their structure—in the internal and minute structure of the eggs of all classes of the Animal Kingdom. There are differences in size but not in structure. The egg of a fish is full of granules. In the class represented in this diagram they are about the size of a pin's head. In some fishes the granules are still more minute. Inside of this yolk there is another little vesicle which is called the germinative vesicle; and in that we have either another or several cells of a smaller size which are called germinative dots. These cells in a cell, containing granules of yolk, constitute a characteristic which you will find without exception in all eggs. In a bird's egg, the shell and white of egg are accessories, but not necessary to the actual formation of the chick, which is formed from the yolk, and not from the white or any other portion of the egg.



Now this yolk, or *vitellus* as it is called, fills the essential portion of the egg, and within that is another vesicle filled with a transparent liquid in which several other similar vesicles swim. This constant and uniform structure of the egg affords a test whereby we can ascertain whether the organized being before us is an animal. The eggs may be as easily perceived in the lower animals as in the highest, as they are so transparent that they are readily examined under the microscope. Now these eggs differ entirely from the seeds of plants. Even in the *confervæ* these seeds are filled only with uniform granules and have no intricate minor cells; and now, when these eggs become movable by having the whole surface covered with vibratory cilia, we have only to put them under the microscope in order to decide whether we have before us the seed of a plant or the movable egg of an animal. (Applause.)

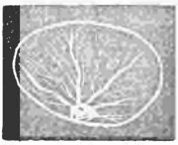


I will now proceed to demonstrate another class of these animals—the *Acalephæ*, or "nettle-skinned."

The name of this class is derived from peculiarities in these animals which I shall immediately explain. You have examples of *Medusæ* in these diagrams. They have many relations to the polypi, but there is one general characteristic which will strike you when it is mentioned. The medusæ are all free—independent of the soil. They have no point of attachment. They cannot fix themselves upon the soil. They have no means by which they can become attached; and all have the mouth downward, while all polyps have the mouth upward. In the very position of the animal in the surrounding element we have one great difference, which is as constant as the most intricate peculiarity of their structure. There are a few moving animals in which the difference of internal structure between them and the polypi is by no means very apparent; they have not one organ more than we have seen among the polypi, only a little complication of the same organs.

In the jelly-fish we have a broad disc, and in that a wide cavity, with a mouth in the centre, from which several, sometimes numerous, appendages hang down. This is the simplest structure of the medusæ. There the mass of the animal is constantly gelatinous. The bodies of this class are exceedingly soft, so much so that when taken out of the water they almost wholly decompose and disappear. They contain so very little substance that a cart-load of them would not, if dried by evaporation, leave an ounce of hard substance—of dried membrane. A single leaf of paper would contain as much solid matter as a full cart-load of these animals when dried. They are so liquid that they are transparent—so much so that they are frequently not seen in the water, and would not be perceived at all if it were not for their beautiful colors. They have, indeed, the most beautiful, delicate colors of all the lower animals. Again, a great number of them are phosphorescent. In the night they appear like brilliant lights, and to some of them is owing the phosphorescence of the sea;—not to them solely, for the phosphorescence of the sea is produced by a great number of animals. Very numerous and different species of animals produce that peculiar, beautiful light that illumes the sea during the night. Some of these animals belong to the articulated types, others to the medusæ; some are polyps; and perhaps the light is in part owing to physical causes—the decomposition of animal and vegetable matter; and perhaps also to electricity. There is some doubt as to the relative agency of these various causes in producing the phosphorescence of the ocean.

The great difference between the medusæ and the polyps is that the alimentary cavity is no longer a simple sac with simple openings. The cavity has branches penetrating into the substance of the animal, so that we have no longer a simple sac opening into the general cavity, but a sac with ramifications. You perceive in this diagram some of these ramifications. They are so delicate that they can hardly be shown without exaggerating the colors. Let me illustrate this peculiarity of the structure of this class of the radiated animals. Let that (diagram) represent the central opening, sometimes angular, sometimes pentangular; from that, light appendages extend toward the periphery, but soon divide like blood-vessels; and these sacs will sometimes divide with numerous tubes, and form as many canals as the most complicated blood-vessel in its divisions. In that way the food, after it has been digested, is carried into the parts. It is no longer in contact with one surface only. It is now carried into the different parts of the animal. It is as if the stomach were at the same time a heart, forcing the digested food into the cavities, as the heart propels the blood into all portions of the body. But here this food, after it has arrived at the periphery, escapes. There are as many outlets as there are tubes. And again, there are from the periphery numerous minute appendages, like tentacles, with an opening at the end, which absorb, pump the water and introduce it into a canal which runs all round the animal. So we have no longer the food introduced into a cavity containing water, but we have the alimentary canal branching in all directions; and in the extremity of these branches we have small tubes absorbing water and mixing it with the food. These tentacles form beautiful appendages in a great many of these animals. They vary very much in different



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animals. In some the appendages are longer than the body of the animal itself. In others they are quite short. In some they meet regularly and form triangles. In some they are few in number, but of large size. But in all they are hollow, and they absorb water, and also admit the digested food, which is circulated through these tubes and introduced into this circular canal. The motion of the fluids is not in a uniform direction. Sometimes it is one way, sometimes another. It is an irregular circulation, which changes its direction. In some of the higher animals, the heart causes the blood to rush in one direction, and, after it returns, propels it in another direction, so that in one and the same animal we have the heart acting in different directions, and we have that singular phenomena in some of the medusæ. In this respect we have a complication which exists in very few of the polypi. It is round these appendages that the ovaries usually hang in large bunches. These colored bunches are bunches of eggs hanging outside the tentacles which surround the mouth.

In some of these animals, colored specks have been seen between the tentacles, usually red, and they have been conjectured, not without probability, to be eyes.

This is about all that is known of the structure of these animals. There are several varieties of them. Some have large gelatinous discs; they are the common jelly-fish. Others have a large vesicle above the tentacles and compact portion of the animal, which allows them to swim on the surface of the water. Others have a great many of these vesicles. Others again have vertical series of singular appendages acting like oars, by which they move very rapidly in the water The locomotion of the first class, those having a disc, is owing to the expansion and contraction of the disc. The locomotion of the second class is owing to the motion of the tentacles and the contraction of the air vessels; while that of the third class is owing to those series of vertical appendages.

In their mode of growth they present most extraordinary phenomena. Not all of them have been studied, but those which have been examined present these phenomena. The Swedish naturalist, Sars, has discovered that the eggs of the common medusa of the Baltic Sea were movable. This might appear almost incredible, had not repeated subsequent observation established the fact. I shall endeavor to illustrate the formation of the egg. In an egg of this form the enlarged upper portion begins to grow with four appendages—these appendages forming a star-like animal. It gradually changes its form, and assumes the appearance of the polyp, for which it has sometimes been mistaken. The number of tentacles increases; as many as sixteen and twenty tentacles are now seen, with much change in the general form. Then a considerable change commences. This animal, with all its tentacles at the upper end, begins to contract, transversely, just as if it were pressed in different places; and these contractions increase, so as to form, very soon, several stages one above the other, like a series of independent cups, only from the contraction of the primitive trunk of this polyp-like animal. This internal column, resembling the back-bone, which keeps them together, still continues to contract so far that the cups soon divide into as many individuals, and become free, movable from that time, and turn in opposite directions. Before they separate, the margin is fringed—divided in such a manner as to be fringed; and the moment these divisions are separated here, then the animal turns the opposite way and we have here a disc with fringes round it, turned in opposite directions. We see a cavity forming here. We see appendages here formed, and we have very soon a regular medusa! (Applause.) Thus after a series of various formations we have several distinct individuals produced from the single egg.—The number of animals thus produced from one egg is sometimes as great as a dozen, and even more.

But what is very singular in this process is this—that the upper portion of the animal does not undergo these changes. The moment the animal divides into these numerous young medusæ, this dies off.—The upper portion of the stem dies away, and it is only the lower divisions, formed in the manner I have described, which constitute new individuals.

More extraordinary phenomena are observed in another type of the medusæ similar to these. In a species little known and not observed that I know of on the American shores of the Atlantic, we find a compound animal—several individuals being attached to one another and swimming freely in the water. They have all the general arrangements of the medusæ. They have been described by numerous naturalists, and two varieties of them have been noticed. Chamisso, the Prussian naturalist, remarked that one variety of these combined animals had always isolated eggs, while the other had eggs in bunches. He was induced to admit that these ten types were of the same species, being only different stages of the same being. This was regarded as rather inadmissible, until lately a German naturalist named Krohn, in the course of investigations on the coast of Sicily, ascertained distinctly that it was the fact, and that in one and the same species there is a set of isolated individuals having eggs which never separate and form individual groups of animals, while each individual of these bunches lays isolated eggs, which form free, unconnected individuals. So then we have successive generations which do not resemble each other, and in which the grand-parents are similar to the grand-children, but the intermediate generation never like that which precedes or follows it! We have in mankind something to remind us of this curious phenomena. We find family likenesses, as they are called, go through two generations, omitting the intermediate. Certainly that is a corresponding fact to this.

These phenomena it is somewhat difficult to trace, as it is necessary to follow for a long while the same individual, but they have been ascertained beyond a doubt, and especially through the care of the Swedish naturalist, Sars. It is singular, I may here remark, that a gentleman should be found in a country so poor in interesting natural phenomena ready to devote himself to the minute investigation of these phenomena, and succeed in so eminent a degree. In some other portions of Europe, on the contrary, where the facilities of prosecuting such investigations are very remarkable, comparatively little advance has been made in natural science.

The next class of which I shall speak is the *Echinodermata.*

The internal structure of this class is more complicated than that of the preceding, though it follows the same plan. We have here also the organs arranged as rays round the central cavity. This central cavity contains numerous independent organs. While we had in polyps and medusæ the function of digestion and respiration produced by one and the same cavity branching within the recess of the body, in this class we have an alimentary cavity forming a stomach and extending sometimes in several circumvolutions through the body; and the respiratory function performed by independent appendages. The fluid is set in motion by organs always independent of the alimentary canal as well as respiratory organs, though all in connection, and in connection similar to what obtains among the medusæ.

Many of the facts which I shall add now were not fully ascertained until lately. But recently I had an opportunity of studying the internal structure of this class while on board a vessel employed in the Coast Survey. I have thus been enabled to observe more attentively the star-fishes, and discover how intimately allied they are to the medusæ and polyps. I may here be permitted to remark that, notwithstanding the material which is at hand on the shores of the Atlantic for the study of the whole of the types of radiated animals, there is no work existing on the polypi of the American coast; there is no work in which you can find even a dry catalogue of this species. Though so many beautiful works on the Natural History of this country, and especially of this State, have been produced, it is somewhat surprising that there is no record whatever of the radiated animals. There is no work on the medusæ. These three classes of Radiata afford an ample field of investigation, and one which will fully compensate the labor bestowed upon it. It is due to the cause of Truth and Science that the public teacher should not only ascertain what is known, but also what is to be done; and here a great deal is to be done, this group having been much more neglected than others of the Animal Kingdom. (Applause.)

The most admirable arrangement is seen in the external covering of the Echinodermata. It will scarcely appear credible that these two specimens are formed of the same hard plates, arranged in the same manner, only of different proportions, so that one presents a sphere-like and the other a star-like appearance. But if in the one case the plates were a little elastic, it would be easy to change the form of the star-fish into that of the echinos, and *vice versa*. After I have shown the structure of one of these animals, I trust that this statement will not be regarded as at all exaggerated.

You see two openings in such an animal—an upper and a lower—not always opposite each other. I shall begin with the simplest class, before approaching the other. Around this simple opening five large plates are placed so as to leave a space between them, and five smaller plates occupy the interstices. In each of these large plates there is a hole. Through these five holes five tubes open. Through these the eggs escape. The plates of the body are arranged in a series of very different kinds. Alternately we have a series of plates perforated and a series of plates imperforated. Upon those plates without holes we have large tubercles, upon which the tentacles or spines are movable. These form, as it were, ten vertical ribs from each of the openings to the other. Through the holes of one of the series little tentacles protrude, having an opening in the end, and which can be retracted and pushed out so as to disappear or extend even beyond the points of the spines; and by these tentacles the animal can move as well as by the motion of the spines. These plates, which are imperforated, are just opposite to the large plates. Those which are perforated, are intermediate. They all meet at the lower end, where there is another large opening, and this lower opening is the mouth.

The spines are movable, and it is their motion which enables the animal to walk from place to place. In some, the power of locomotion resides in the minute tentacles in the plates.

The food is introduced through the mouth, and is crushed between very powerful plates. You find the jaw very complicated. The complication is so great that it would require a full hour to explain merely the structure of this part of the animal.—There is scarcely any portion of the organization of the animal creation more complex than the jaw of these animals. It is formed of almost innumerable hard plates, furnished with teeth, moved by very distinct muscles, and put in action by a complicated nervous system. I will mention merely that these jaws are five in number, and are arranged in such a manner as to correspond with these ten series of plates. One jaw is always before an imperforated plate. These jaws are so powerful that they can crush shell-fishes and the hardest bodies. The intestinal tube is a wide tube provided with several appendages, so as to make it more complicated than in any of the other radiated animals.

But what is more singular in these animals is the existence of a heart and actual respiratory organs. These tubes, which can be protruded through these small holes, terminate by a hole, and inside of the shell there is in each of these tubes a considerable vesicle which is filled with water, upon which there is a number of blood-vessels. But here these tubes can be shut, and there is another apparatus for injecting these vesicles in the tube. I should have mentioned that one of these plates is larger than the others; and there is then a sieve of little holes by which the water can enter into the body; and by another tube which comes down in that way and reaches to the lower opening, all these minute vesicles can be filled; so that there is an alternate movement of the water from outside and through these tentacles and shell to maintain a current upon the organs which are covered with blood-vessels. Respiration is nothing but an interchange of air and liquid moved in vessels. Here we have all these conditions in the interior of the echinos, the heart being placed near the intestinal tube.

Still more, we have a complete nervous ring around the jaws and from five points of the ring threads arising and proceeding along the imperforated plates so as to reach the upper ridge where they terminate on the five smaller plates which are perforated. In each of these holes we have an eye, so that we have five eyes at the termination of those nerves arising from the ring around the mouth.

There are two principal forms of the echinos. The star-fishes are one of these principal formations, and are by no means so simple in structure as the polyps. They have a peculiarity not easily explained. The whole body is full of water. We have a similar general cavity as that found in the polyp and jelly-fish, but no hole by which the body could be filled. This hole forms the mouth, but the mouth and the intestinal tube do not communicate with the general cavity of the animal. Again: these perforations through the shells, by which the tentacles come out, have no communication with the internal shell. The question, then, was—How does the shell fill with water? No opening was seen. But there are really openings, so minute as to be seen only under a high microscopic power; and I have been fortunate enough to ascertain that these holes exist. I have even seen the membraneous tubes which pump the water and fill the whose cavity of the animal. These are so extremely minute that they cannot be seen by the naked eye until it becomes accustomed to the investigation of them. Then they are just as plain as any other part of the animal. But they are extremely contractile, and the moment the animal is touched they become retracted and will not be seen for a long time. I have injected these tubes with colored matter; and by keeping the animal in colored fluid, I have demonstrated that there can be no doubt of the fact of their being the apparatus by which the water enters the animal.

Notwithstanding all these complications, there is only one plan in these animals. All have one central cavity, an alimentary canal. This canal is either a single sac, or it is an alimentary tube complete of itself but with an independent system for respiration and circulation. But the arrangement of the blood-vessels is such that there is the strongest likeness between it and the arrangements of the circular canal in the medusæ. One and the same plan are apparent in all these complicated structures. The question is, what does such a plan indicate? Have we here only material phenomena, evincing the influence of physical causes in the combination of various organs, so as to form a system more or less complicated? No; we have more than that. We have a succession of forms which show a progress. We begin with a lower type. We pass through more complicated types. We come to the very complicated form of the echinos. And, though these forms are so complex, we find them in the same type of animals, in the same climate and in the same conditions of life. In all parts of the world—in the most different conditions and in the most similar conditions—in the arctic, the temperate and the tropical regions—we meet these varied classes of the same type, so that the whole amount of external circumstances in which any organized being can exist, are acting on these animals. It would be very unreasonable, then, to admit that all these varieties were produced by these external conditions.

Again: Have we a mere complication of organs in these animals? No. We do not trace only material phenomena. It is not we, who by our investigations have made these creatures to agree on one and the same plan. They exist on one plan; and instead of tracing material phenomena, we actually trace thoughts, and thoughts not ours—but the thoughts of that Mind which created them. I think in this way it can be shown by sufficient evidence that there is an Intelligence which planned these things, and formed and created them on a premeditated plan—a graduated scheme of structures from the simplest to the most complicated; and that each animal was endowed with the power of so resisting the influences to which it is subjected as to retain its original conformation under the most diverse conditions of climate and circumstances.

LECTURE IV.

The Calcareous Deposits of the Polyps....Why the Polyps cannot be considered higher than the Acalephæ....The Mollusca—their great number....Recapitulation of the Structural Characteristics of the Radiata....Entirely different arrangement of Organs in the Mollusca....Softness of the Mollusca....Contractibility....Nervous System....Alimentary Cavity becomes complicated....The Respiratory Organs....Structure and Position of the "Gills"....Organs of Circulation....Extraordinary Structure of the Blood-vessels....Theory of the Formation of the Blood and Circulatory Apparatus....Subdivision of the Mollusca....The Acephalæ....Characteristics of this Class....Mode of ascertaining the Type to which Fossil Shells belong.

Ladies and Gentlemen: Since the delivery of my last Lecture I have received several letters asking questions relative to the structure of the Radiata, which I shall be happy to answer as far as in my power:

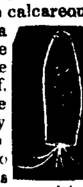
"Is the carbonate of lime, which forms the coral formation, secreted by the polyps from the food upon which they subsist, in a way similar to the bones of other animals?"

"Are not the Polyps a grade higher than the Acalephæ, inasmuch as we have in them the first exhibition of bony structure, which appears more perfectly in the Echinodermatæ, the next higher grade?"

These questions relate to one point—What is the proper value of the hard calcareous matter which is secreted in the polypi? This calcareous matter has not been long investigated. In fact, the first correct work on this subject is to be found in the volume alluded to, forming a part of the Narrative of the Exploring Expedition. In that beautiful work of Mr. Dana, we have for the first time the results of accurate and patient investigation of this subject. He showed what was not known before, or what at all events was not understood, that the limestone portions of the polypi form a portion of the animal, and not mere excretory matter, similar to shell. They belong to the body of the animal, and are not a deposit of the external parts of it; and in this respect they are really altogether different from the shells of the Mollusca, which are secreted within the skin.

To explain fully this difference, let me enter into some details relative to the structure of the skin. The skin in animals is composed of three layers. If we cut through the skin into the body of any animal, we find first a superficial layer composed of cells, very readily seen. Under that is a network of vessels and nerves, the latter giving to the skin its sensitiveness—the sensitive portion of the skin. Then we have a third layer: a tissue of threads intricately interwoven in all directions, forming the protective layer. These three different portions have different functions.

The external layer is constantly reproduced by blood-vessels, which deposit a liquid in the vessels already formed and from which the new vessels are constantly formed. When the skin is cut we sometimes see a transparent fluid escape from the cells and accumulate on the surface: and this lymphatic fluid, as it is called, is the medium of the reproduction which is always going on. Now, in the Mollusca, the shell is formed in this layer by successive deposits of limestone, into which I shall not now enter as I shall have occasion to go farther into these details by and by. But let me now mention that between the upper or external coat of skin, which is called *epidermis*, there are layers of limestone in that way by the secreting portions of the skin formed of a network of blood-vessels, so that the shell is formed of calcareous matter formed within the skin itself. Not so in the polyps, where the mass of the animal—the walls of the body—secrete within the substance the calcareous portions. I make here the outline of a polyp, with its tentacles: here is the mouth, here the walls. Now, within the walls, in the mass of the body itself, there are little fragments of limestone deposited in an irregular way, entirely unconnected with each other, which separate in several, but in others unite to form a porous mass; and these calcareous particles are sometimes formed in such quantities as to form an internal framework, covered w



soft parts of the animal. So you perceive that there is not only in the position, but also in the mode of deposition of the limestone, a great difference between the polyps and the shells.

Again, this skeleton, or this frame of solid parts within the animal, cannot be considered as identical in different types. The skeleton of the vertebrated animals is not only carbonate of lime, but it is, even chemically speaking, somewhat different. It is a carbonate and a phosphate of lime; and in this respect there is already a difference; but the difference is still greater when we consider the general arrangement and relative position of the internal skeleton of these animals, and the external skeleton of the shells, or the internal skeleton of the polyps. In the polyps these solid parts do not protect any essential organ. They are within the walls of the animal, but the soft surfaces of these walls are the parts which protect the intestine and form the internal cavity; while the bones themselves protect the large cavities of the higher animals, circumscribed to spaces in which the brain and spinal marrow are on one side, and the alimentary canal, the heart and the lungs on the other side, are contained. So that these two systems are by no means to be regarded as identical. They are identical only in one respect. It is true that these hard parts protect the body in general; but in an essential point they are different, inasmuch as they are formed in a different way, formed by different portions of the animal, and sustain different relations to the various internal systems of organs.

Much remains to be done in the investigation of the corals themselves. The proper organs of secretion of those hard parts in them are not known. It has not yet been ascertained in what way the calcareous matter is secreted from the soft parts.—There is, then, here also an ample field for investigation. Unhappily, this investigation will scarcely be attempted on these shores, as there is only, as far as I know, a single species of calcareous polypi on the western shores of the Atlantic, north of the Gulf of Mexico.

The other question—Whether the polyps are not higher than the acalephæ?—is answered by itself. If the calcareous parts of the polyps have not the same meaning as the analogous parts of other types, the existence of such a hard skeleton will of course not be a test for the degree of their organization. And again: we have among polyps themselves, some with, and others without hard parts, and even the great amount of calcareous matter which is deposited in many of them will never be a sufficient reason to consider the polyps in any way higher than the acalephæ, as the alimentary cavity is a simple sac in polyps, while it is a branched cavity in acalephæ, performing at the same time the functions of a digestive tube and circulatory organs.

—We now enter into another field of the Animal Kingdom—into the study of the *Mollusca.*

These animals are very numerous. The number of species which have been collected at this time—including those only which are provided with shells,—is perhaps six thousand, perhaps even as high as seven thousand; and we may suppose that the whole number existing now, will not fall short of ten or twelve thousand, if we include the soft, naked species as well as those protected by a hard calcareous shell. The number of species which have existed in former ages—in geological times—whose remains we find in a fossil state in the successive strata which constitute the crust of our globe, is still greater. It is astonishing what a quantity of fossil shells are found in the different strata of the crust of our globe. There is scarcely any locality which has been well examined that does not exhibit almost as many fossil species as we find on any extensive coast of any sea. Compare, for instance, those shores which have been most investigated—the shores of France for instance—where the shells from the time of Lamarc up to this period have been so assiduously collected. There the number of species known to exist, when compared with the number of species, found in one and the same stratum of the tertiary deposits in the neighborhood of Paris, is much smaller. There are scarcely eight hundred living shells found in the Mediterranean or French shores of the Atlantic Ocean, but more than twelve hundred fossil shells have been found in that single stratum—in that limestone on which the City of Paris is built, and of which such extensive deposits exist in the neighborhood. In that single stratum is found at this day one-third more fossil shells than live on the whole extent of the French shores! This will show how large the number of fossil shells must be, and how large it will turn out to be, as soon as we have made more extensive researches in the field of fossil shells.

To understand properly the character of the Mollusca, it is well perhaps torec apitulate briefly what I have said of the Radiata; as the differences between the two large types is less in the details of their organization, than in the mode of the arrangement of their organs. The Radiata have their organs distributed around the centre. This centre is the mouth, and the mouth is turned either upward. We have the mouth upward in the polypi, downward in the echinodermata. Nowhere have we the mouth on the anterior portion of the body. Among the Radiata there is no anterior extremity which prevails over the sides or posterior extremity. All the rays diverge from the centre and are of equal value, and when we can trace some indications of a bi-lateral symmery it is owing only to slight differences between these rays, and not owing to any general arrangement on the two sides of a longitudinal axis. There is no longitudinal axis proper in the Radiata.

In the Mollusca we have an entirely different arrangement. The mouth moves toward one end of the animal, and now we have an anterior extremity, though we have not yet a head—not organs of sense placed always round the head. But there is at least an anterior extremity, on which the mouth is situated, and round it there are tentacles by which the food is introduced into the alimentary canal. Thus the anterior extremity is given by the position of the mouth, and the two sides by the general arrangement of the viscera. We have not only an anterior extremity but we have a dorsal region, a right and a left-hand side—a lower and an upper region—and in all the Mollusca those regions can be readily distinguished, though the animal does not always stand on the lower extremity. There are some who for their whole lives rest on one side. For instance, the oyster lives constantly lying on the left-hand side; others are attached by the upper extremity and stand the lower extremity upward, and it is only by means of comparison that we can ascertain which is the right and left hand, and by finding where the mouth is placed and by examining the relative position of the different internal organs.

The body of the Mollusca is always very soft. Hence their name Mollusca, which signifies "soft animals." The body is exceedingly contractile. It can be contracted so much that large animals will occupy a very small space when contracted. For instance, the animal which

forms this shell, which is, as you perceive, of large size, and out of which it pushes a large foot on which it walks, when contracted is entirely concealed in the bottom of the cavity. In others there are two shells which cover the soft parts. Sometimes there is but one shell very much curved on itself; and in other cases forming only a flat disc, covering only the upper part of the body.

The softness of these animals is very characteristic, and in no other type do we find tissues so soft as in this class and so capable of containing a great quantity of water. They continually absorb a certain quantity of water, which penetrates the mass of the body and maintains it in a state of expansion. But when contracting this water, is expressed in a way quite similar to the water contained in the sponge when it is squeezed.

The organization of the Mollusca is, in some cases, highly complicated. In others it is as simple almost as in the polypi. The difference in the latter case is only in the symmetry. The mouth being in the anterior region, and the nervous system surrounding the anterior extremity of the intestinal canal in a vertical position, while in the Radiata the nervous system is placed horizontally. The nervous system is placed above the intestinal canal,forming a ring around the tube; with some other ganglia below, from which the nervous threads run into the different organs. From the upper ganglion we have nervous threads going into the tentacles. Here are threads going to the other organs placed in the cavity of the animal; and here are threads running into the muscular fibres which move the animal. A similar structure is found in those having two valves, only the symmetry is somewhat different. Always the nervous system is composed only of a swelling above and a swelling below the alimentary canal from which the threads are sent to the different organs. That is the general arrangement of the nervous system in all the olluaca; the Malimentary tube passing through the nervous ring, but the ring having a vertical position, while in the Radiata it has a horizontal position.

We see the difference here is rather in the position of the organ—in the relation with other parts —than in the structure. This nervous system is scarcely any more complicated than the nervous system of the star-fish, or echina. Perhaps these ganglia are somewhat larger and less numerous; and in the smaller number is evinced a degree of superiority. We see in the higher animals that certain organs not unique but in pairs, in the lower animals exist in great numbers. In the star-fishes and echina, where we have the first evidence of eyes, we have an eye at the end of each ray—as many eyes as there are rays, and as many ganglia as there are rays, and from each a nervous filament running through each ray. Here we have a smaller number of nervous ganglia and they are placed so that one stands above the other and on the anterior region of the animal; in that way this ganglia or nervous centre has a greater influence upon the whole animal; and it is only owing to the position of that nervous mass that the anterior region of the animal has become more important and possesses greater vitality; while other organs round the mouth have a higher importance to the functions of life. Wherever the nervous system becomes larger and acquires a preponderance over the other organs, then we see that life acquires greater intensity and that all the important organs are accumulated. It is so with the head of vertebrated animals which contains all the organs of any high importance.— The organs in other parts of the body are just as important to the maintenance of life and the sound condition of the animal, nevertheless they do not possess the high value which the organs in the head of these animals exhibit.

The alimentary cavity is complicated in the Mollusca. It is no longer a simple or branched sac, as it is in the Radiata. But we have in them, behind the mouth, which is usually surrounded by tentacles, to introduce the food, sometimes two in number, and sometimes four, arranged in pairs, two above. two below, or only two on the sides— behind the mouth, I was about to say, there is a narrow tube, the œsophagus, and usually a large bag which is the stomach, and the intestine behind. Now this stomach is complicated, inasmuch as there is a liver, a glandular organ united with it; and this liver is sometimes very large, surrounding the whole stomach, and secreting a greenish dark liquid, known under the name of "bile," which is introduced into the stomach and helps digestion. This bile, the secretion of the liver, is very considerable in all the Mollusca. The liver is sometimes so large as to exceed in size the whole of the animal. It is more than half the weight of the body. Sometimes there are several livers, two three or four, arranged around the stomach and opening directly into it.

The organs of respiration are always distinct, and uniformly present the form of gills. Their position varies very much in the Mollusca, and I will not now enter into the details of the arrangement of these respiratory organs, as I shall have occasion to explain the differences which they exhibit in different types of the great group of mollusca. But everywhere these gills are present; and when I say everywhere, I do not exclude that class which breathe the atmospheric air, which have no lungs, notwithstanding they respire by air, but have gills like other Mollusca, only they are kept in contact with atmosperic air, and not with water. Their gills, then, are not at all similar to the lungs of higher animals, and are entirely similar to the gills of other mollusca. What are gills? Everywhere a blood-vessel divides into parallel branches which are brought into contact with the air contained either in the atmosphere or in the surrounding water; these organs are called "gills." Sometimes these blood vessels are united by a membrane which forms them into appendages of very varied forms. Sometimes they are loose, and then they form tree-like branches upon the back or into the cavity of the animal. The gills may be external, as in many Mollusca—internal as in others.— Sometimes they are placed in such a way as to be used at the same time as organs of respiration and of locomotion, acting on the sides of the animal and performing the functions of feet. Sometimes they are entirely concealed in the interior, and the water and air are introduced by external openings. We see all these differences among the Mollusca, and it is more important to know these differences, as they have been made by some naturalists the basis of the classification of this department of the Animal Kingdom. Cuvier's classification of this great group of animals is almost entirely based upon the arrangement of the respiratory organs.

The organs of circulation are very singular in their arrangement. There is uniformly a heart in the Mollusca. But this heart is placed in a very singular manner. In some it is placed in the centre of the body. In others it surrounds the alimentary tube, so that the intestine passes right through the heart. In others there are several hearts placed in different positions in the animal. Sometimes there is a heart at the base of the respiratory organs, and sometimes a central heart to supply the body. In some cases the heart is very near the mouth, and opens into wide cavities containing other organs. Nowhere is the circulation more unequal in different animals than among the mollusca. There are not two families in which the blood is circulated by similar apparatus, and moreover there is no class among the Mollusca where the circulation is continuous. I will give an example: Here is one of the Mollusca, resembling a slug. It has a large foot on which it walks and a flat shell on its back, in which the viscera are contained. From the heart in this animal there originates a large blood-vessel running downwards toward the head, and the blood no longer contained in this vessel is diffused into a cavity, so that the tongue and posterior apparatus of the digestive organs are actually swimming in the cavity full of blood. From the walls of this cavity new tubes arise, which unite into other vessels, and thus form an artery or a vessel running backward and dividing into the body.

In others of these animals we have the blood-vessels opening into the cavity which contains the viscera and surrounding the stomach—surrounding the intestines—and surrounding the liver, and then again absorbed by vessels to be diffused into the lower parts of the animal. So that there are everywhere blood-cavities into which the blood-vessels open, and from which other vessels arise and diffuse again the blood into the organs.

The extraordinary structure of the blood-vessels, and of the circulation in the Mollusca, has not been long known. It is the discovery of one of our most eminent naturalists—the present Professor of Natural History in the *Jardin des Plantes* in Paris. It throws most important light on the mode of circulation and of the organs of circulation in the animal.

How are the blood-vessels and blood formed in animals, and how does circulation begin? In examining the egg of a fish, for example, we first observe an accumulation of red corpuscles, which begin to move in different directions, but without vessels, till, after a certain time, there is a regular movement of some of these blood-corpuscles in a straight direction; and then they will extend over the surface of the yolk and form regular streams, but always without vessels till the vessels are formed around the blood, when regular channels for the circulation arise from the fact that vessels begin to form around the corpuscles, similar to what we see occur after a heavy rain. When the water runs over the street, there is at first no channel for the water; but after it has run for some time in different directions, channels begin to present themselves, which gradually become deeper and deeper in the softer parts, till the water remains bounded by them. So in a living animal, the cells, being excited by the current of the blood, are gradually formed into channels. The young animal is formed entirely of cells. Some of these cells become movable and are moved in different directions and form little streams—little currents in different ways, and then after these streams have become regular the vessels are formed around them. In this way you have a full explanation of those large blood cavities in the Mollusca; and those unconnected blood-vessels opening into the larger cavities and a heart which is central, but which does not communicate with the most distant portions of the body. I think the only way to understand the circulation is to consider it and the blood as arising from the liquefaction, as it were, of the cells which form the animal, which then become movable, undergo a motion in precise and uniform directions, and then are surrounded by cells which form the vessels, and which form the heart. It is only when tracing all these phenomena in the young animal within the egg that these details can be understood. But I could not help adverting to the formation of the blood-vessels when speaking of a class in which the circulation is so unique as it is in the Mollusca.

Let us now turn our attention to the Mollusca themselves, and see what form they show in the whole range of the class. All the diagrams on the wall belong to that class, but you will perceive that they present many different forms. Here is an animal resting on a stem. There is one very like a coral. Here is one which for a long time has united with the coral, and by many naturalists is ranked as such. You perceive that it has cells similar to those of the common coral. Here you have animals with two unequal valves. Here, others with two equal valves. Here one with one central valve curved. Others without any protective valve. All these diversities exist in one and the same class.

The Mollusca have been divided into three classes. The first class is the *Acephalæ*—animals without a head. They really have no head. The anterior and posterior extremities hardly differ. This class of acephalæ have the bivalve shells. You have here examples of them; two shells united in the superior margin and movable along the back. But many of them unite to form compound masses.—Yet the organization of the individuals thus connected has been ascertained to show the same structure as that of the bivalve class. I shall soon enter upon the details after I have explained the characteristics of the acephalæ.

The characteristic of this class is to have two symmetrical regions; a right and a left side, over which hang the respiratory organs. If I cut across an oyster, I find that the vertical line is longer than the longitudinal diameter. Here is the anterior region of the oyster—here the posterior region: and you perceive that the vertical or perpendicular diameter is greater than the longitudinal diameter.—Here we have the interior mass of viscera, the stomach; and here are both sides, the membranes covered with blood-vessels, which are the gills, two on each side. That is the general character of the acephalæ, to have the gills surrounding the alimentary canal, the liver and other organs which are in the centre of the animal; and over these sometimes only one pair of gills; over that, again, a skin, which lines the shell all over its internal surface, which has been called "the mantle." This arrangement of parts is the general structure of bivalves or acephalous mollusca. This "mantle" is sometimes open the whole length of the animal. So it is in the oyster. Perhaps there is no animal among the Mollusca so interesting in its structure as the oyster. [Here the learned Professor explained a diagram illustrative of the structure of the oyster, which, with the other diagrams, will be given hereafter.]

Allow me a few minutes beyond the hour, which I see has now expired, in order to finish the description of the acephelæ. (Applause.)

The shells are not always symmetrical. Sometimes that of the right-hand side is larger than that of the left-hand side, and *vice versa*. Sometimes the anterior and posterior extremities are equal, while the two sides are unequal. Sometimes, on the other hand, the two sides are equal and the extremities unequal, and in these differences we have characteristics by which a great number of these bivalves may be divided into families. It is important in the beginning to give them the same position when we desire to compare them. For instance, in some of them we have one valve convex and the other flat. Many naturalists have considered these cases to present instances of a dorsal valve and a ventral valve. But when we examine the formation properly, it is easy to perceive that this is an error, and that what was called the dorsal valve is nothing more than an exaggeration of this form which we see in the oyster, where one of the valves is deeper than the other and is flat. The only difference between the terrebrachela is that in them the anterior and posterior margins are entirely symmetrical, and only the right-hand and left-hand sides are unequal. It is not so in the oyster. It is important to understand this point.

Let us take a symmetrical bivalve shell and begin with that. In that the right and left sides are easily known by the positions of both, by the appendages round the mouth and the symmetry of the valves. There are two equal valves—one on the right, the other on the left. Here is the mouth. Here is the back. Here is the foot by which the animal walks, protruding between the two valves. Here are the tubes by which the water enters.—You see that the anterior end of the animal is broader than the posterior, and in every respect it is easy to see the proper position of such a shell. In the oyster these anterior and posterior ends are so irregular that we have no means to ascertain which is the anterior and which the posterior until we open the animal and discover the position of the mouth. There we see that the mouth is between the two shells here; that the long diameter is the vertical diameter; that this is the right valve and that the left valve, the valves being unequal, one convex and the other flat. But in the terrebrachela we have the right-hand valve convex and the left-hand valve flat, but the anterior and posterior edge cut precisely in the same way—and thus the extremities are so precisely symmetrical that the blood-vessels which you see in the anterior and posterior half are distributed in the same manner, and that there are two hearts, anterior and posterior, so that if it was not for the position of the mouth and the direction of the alimentary canal, it would be impossible to ascertain that this was the anterior extremity and this the posterior extremity of the animal; this the back and this the foot.

Another important peculiarity is this: that the mantle lobe which covered the internal portion of the shell leaves a deep impression on the shell, from the action of the muscular fibres by which it is attached to the shell; and as there is a long tube by which the water is introduced between the valves in some of these animals, and which is retracted and introduced between the valves, a large sinus is formed. Thus, on opening a shell, you can ascertain whether the animal to which it belonged had this tube or not, by the absence or appearance of this sinus—the impression of the tube. When the tube, or "siphon" as it is called, has been long, the impression is considerable; when short, the sinus is not so marked. This difference is important, because in the examination of fossil shells, these impressions constitute the great test by which we ascertain the character of the animal which occupied them. It is in this way that an idea has been formed of the animals which occupied the fossil shells, almost as precise as if the animals themselves were before us. The only difficulty is to compare a sufficient number of types in order to become completely acquainted with all the variations and relations of those parts, and to trace the analogy with accuracy and success.

LECTURE V.

The Anatomy of the Oyster....The Ligament....The Mouth....The Gills....The Stomach, Liver, Ovary and Heart—Position of the Oyster....The Fossil Bivalves....Important considerations relative to the Symmetry of the Bivalves....Order of Succession....The various Groups of the Acephalæ....The Shells of comparatively little Importance....Changes in the Classification of the Mollusca and other Animals....Tribute to the Labors of Cuvier.

CLASSIFICATION OF THE MOLLUSCA.

I..ACEPHELA..............(Without head.)
- 1. *Bryozoa*..........(Moss animals.)
- 2. *Tunicata*..........(Having a coat.)
- 3. *Brachiopoda*......(With feet like arms.)
- 4. *Monomyaria*......(With one muscle.)
- 5. *Dimyaria*..........(With two muscles.)

II..GASTEROPODA..........(Feet below the abdomen.)
- 1. *Phlebentera*.......(With branched intestine.)
- 2. *Trochoidea*........(Trochus-like.)
- 3. *Buccinoidea*.......(Buccinium-like.)
- 1. *Pulmonata*........(With aërial gills.)

III..CEPHALOPODA...........(Feet round the head.)
- 1. *Sipiodea*...........(Squids.)
- 2. *Nautiloidea*........(Nautilus-like.)
- 3. *Ammonitidea*......(Ammonites-like.)

LADIES AND GENTLEMEN: After having given a general outline of the characteristics of Mollusca in the last Lecture, I proceeded to illustrate the peculiarities of the first class of that group called acephalæ. Then having entered into as many details as possible with regard to their structure, I alluded to the different groups which belong to that class, but as perhaps many or some of this audience may wish to know how these facts are ascertained, I have brought here some of these animals in order to demonstrate in them the peculiarities of their organization. For, let me remind you that the objects in Nature are not seen as you see them delineated in the diagrams. In the diagrams the objects must be represented of larger size than natural, and in strong outlines. Things are not so easily seen in Nature, and therefore I wish to show you in what manner we must proceed in order to see for ourselves the objects in nature, and how we are able to proceed in making new observations and comparing the types not yet understood.

I have thus taken for example the oyster, as it is the most common of this order of animals. I have been told that there was some misunderstanding in the minds of some of my auditors, when I explained the difference between the oyster and the common bivalve shells. The misunderstanding was with respect to the shell which is concave, and arose from not attending to the manner in which the shells were held in the hand when demonstrating them. The two valves are united at one end by what is called the ligament. It is an elastic substance, which contracts when the muscular power of the animal which closes the valve is relaxed. In order to open an oyster, particularly for anatomical investigation, it is only necessary to pass a knife between the valves on the back, near the projecting portion, where the two valves are united, so that the strong muscular portion of the animal, and which passes across the whole body and fixes itself to the valve, be divided. You see this dark spot in the centre of the valve. Here is the muscular portion, tough like meat; and the fibres of this part of the animal are transverse, running from one valve to the other. Now after the valve is removed in such a manner—it is not much matter what valve is removed, only perhaps it is more convenient to allow the animal to remain in the deep valve, which retains the water—you see at once the animal in its natural position. Here you have this muscular portion, which is the toughest part of the animal, and then a skin which runs all around the shell. This skin which lines the whole inside of the valve, and which can be upheld very easily, is attached to the muscle, and runs all round the shell to the margin. If it appears now not to cover entirely the surface of the shell, it is owing to the contraction of the fibres which are in this membrane. The margin of the membrane itself has a very complicated structure. There are fringes, sometimes most beautiful and of very elegant color, in the different species of clams and bivalve shells and when you remove this portion of the shell, which is called the "mantle," you have another membrane quite similar to that, which is situated transversely. This is the gill. There is another inside—a second one, so that there are two lobes of the gill on one side; and above that two long tentacles, which are placed here above the mouth. On the other side we have the same structure. Now the mouth is here on this upper portion of the shell. All that may be more easily seen when you keep the whole animal in water, as then, with a brush or pencil, you can elevate the one above the other, and examine their beautiful structure.

In this upper portion of the animal is the stomach, a large cavity surrounded by a dark brown colored liver, which forms the softest part of the oyster. Around the liver is the ovary. The eggs are so minute as not to be perceptible to the naked eye, but are readily seen under the microscope.—The intestinal tube, which begins here between the tentacles, at the anterior portion of the body, turns twice between the liver and the ovary, and then passes through the upper region, in which we see the heart of the oyster. The intestinal canal does not pass through the heart of the oyster as in other animals, which I shall demonstrate immediately. What is peculiar to the oyster is that the "mantle" is open all round. There is no siphon, but the water, as often as the shell opens, can reach immediately the whole surface of the gill—the food can immediately reach the mouth, so that the animal has no need of a tube which could be elongated and protruded between the valves in order to ab sorb the surrounding water.

You see that the position of the mouth indicates, without any doubt, that this is the anterior edge of the oyster; and this the superior; this the inferior side; and this the posterior. As I have remarked the animal rests forever on the deep valve; so that when examining an oyster anatomically, in order to compare it with other shells, we must put it in a position different from that it used to have in nature. But this is the case with many other animals. Among the water-insects, for instance, there are many which constantly swim with the feet upward, but nobody when comparing them with others would think it proper to compare them in that reversed position. We must in these cases bring the animal into the natural position of the greatest number of animals in order to come to a right understanding of the correspondence between the parts. So it is with the common hard clam. Thus the two valves are precisely identical in shape — But after having removed one of them you see a great difference in the structure of the animal. There are two muscular bundles uniting the two valves; one on the anterior and the other in the posterior portion of the animal, so that the two valves are shut by two sets of muscular fibres, and not by a central set as in the oyster. And these two sets of muscles are placed one on the anterior and the other on the posterior end of the animal. Those two muscles act, however, in the same manner as the single muscle in the oyster. The mantle here surrounds the shell precisely in the same way as in the oyster, but it is not open all around. Here, about two-thirds backward, the mantle unites from the two sides. It is open only on the anterior ridge, so that the water can enter either between the mantle lobes or through the hole which is formed by the junction of the two portions of the mantle.

If, as I have done here, you remove the mantle, you see similar flat membranes, which are the gills. They are so collapsed in this animal that I cannot show them. They should be covered with water, and those who wish to see their structure may remain after the Lecture, and I shall put the animal in water and demonstrate these membranes. There is a considerable muscular mass, underneath which is the muscle or foot by which the animal walks.—This foot they protrude between the valves, and by means of it fix themselves on the sand or stones and creep along by successive contractions and expansions of their body. In the same way as in the oyster, we have here the mouth surrounded by tentacles. The liver is above, and of a brownish color, as in the oyster. Then we have the heart here, between the gills, and the intestinal cavity, and the alimentary canal which passes through the centre of the heart. The beating of the heart can be seen for a long time after you open the valves of the oyster. It beats seven or eight times during a minute. In the hard clams the pulsations are almost the same in frequency. When contracted, the heart is of very small size—when expanded, it is three times as large. This operation of the heart may be very easily seen if you put the animal after you open it in the water, so that all the parts expand. Here the two valves are symmetrical, and the anterior extremity differs from the posterior. I have already alluded to this fact, but I want to show one thing more about them, as it is important in order to understand the gradations among the bivalves; and to understand the reason why so much importance is put upon the question how the animal stands or lies in its natural position?

We have seen that some of the distinguishing characteristics of the Mollusca are, to be symmetrical, to have a longitudinal axis and an anterior extremity at which the mouth is situated. But what is singular, these animals in their organization do not yet stand so high as to assume a constant position of the sides of the body.

The anterior extremity is constantly marked as the anterior, the prevailing portion of the animal; but the sides of the animal, the posterior extremities are sometimes lying on the right or on the left, and sometimes even uplifted in a very irregular way:

Now, here we have a bivalve with two symmetrical shells. Here is the ligament uniting the two valves, and here some tubercles on the edge of the valve which are usually but incorrectly called teeth. They are by no means teeth. They are merely serratures or dentations. Here is the margin of the shell by which the two valves unite more strongly; this portion of the shell has been called the hinge.

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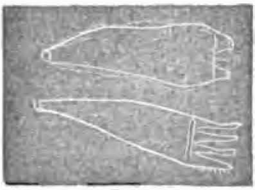
Now this being the anterior extremity where the mouth is placed, this will be the posterior extremity, and we will have an animal walking with the aid of its feet in an upright position, the mouth forward, the feet downward, the right and left hand in an equilibrium on the right and left hand side and the back upward—the posterior being backward. But in the oyster, when the two parts are compared with one another, in such an animal we will find that no longer is this position maintained, but the animal through life lies flat on one side, from the beginning. The young oyster lies on one side of the egg; begins to grow in that position and never comes to have the anterior extremity forward and the sides in equal position. One side, the left, remains below, and the right in the form of a cover upward, resting upon the lower side.

Now, in the oyster, the anterior and posterior margins of the animal are not equal; nor are the right and the left valves equal. Here we have inequalities between the two valves, and these inequalities are very great—not only are the two valves very unequal, but you see the anterior edge carried forward—the posterior edge is emarginate. Now, we have other bivalves where one valve is very deep and the other flat; but where the extremities are identical. They are called the Brachiopoda. It is very important to ascertain these facts, because they point to a most extraordinary circumstance—it is this: that in shells found in strata forming the crust of our earth, we have none which have the two valves unequal. There is not one bivalve shell with equal valves in any of the ancient strata. There was not one of the ancient bivalves which had this bilateral symmetry in its shells. All belonged to that class where the two sides could not yet be equalized and stand upright, and of course we must consider them as of a lower grade than those where the symmetry is entirely perfect.

There is even something more. We have not only the valves unequal, but the anterior and posterior extremities unequal. Though these valves are still unequal, there is still an approach to a difference between the anterior and posterior extremities. The anterior extremity curves forward, though the posterior does not yet extend backward. But the fact that there begins to be an equality shows that these stand above those where the anterior and posterior extremities are precisely identical.—Now again, those which are terrebrachela, which have the anterior and posterior ends precisely identical and the valves unequal, are the oldest. They fill the strata below the coal, and in the coal. We have not yet any of those which have unequal valves, with unequal anterior and posterior ends before we have passed the epoch of the coal. So we see a gradation of the animals in each series, corresponding precisely with the order of succession of animals in time. Thus the great importance of understanding these facts, which at first appear to be rather insignificant. But, you see, when I attempted to show that there was a difference in the actual position of the animal in water, how it stood, or lay, I expressed the law of succession of types, the law of gradation of organization from the earliest appearance of organic life up to the present time. Of course, the oldest types once introduced have not been allowed to die out. We have in a living state several brachiopoda, but very few, perhaps one-fiftieth of the whole number, of the acephalæ. We have of these bivalves a great number, but they begin about the middle age of the history of our earth, and the number is about equal to the number of types now living. Now the symmetrical bivalves are the most numerous living in our days, and those which occur only in the upper strata of the crust of our globe, which begin in the last time, as it were, the last historical and geological periods. Of course there are some few species which run through a greater range of geological time. I give only a general outline of this succession, in order to show the importance of this thing.

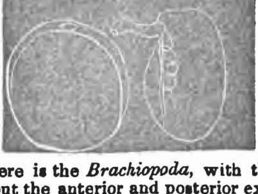
Perhaps it would be more attractive to enter into details of the mode of living of these animals, their uses, habits and so forth; but these things may be found in almost every text-book, while anatomical details and these more general bearings of the structure, with geological phenomena, are scattered in isolated papers, and some of these views have only been known for a short time, so that perhaps it is more advisable to stick to this point of view rather than what is usually called the history of these animals. (Applause.) It will of course be perceived that this difference between the bivalves is less important than has generally been considered. Whether the mantle be united with the whole length of the animal, and whether it be opened for a greater portion is of less importance than many conchologists have thought.

And again, whether such an animal has a hard shell or not is of trifling importance. We have, in fact, a great number of animals, quite similar in their structure with the bivalve shells, which have no shells at all—and have only a membraneous covering, and it is according to this difference that the class of acephelæ has been divided into the following groups:



First, the *Bryosoæ*. These resemble the polypi in size. In these the anterior end of the animal is surrounded by a circle of tentacles, and these have cilia all round, by which they can introduce the water. Within this membraneous covering of the animal, is a structure quite similar to the shell of the oyster. Sometimes members of this group have calcareous stems like the coral.

Next we have the *Tunicata*. They have merely the opening for the introduction of the water to the gills and the mouth. It is like an oyster without shells, where the skin is entirely united the whole length of the animal:



Then there is the *Brachiopoda*, with the valves unequal, but the anterior and posterior extremities symmetrical. Here is the hole through which these animals protrude a ligament which is used as the means of attachment. These animals constantly lie upon the flat valve attached by this ligament, which passes through a hole in the larger valve. It is this type which is the most common, and in fact the only one, found in ancient strata. All the limestone and coal strata in the United States contain a

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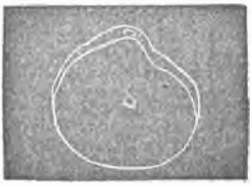
great number of these bivalves which are very well known to conchologists:

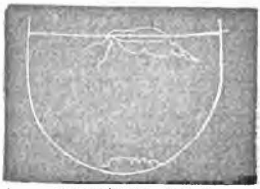


Here we have the type of the oyster—the *Monomyaria*. These have unequal valves and are also unequal in the anterior and posterior sides, and have, as their name imports, a single muscle running between the valves.

The last group is the *Dimyaria*.

I have taken up this view of the subject in order to impress the audience with the importance of anatomical investigation with reference to successive types during geological epochs. *It shows that there is a plan successively realized in Nature; and that the types now in existence were in view at the beginning*. Such a series cannot be realized, unless at the beginning, the termination of the plan was already sketched out. If it were otherwise, then it would be precisely like one sitting down to write a book without having formed his plan. If he does not know where he is to go, how can he ever come to an end? (Applause.)

We next come to the class of *Gasteropoda*, the name being derived from the large muscular disc by which the animals creep. Here it is a flat disc of muscular fibres which contract successively and so move the animal. What is very singular is that some of these animals are able to walk against the air when swimming at the surface of the water.—It is necessary to explain that in order to make it understood:



Let this be a water-basin, and the level of the water above. We have here the pressure of the atmosphere upon the water. Let now a fresh-water mollusc of this class be placed at the bottom of the vessel in this position. It will rise to the surface by expansion. It will diminish its own weight so much that the animal will rise to the surface. How is that possible? The animal sinks because it is heavier than water. But its weight is so nearly equal to that of the water that the moment it assumes a larger size, by dilation, it displaces a greater quantity of water and becomes therefore comparatively lighter than the fluid, and by this process it slowly comes to the surface of the water. The moment it contracts it of course again sinks. When at the surface of the water the feet will be upward, and by the contraction of the feet the pressure of the air upon the water is a sufficient resistance for this animal to walk along on the surface of the water, and any one may have the pleasure of seeing this by observing the motions of any of this species so common in all our fresh-water ponds. Nor is the motion of this animal very slow. I have seen some not more than half an inch in length walk a foot in this way in a minute. This shows that the resistance must be considerable.

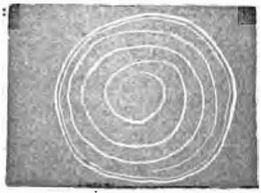
All the gasteropoda have that muscular disc at the lower portion of the animal, and have been so called because the disc is below the visceral cavity or abdomen.

Here I take occasion to remark that many improper names have been give to animals of these lower groups, because the animals themselves have not been sufficiently understood. Still it is perhaps advisable to retain the names, as if the mode of classification were to be changed to meet every fresh accession to our knowledge, the memory would be embarrassed and endless confusion be produced.

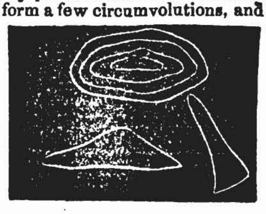
Most of the gasteropoda have the body covered with shells; but a great number of them are naked. Here are some very beautiful from the variety of their colors. The size and thickness of the shell vary very much. In some the shell is so minute that it covers only a small portion of the animal. In others the shell is entirely concealed in the skin, and is seen only when the skin is cut open. The shell cannot be considered as a very important part of the animal. There are almost as many of the Mollusca destitute of shells as there are possessed of them. Again: all those without shells had them when young. If the shell were of as great importance as it is generally deemed by conchologists we would not see so many of these animals naked. Though very beautiful and diversified, the shells, then, are of comparatively little importance.

Yet the shells after all are not without their value in the study of Natural History, for it is by means of them that we can study the Mollusca of ancient geological times. In a fossil state there have been found a great many of these univalve shells. But we do not know how many or what sort of naked shells existed in those epochs simultaneously with the others. It is only from those which had a hard coat that we can form an idea of the gasteropoda of ancient times.

The shell of this class is often a single flat disc without any circumvolutions. In that case it is formed of successive layers, growing larger and larger, and forming concentric lines as you see here. The mode of deposition of this shell is in this way:



First above the animal there is a small calcareous disc. Then, as it grows larger, the mantle secretes another layer, a larger layer, and another, and another, each still larger, and so the shell grows in proportion as the animal grows. Now in several this disc is flat. In others it is more or less conical. Here is the beginning of a cavity into which the animal can retreat. In some it is even a deep cone. In some the cone is so high as to be like a cylindrical tube. But usually this tube is rolled up, and that in a very peculiar manner. Sometimes in rolling it will form a few circumvolutions, and you have an apex.



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In some the circumvolutions are very numerous, and succeed each other in such a way as to form a high spire, and you easily understand that that is a mere tube rolled in a spire. Sometimes the tube thus rolled turns to the right—sometimes to the left. But what is remarkable, all the individuals of a species which is designed to be rolled up to the right are turned the same way, and perhaps of thousands and tens of thousands you will not find more than one reversed. These reversed individuals are highly prized by collectors of shells. They are extremely rare. Among the common snails we find perhaps more of these reversed shells than in any other class. What may be the cause of this constant rolling in one and the same direction is not known. It begins in the egg.

The opening in the shell is generally circular.—In some cases it is oblong. In some it has a notch, and through that there passes a membraneous tube, through which the water is introduced and reaches the respiratory organs. Here is a case in which this prolongation forms a kind of siphon, protecting the membraneous tube. An animal with such a tube can breathe without moving its body. Those which have a circular opening are obliged to come out when they breathe. Sometimes the membraneous tube coming out of this notch is very long, as long as the shell itself, and forms a kind of horn, rising above the animal. Many of this class become blind when they are full grown.

The mouth is usually surrounded by the tentacles and is at the anterior part of the head. But sometimes there is a proboscis, a long tube, at the end of which we have the mouth.

In some, on the contrary, the mouth is very short, and in such the proboscis protrudes. In this respect there is a great variety, as there is also in the form and shape of the foot and mantle. In some the foot is much broader than the shell, so that when you look on the animal from above, the shell does not seem to be more than half the size of the foot. In other cases the foot is so large that the shell and head of the animal constitute the smallest portion. In this respect great diversity exists.

Again, in some the mantle is so broad that it will cover a portion of the shell by folding itself backward, thus concealing the greatest portion of the shell, and we have cases where the foot is of an amazing size when compared with the size of the animal. All these differences are important, as it is owing to some of them that conchologists have divided the gasteropoda into several classes.

One is that class called *Phlebentera*, entirely naked, and peculiar for the structure of the intestinal canal. Their name indicates that peculiarity. The alimentary canal forms a kind of circulation, and in this respect this family does not stand much higher than some of the medusæ, but they differ in the respect that the alimentary canal has a longitudinal axis. They have, all of them, external gills, sometimes most beautiful, forming bunches of blood-vessels hanging outside, which are used as oars and constitute the means of locomotion. The modes of locomotion are either by the feet creeping along or by the gills in swimming.

There is another group rather interesting, which contains animals of so greatly varied appearance, that to one accustomed to combine animals according to their general appearance, it seems unnatural to classify them in one family; but they have been so classified by so high an authority in Natural History that no one has dared to alter the classification. A Swedish Naturalist has proposed a modification of the classification of Cuvier, and indeed it is quite reasonable to suppose that as the investigation of Natural History proceeds, and fresh discoveries are made, modifications of classification will become necessary.—Nor does it in the least reflect upon the exalted character of the great Naturalist I have named, to whom the science owes so much, that these changes should be deemed necessary. It has perhaps been owing to his immortal work that scientific men of our day have been able to improve the methods of our earlier naturalists.

LECTURE VI.

Remarks Explanatory of the Lecturer's Views with regard to the Succession of Animals in Geological Times....His Views entirely different from those advanced in the "Vestiges of Creation"....Character of that Work....Classification of the Gasteropoda not Natural....The Trochoidæ....The Pulmonata....The "Cuttle-Fish"....Interesting Peculiarities in the Organization of these Animals....Fossil Shells.

Ladies and Gentlemen:—Several questions having been put to me with respect to the views which I entertain in regard to the development of organic life, and some observations having been made with respect to the tendencies of the facts presented in my Lectures, I deem it necessary to explain what I understand, in reference to the succession and development of organic life.

These words are constantly used and sometimes in very different senses, so that there is infinite misunderstanding among those who use the same words and mean very different things by them.

When we speak of what comes later we of course have reference to what comes before. We will take for illustration the chick. From the time when the egg is laid to the period when the mature chick is hatched, a succession of changes takes place. This epoch between the formation of the chick and its full growth is called its development, and the changes which such an animal undergoes during this time are its metamorphoses. We have often limited the meaning of metamorphoses to the changes which we perceive in the butterfly—in the caterpillar, where these changes are interrupted and are very striking. Everybody knows that a butterfly is formed from a caterpillar out of an egg. The caterpillar, or worm-like animal, after it has grown to a certain size undergoes a change—it assumes a new form, that of the chrysalis. It is motionless and so remains for a certain time, till out of this comes a living butterfly with all its brightness and vivacity of life. Now

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these changes have usually been called metamorphoses, although not so striking, nor interrupted in such a manner as to form distinct ages in the life of the animal. They pass from one to another, and the early state of the chick, for instance, is so dissimilar to the full-grown chicken that no one recognizes them if they have a chance to compare them. But if we can trace all the intermediate stages we find that they are connected in such a manner that there is no interruption to the succession of these changes—and thus we do not in that case usually speak of metamorphosis but of development, and such a development is also called the progress of an animal during the different stages of the egg. In a metaphoric manner we are also accustomed to speak of metamorphoses in the Animal Kingdom through different ages of geological time. Everybody knows that the earliest Geology has been made so clear that I suppose all know that the strata which form the crust of our globe contain a great number of fossil remains—remains of fossil beings in all classes of the Animal Kingdom—and when tracing the whole succession of these animals we find that the most ancient strata—those which form the lower beds of this crust of the earth—are different from those which are found in the intermediate beds, and which differ again from those found in the uppermost beds.

Now in this succession of strata and of animals through the whole range of geological epochs, we have what is considered a progress. We find that the types in all the lower beds resemble the lower types of the now living animals. For instance, I have mentioned that the Brachiopoda among the Mollusca are the most ancient acephala. We find among the vertebrated animals that fishes only are found in the lower beds. There are no reptiles, no birds, no mammalia, nor any of the higher classes of the Animal Kingdom. And here, again, we may speak of a progress in the succession of types. We can speak, also, of a metamorphosis in the Animal Kingdom, but not in the same sense in which we speak of the metamorphosis of an animal; because, when we have a butterfly arising from a caterpillar, then we have one and the same animal continually living without interruption, and passing through successive changes; while, when we speak of the metamorphoses of the Animal Kingdom of the different classes—when we speak, for instance, of the metamorphosis of the class of Acalephæ, and consider the Brachiopoda, Monomyaria and Dimyaria as different stages of this metamorphosis, of course we would have here a succession of different types, different animals, unconnected materially—not the same living beings undergoing these changes, but a number of distinct individuals unconnected with each other, not derived from each other. Nevertheless, there is in their succession a great analogy—a striking analogy, with the changes, the progress, the development observed in one and the same individual while growing from the egg to the full size; therefore, what we call metamorphosis, progress, development, in one sense, is entirely different from that which we call by the same name in another case. In the succession of the changes of an individual, we have really a progress in one thing; but we have in the other case a progress of the plan—and a progress on a plan arising in a succession of species which do not descend from each other—which have never been derived from each other, as two different individuals of one and the same species are derived from each other through successive generations.

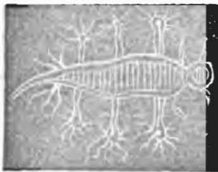
Therefore we should never mistake these two things. In the one case we have individual successions of changes—in the other case we have a plan which is successively modified and where the progress is introduced by a series of species undergoing changes independent from each other; and in that view, in such a progress, such a gradation only, in the plan, we recognize the mode in which this succession so introduced proceeds in different epochs.

I make these observations in reference to some remarks made and questions which agree with certain philosophical views entertained in some quarters. Now, I have not to teach Natural Philosophy, but to give a sketch of Natural History—of the Animal Kingdom; but as a knowledge of the Animal Kingdom has constantly a bearing on philosophical questions, of course you cannot avoid reference to them. But I would only make this distinction, that in the case of the metamorphoses of individuals we have a series of phenomena arising from the fact, that the species has been called into existence with the properties of undergoing successively these changes. But with the progress of species, as we find them in different geological strata, the question is: can we find in Nature external causes which will produce these changes? and, again, can we refer these successive appearances of different types to the influences of external causes? I say no; because, since Man has studied Nature he has never seen any species modified under external influences. The most ancient monument whose mummies have been studied, shows animals quite identical with those who live in the same country now; therefore we see, that as far as we can reach, the species which exist now have had the same characteristics which they have at this present day; and, therefore, it would be illogical to suppose that what does not occur for so long an amount of time has been the cause of all the varieties which we see in Nature. And again, the fact to which I alluded in the last Lecture, that such a vast variety of animals, living in the same circumstances, in the same locality, and again animals of the very same types as we have in the different geological epochs, shows evidently that these external circumstances are not the product—have not been made by external influences—but have been arranged with the plan which was formed at the beginning, when the world and the organic beings were called into existence with the end of introducing Man. (Applause.)

These views—to which I shall recur when I come to speak of the position of Man in Nature, and of his relations to the Animal Kingdom—disagree entirely with the views, and have not the slightest alliance with the views of a work which is very much spoken of, but which I consider entirely unworthy of notice by any serious sceientific man—because it is made up of old-fashioned views which have been brought before the notice of the public for half a century, by the French school, and are supported only by antiquated assertions, and by no means by facts scientifically ascertained. It must be owing to some particular circumstance that this work has been so much noticed, because really it is not worthy a critical examination by a serious scientific man.

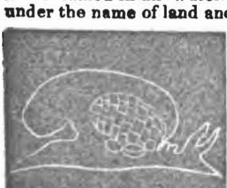
Now, after this too tedious explanation, let me come back to my proper subject, and I beg to be allowed to go on regularly with the subject, as questions are frequently submitted in reference to Lectures already delivered, which really are not relevant or pertinent to the present object of our investigations. In the proper place I should have been led to speak of the points which have been the subject of this explanation, and the remarks just now made would with more propriety have been introduced at the close of the Course, had I not been asked so often to give my views in relation to these questions. (Applause.)

I remarked that the gasteropoda are not properly classified. Their structure is generally well known, but the details of the different groups have not been sufficiently ascertained for the purposes of a strictly natural classification. The gills, which have been made the principle of classification, vary so much, and the variations are of so little importance that I do not suppose a natural classification can be educed on that principle. You remember I mentioned the *Phlebentera* as the first group. The alimentary canal is distributed in them in a manner similar to blood-vessels, and diffuses the product of digestion through the body, and even in the gills. You have here this canal, which is a ramification of the alimentary tube, and you see here how a vessel, as it were, runs in the branchi, which is nothing more than a duct arising from the alimentary canal, and performs functions similar to a blood-vessel.



The next group is the *Trochoidæ*, according to Cuvier. This group contains the only species provided with shells. There is a circular opening in the shell, without the notch, and the animal is quite similar to those which have a notch; and again, quite similar also to some of the naked animals. To those familiar with the structure of Mollusca it will be obvious that there is scarcely any difference between this group and several of the other classes. The only difference appears to be that a portion of the animal is in one case covered with shell, and in the other it is naked. I am satisfied, then, that the distinction is not natural, but that this group should contain all the naked mollusca, which have the same structure. The difference between those which have and those which have not the notch is of no value at all. I will quote an example: The common limpet has no notch, but there is an opening on the side, for the introduction of the water, as large as on any of those which have a notch, and the animal can breathe without coming out of its shell just as well as those which have this long membraneous tube coming out of their notch. It forms a group entirely different from all these. The classification of the gasteropoda, then, is not at all natural. Perhaps this may offer an inducement to some young naturalist to begin the study of this class of animals, which are so numerous along these shores, and some types of them so large that an opportunity is afforded for their examination such as is not to be met with on any of the European coasts.

I have yet to speak of two additional groups of the gasteropoda; and first of the *Pulmonata*, or those provided with so-called lungs. The slugs—the snails, belong to that group. They form undoubtedly a natural group. Though they have an organ of breathing similar to the gills of the other Mollusca, it is peculiar in this respect that the air which is brought in contact with the blood-vessel is not mixed up with water. These animals breathe the atmospheric air and not the small quantity of air contained in all water. They are well-known under the name of land and fresh-water shells.



I would here mention a peculiarity in the respiratory structure of these animals which is worthy of notice. In this protective portion of the shell we have a large cavity opening outside of an oblong hole. The whole of this cavity is covered with blood-vessels, parallel to each other but connected by transverse vessels, and forming a kind of net work all over the cavity, so that the air which is introduced into this cavity at once is brought in contact with a great many blood vessels. The heart is near the base of this cavity, so that from there the blood is carried directly to the respiratory organs. The only difference, then, between this organ and the gills of the common Mollusca is that the blood-vessels are united with the vessels of the cavity, and do not form a tube-like free appendage hanging in the water.

The number of species in this group is very considerable. There are as many living in the fresh water as there are upon the dry land; but usually they seek moist corners when they conceal themselves, along fences, or between the roots of trees in wet localities. They are very voracious and consume a great quantity of carrion, and are thus useful in many respects, though in other respects they are quite the reverse, being often very destructive in our gardens.

Another group is that of the *Terrepadæ*, not mentioned in my diagram, because I consider the classification as little natural as the others. It has, indeed, been shown by a Russian naturalist that they have such an affinity with so many other groups that they should be divided and placed among the different families. What was considered the common characteristic was a kind of membraneous appendage on the sides of the head by which they swim; but this is not formed in all by the same part. In some it is a dilatation of the body, in others of the anterior ridge of the head; and therefore you see in this case a classification of animals in one group from an external likeness in one respect, which is not owing to an uniformity of structure.

I now pass on to the examination of the *Cephalopoda*. The diagrams present numerous illustrations of this class. Here are some without an external shell. Here is one apparently naked, which has an internal shell. The most striking external feature is that the head, is more distinct than in any other mollusca. There is a contraction about the anterior ridge where we see two distinct eyes. The posterior part of the body is in the form of a sac. Around the head we have membraneous appendages which have been called arms or feet, and on whose surface you see numerous suckers, by which these animals seize their prey and convey it to their mouth, which is in the centre of the tentacles. Some of the cephalopoda have only eight of these tentacles and feet.

Here you have eight of the same size; and two much larger, of different form, with a cylindrical base and flat extremity. Some are even provided with hooks in this more elongated form, by which they seize their prey more vigorously. In this species the arms are very numerous and they have appendages like numerous tentacles, forming bunches, which are arranged around the mouth in a similar manner as the four tentacles in the other species.

In their internal organization they agree in this respect—all are provided with large gills placed on the sides of the animal; and at the base of these gills we see two venous hearts and one which is colored in blue and another in red. So that there are three hearts in these animals. But when we here speak of several hearts we must understand what we mean. These several hearts are little

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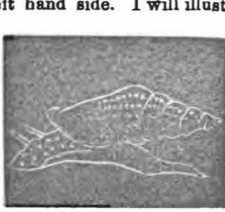
more than dilatations of the tubes which carry the blood. They are large sinuses in the blood-vessels and not muscular hearts like the hearts of higher animals. The blood reaches the heart from the two large-lobed sacs situated at the base of the gills, which are considered as hearts by some naturalists. They force the blood into the gills, where it is brought in contact with the extensive surface of water, and then it is changed into arterial blood and is again appropriated for the functions of blood in the living animal. It then comes again into the heart proper, which propels it into all parts of the body.

In the diagrams the blood-vessels are colored as in the higher animals. But it is not so in Nature. In these animals the blood is transparent; and it is only for the sake of illustration that the coloring has been here employed.

Near the stomach, between that organ and the liver, these animals have a little gland which secretes a dark-colored fluid of a very dense consistence, which is used in the manufacture of the "China ink." All the cephalopoda have their sac filled with this black or rather brown substance in great abundance, and it is so tenacious that in all the fossil cephalopoda, which are very numerous, those ink-bags have been found in the fossil state, full of fossil ink—and this fossil ink is so well preserved that when prepared it has been used in the same manner as the China ink made from the recent cuttle-fish. I have repeatedly seen fossils drawn with the China ink furnished by these shells existing for thousands and thousands of years in the strata in which the greatest number of these animals is found.

I have just mentioned that in this group we have some without a shell, some with an internal shell, and some with an external shell. This clearly shows how little value can be placed in the existence and possession of shells, and how erroneous would be classification resting only on that principle.

In the form of the shell this group presents a marked difference from the gasteropoda. In both types the shell is rolled up, but in the gasteropoda the animal moves sideways when rolling up, and thus in the snail you have the right hand side turning on the left hand side. I will illustrate this by a diagrams:



In the cephalopoda the shell is rolled up in a very different manner. You see here the back outside and the lower region below and the right and left

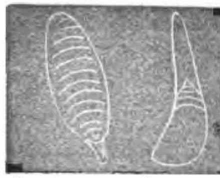
hand side are symmetrical. So that the cephalopoda which rolls up to form its shell, rolls up head forward and back outside, while the gasteropoda rolls in a different manner.—Again, in the gasteropoda the interior of the shell is completely occupied by the animal when it is contracted.—Not so in the cephalopoda, or at least in most of them. There is onewhich makes an exception. The nautilus proper is divided into numerous chambers, and those chambers are at equal distances, constantly growing as the animal grows larger; and the animal occupies only the anterior portion of the shell, though it formerly occupied all these partitions, only when growing larger it moved on and formed partitions between itself and all these chambers.

The siphon which communicates with the heart is in part a prolongation of the pericardium. We have only one genus of these chambered shells rolled up in that manner living now, and another where the shell is not entirely rolled up as it is here, but where the successive convolutions are detached from each other, so that it is as you see here:

This has been called *Spirula*. It is an animal not very well known. Though found on these shores, it is rarely met with in a good condition for examination. The siphon passes through all these partitions in a similar way as in the nautilus. These two are the only ones now living with chambered shells; and you will perceive that it is this animal which has not simple tentacles, but bunches of appendages forming masses similar to the tentacles in other diagrams. The structure of the gills and tentacles alone considered would make the nautilus inferior to those beautiful animals in our seas.

There are other anatomical reasons to consider the spirula as well as the nautilus lower in their organization than the true cuttle fish. The fact that they are rolled up in this manner, while the body is straight in these and comes nearer the natural symmetry of an animal having a longitudinal diameter and two symmetrical sides, shows evidently that their type is higher than that.

Now all the cephalopoda found in a fossil state below the coal during the coal epoch—during the series of secondary rocks—belong to this group. They are as numerous as the gasteropoda are in our seas. In a living state we have only two types, but hundreds and thousands of them are found in all the ancient strata, up to the most recent deposits forming the outermost beds of the crust of the earth. Those which have internal shells have also existed in former epochs, but not very late. They are only found in the oolitic beds, in the series of strata extremely extensive in the British Islands and Continent of Europe, but found in a very rudimentary condition in this part of the world. They are well known in every part of Europe under the name of "devil's fingers." They have a conical form, and inside of them a hollow cone; and this cone is divided into partitions, and on one side it is prolonged in the form of a flat disc.



For a long time it was not known to what group

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of the cephalopoda they belonged. They have been considered as belonging to the chambered shells in the division of this hollow cone. But when studying the shell which is found in the back of the cuttle-fish, and is known under the name of "cuttle-fish bone," I found that this disc is divided in the interior by plates of calcareous matter.

But it had not been noticed that there was constantly a little point here, which, when minutely examined, is found to be hollow. On comparing the arrangements of these plates it will be found that they go into this point, and in fact the cuttle-fish is a belemnite in a reversed position. So that there is no doubt now—and this explanation is generally admitted—that the belemnites are by no means the external shells of cephalopoda, but the bones of some cuttle-fish of the oolitic series; and the fact that in the beds where belemnites occur, we find the greatest quantity of those loose ink-bags in a fossil state, is a confirmation of that view. (Applause.)

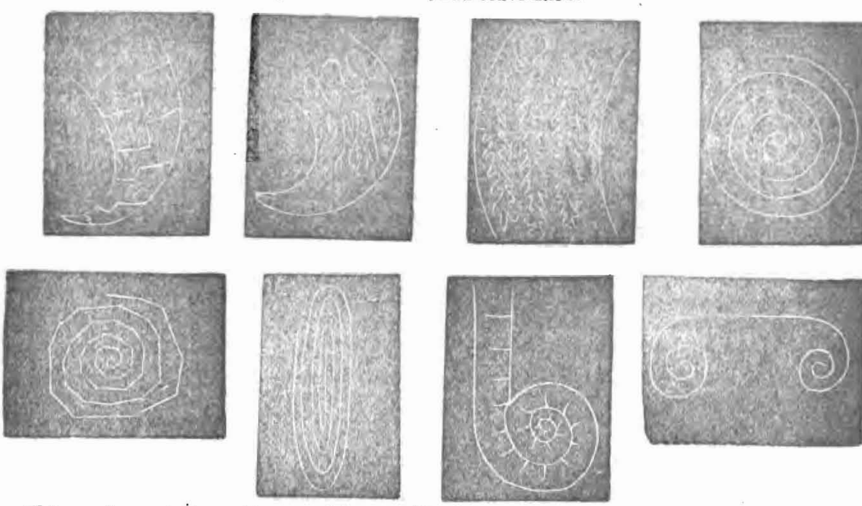
The naked cuttle-fish of our day are numerous; and as you see, have tentacles arranged in pairs. Those which have only eight tentacles never have a hard shell or any hard part. Those, on the other hand, which have ten tentacles always have hard parts. But in some of them this shield which is placed in the back is cartilaginous—not very hard in the species common here, but in the common cuttle-fish of Europe, very hard and calcareous.

Now, it is not enough to have shown that the chambered class are last and appear first—that those which have an external shell are younger, and follow those which have hard plates. I want to show that there is a very regular mode of succession in these. In the most ancient beds below the coal, where the chambered shells are the most numerous, we find types already with varied plates. I have shown already how these chambered shells are rolled up. It is not necessary then to draw a full shell, but just enough to give a notion of it.

In the most ancient strata some of these chambered shells are perfectly straight, having a siphon in the centre, or on the margin of some of them.

Already these two types occur in the mos ancient strata, and you see here the beginning of a series which will pass through all possible modifications of their shape. Some have the shell curved only in this way with a partial curve, and some have the shell curved thus, like a hook in the beginning, and then becoming quite straight:

Here are specimens of these extremely diversified convolutions·



All forms of convolution, as it were, of the straight tube are to be found in these shells just at the epoch when the family dies out.

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LECTURE VII.

The Articulated Animals...General Division into Worms, Insects and Crustacea....Errors in the Classification of Animals....Results of Recent Investigation....Mistakes should be Corrected....Curious Facts about the Barnacles....General Structure of the Articulata....Peculiarities of their Nervous System....Discovery of Mr. Blanchard....Worms....Great Variety of Form and Structure....The Helminthes or Intestinal Worms....How do they come to Exist in other Animals?....History of the Formation of Intestinal Worms....Curious Discoveries ....The Theory of Spontaneous Generation Exploded....Explanation of the Phenomenon of Red Snow.

CLASSIFICATION OF THE ARTICULATA.

I..VERMES..............(Worms.)
1. *Helminthes* ....(Intestinal Worms.)
2. *Apoda*...........(With feet.)
3. *Chætopoda* ....(With feet like hairs.)
4. *Dorsibranchiata* ..(Gills on the back.)
5. *Tubulibranchiata*.(Gills like tubes.)

II..INSECTA...............(Insects.)
1. *Arachnoida*.......(Spiders)
2. *Suctoria*..........(Suckers.)
3. *Mandibulata* .....(With jaws.)

III..CRUSTACEA ....(Crustaceans.)
1. *Parasita*..........(Parasites.)
2. *Entomostraca*.....(With articulated claws.)
3. *Malacostraca* .....(With calcareous claws.)

LADIES AND GENTLEMEN:—The subject of the Lecture this evening will be the structure of the Articulated animals in general and of the worms in particular.

The general structure of this order of animals is well known. The bodies of these animals are perfectly symmetrical. The two sides are equal.—We have no longer here any such differences between the right and left hand sides as we have among the Mollusca, or anything similar to the radiated structure of the lowest type of the Animal Kingdom. The Crustacea only show in their limbs—in their claws—such a difference. In them we see frequently one of the claws much longer than the other.

But it is well known to what circumstances this difference is owing. The Crustacea frequently lose the claws and these limbs are reproduced, but usually of diminished size. When the animal does not meet with such an accident, the claws continue of the same size, and this accidental disparity is still farther illustrated by the fact that sometimes it is the left and sometimes the right claw which is smaller than the other. This shows that the difference in size is not a characteristic of the type.

I propose to divide the Articulated animals into only three classes—the *Worms*, the *Insects*, and the *Crustacea*.

This type has always heretofore been divided into a great number of classes, and even some classes have been left out of the *Articulata*, which I think really belong to that division, and here, in this connection, I design to make a few critical remarks on the general classification of animals as we find them in the most recent works on Natural History. This classification has not kept pace with the progress of our knowledge. Our text-books do not give the results of recent investigation and discovery. I would refer to the best of the classifications, not perhaps the most recent, but the most extensive—that contained in the great work of Cuvier on the Animal Kingdom. That is the greatest work on Natural History; not very voluminous, in five octavo volumes, in which the celebrated author has given the general characteristics of all the principal types of the Animal Kingdom, and for the first time classified them according to their organization. It was Cuvier who for the first time divided the Animal Kingdom into four types—who recognized four different modes of arrangement in the structure of animals, and that there was not a simple gradation from the lower to the highest animals. When he divided the Animal Kingdom into those four groups, he designated those groups by a very happy name for which I cannot find an English term sufficiently explicit. He called these divisions embranchments. By this he conveyed the idea in a felicitous manner that the groups of the Animal Kingdom did neither form a single series nor parallel lines, but a complicated grouping of individuals connected together by affinities in a similar way as the branches of a tree, forming groups with very natural proportions, though not divisible into families of equal value. The groups we may call types—great divisions of the Animal Kingdom. For want of a better name, some have proposed the term "departments." Thus you see, if I am correct, that we have not in the English language any term which conveys the idea so happily as that employed by Cuvier.

When Cuvier divided the Animal Kingdom into these four groups, some of the groups had not yet been studied anatomically as fully as they since have been studied, and therefore it is not to be wondered at that that illustrious naturalist introduced into several of these groups animals which did not properly belong to them—that have only an external likeness—which are analogous to them, but not really identical in their structure. For instance, in the group of Radiata, to which I refer only three classes—the polyps, the acephala, and the echinodermata,—Cuvier had five classes, one of them being the class of intestinal worms—the *Helminthes*—and the *Infusoria*, a class which, I think, must be entirely broken up, and does not form a natural group, but contains animals of very different structure, and which have been combined together as a class only in consequence of their minute size. That is the only characteristic which they have in common, but their structure is not such as to justify this union in one class, nor to justify their admission as a natural group among the Radiata.

Cuvier, Lamarc and other eminent naturalists were induced to maintain the class of Infusoria, in consequence of the general arrangement of vibratory cilia around the mouth, presenting the form of a circular disc vibrating round the mouth, and giving these animals an appearance of radiated structure like some of the polypi. But on examining the bodies of these animals, it has been found that there are transverse divisions in these animals. Some of the infusoria have been found to agree so fully with articulated animals that nobody now doubts the propriety of combining at least the so-called *Rotifera* with the crustaceous animals. Others are worm-like, and belong more properly to the Vermes than any other group, and we know that many of the so-called infusoria are merely germs of plants which have been mistaken for animals; and germs of different other animals which have been mistaken for full-grown animals. Thus it has been discovered recently that organizations which have been regarded as independent animals, and as such have been placed among the infusoria, are really the young of certain Mollusca—certain gasteropodous mollusca.

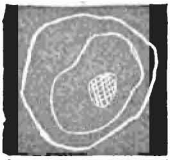
Now such mistakes should be corrected. When they were made, the facts by which we are enabled to correct them were not known. The works in which the mistakes occur are and must long continue to be the great fundamental books of Natural History, and hence the greater necessity for rectifying these errors.

The class of intestinal worms, heretofore ranked with the Radiata, belongs to the Articulata. All these worms are articulated transversely. These articulations are very numerous. But they have a circle of radiated folds around the mouth. Hence the mistake to which I have alluded in classifying them with the Radiata. The existence of a nervous system with ganglia was then unknown—so that the mistake of Cuvier cannot appear strange, particularly when we reflect on the extreme difficulty of observing the structure of many of the intestinal worms.

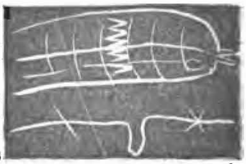
I have said that I divided the *Articulata* into only three classes, though I admit all the intestinal worms and the greater number of the infusoria. Cuvier admitted more classes than I think proper to admit. The spiders were considered by him as a class distinct from the common insect, because they have no wings and because their respiratory organs are somewhat different from those of common insects. But many true insects have no wings; and when tracing all the modifications of certain insects we find the transitions so gradual as not to allow the differences between them to be of the value which was formerly placed upon them; and so the class of spiders is now merged in the general group of insects. Beside, we have now ascertained that the metamorphoses of insects are not so peculiarly a trait of that class as was formerly supposed, and therefore in the absence of that characteristic in the spider we do not see the same ground of making a prominent distinction between them and insects. There are many insects which do not undergo so striking a metamorphosis as the butterfly and some other two-winged insects.

Then again, certain crustacea, which had been distinguished as a particular class, must now be combined with the true crustacea. It will perhaps appear singular that the *Balani*—there is a common English term for them, which now escapes me—ah! I recollect it, the "barnacles"—should belong to the Articulata. They have been placed among the shells. But that classification was erroneous, and this is perhaps one of the most unexpected results of recent investigations. Even during the lifetime of Cuvier—fifteen years ago—nobody suspected that the barnacles did not really belong to the class of shells. Cuvier himself published an elaborate paper on the nervous system of the barnacles, in his memoir on the Structure of Mollusca, and he considered all barnacles as true mollusca. He made only one remark, that he was struck by the complicated nervous system of these animals; and that remark has been the foundation of that true distinction between the Mollusca and Articulata. He found that the ganglia were more numerous in barnacles than in Mollusca, where there is only a large ganglion above, and another or two below the alimentary canal; while in the barnacles we find that below the alimentary canal there are several ganglia, and when comparing the nervous system of the barnacles with that of the greater number of Mollusca, and with that of the greater number of other articulated animals, it was found that this very great peculiarity constituted the most striking difference between them. From that time it was suspected that, though the barnacles were supplied with shells, they might yet belong to the articulated animals. A British naturalist—Mr. Thompson of Cork—when engaged in the study of the barnacles found that the young, when escaping f om the egg, is a true crustaceous animal; precisely like other crustaceous animals, and fixing itself only after a certain time, when the shells are formed to protect it, and combine in such a manner with the animal as to give it an external resemblance to the Mollusca. But the internal structure is entirely different. So there is no doubt that the barnacles, cons dered as a class of Mollusca by Cuvier, do not only not form a class by themselves but are true Crustacea. This change in the classification is made necessary by those recent researches into the structure of the nervous system of barnacles and into the growth and metamorphosis of the young. But it has not yet been effected in general works.

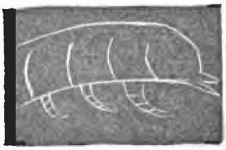
Through the kindness of Professor Watts, I am enabled to show this beautiful preparation, illustrative of the structure of the articulated animals. This is a large *Scolopendra* where the divisions of the body into transverse sections, and movable rings, with appendages on each side in the form of feet, are seen much more distinctly than they could be perceived in any insect.



The body is divided transversely. Every one of these divisions forms a protecting ring of horny substance. Here we have no calcareous substance, only in some lobsters. In some of the crustacea the shield is hard and contains limestone.—These rings are united together by a membrane.



Here is the articulation, but the ring does not pass across the whole. There is a fold and the next ring iss The membrane here is thinner and allows a fold to be formed, and so the next ring is movable on this one. Many of the articulated animals have all their rings uniform and very numerous. So it is with worms. Others have appendages to these rings of very varied form. In some these appendages are even very complicated. In some insects with rings there are as many feet as rings.

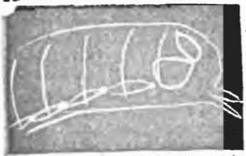


All the rings have feet. The number of them may reach hundreds, even several thousands. When there are appendages they are soft, as indeed in general the covering of the worm is soft. The rings are also soft, so that the body of these animals has a less constant form than other articulated animals.

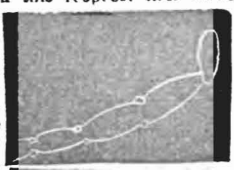
In insects, if several rings are combined, we usually see the body divided into two or three regions—two more distinctly—sometimes three.

You see here a long tail-like appendage. Here the tail is shorter—the head very distinct. All these appendages can be combined together, and we find them to be very analogous It is in the worms that we can best understand what they are, and I shall defer these details till I come to speak of the worms.

You will recollec the characte ristics of radiated animals. Bear in mind now that I direct your attention to the structure of the intestinal worms, which are now classed not with the radiated, but the articulated animals.



It is only recently that a young French naturalist found that there was a nervous system in all intestinal worms, even where least expected, and found that it differed somewhat in arrangement from the common articulated animals. It is in this respect: that these threads go from one ganglia to another, and, instead of joining as a common swelling, form two independent series of parallel nerves. But you see that the difference is not very considerable. After all,



it shows how we ought to consider these as arising from the juncture of the parallel threads, rather than as one only with swellings intermediate; and far from being the exception to the rule, it gives the true key to the understanding of this arrangement, which in fact we did not know before the discovery of Mr. Blanchard.

The class of worms, insects and crustacea rest for their distinction particularly on the respiratory organs—the circulation and mode of respiration.

The worms are elongated, cylindrical and composed of very numerous and rather soft rings. The skin shows superficial folds, and these folds are movable on each other, not to be compared with the hard rings of higher articulated animals. We find in worms the greatest variety of structure.—There is perhaps no class of the Animal Kingdom which shows more of this variety. Many characters which are considered of the highest value disappear here entirely. For instance, in the intestinal worms we have no circulation whatever—no heart—no blood-vessel—no blood even; while in other worms of the same class and which cannot be separated from them, we have not only blood, but blood of the most ruddy color—blood-vessels very complicated, and not even one alone, but sometimes three or more pairs of hearts. Thus the most complicated circulating apparatus and a total absence of blood-vessels are found in one and the same class of animals. More than that, some of the worms have organs of respiration, gills, highly complicated gills, perhaps more complicated than the gills of fishes, or of any of the Mollusca. The most complicated structure of the gills is found in some of the worms. In others there are not only no gills but no respiratory organs at all. I would go beyond that. In some we have an alimentary canal, which is simple. There is only a mouth and an alimentary canal branching into the body and diffusing the product of digestion like a blood-vessel through the organs without causing that fluid to pass before through peculiar tubes or through any organs of circulation. What, then, is there in these in common? Why combine animals presenting such dissimilarity of structure? This is really the question I have to answer, because they have heretofore been divided into distinct classes. Worms with respiratory organs and circulating apparatus have been united into one and the same class under the name of *Annulata*, and worms without these organs have been united in the class of intestinal worms, while some others which are less known and are also parasitical have been formed into a third class under the name of *Tubularia*. The common character of all these insects is to have the elongated form, with numerous articulat wings connected in such a manner as to able on each other in all directions, the stru the skin being more simple than it is in animals, not being divided into so many layers; and the muscles so combined with the skin as not always easily to be distinguished, so that the skin is formed of interwoven muscular fibres with hard horny rings moving on each other.

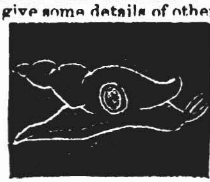
Again: the nervous system is uniformly constructed; and there are intermediate types so numerous that between those very complicated worms with highly organized organs of circulation and respiration and those which have none at all we find all intermediate steps; some where the circulation is farther developed but where the organs of breathing are not so highly organized, and *vice versa*.—From the uniformity of nervous structure and from the fact just mentioned with regard to the numerous intermediate steps in the cavity of respiratory and circulatory organs, we are justified in arriving at the conclusion that all these animals must be combined in one class.

The *Insecta* in the full-grown state have no organ of circulation—at least they have no heart. But they breathe through a very complicated system of air-tubes penetrating into the body, having numerous external outlets, penetrating, like vessels, throughout the body, and undergoing considerable and very striking metamorphoses; while the Crustacea have a circulation and breathe through the gills. This evening I must, however, limit myself to the investigation of the worms.

So many changes have to be made in the classification of these animals, that, at present, it is scarcely possible to admit any of the classifications in the books; though these classifications appear very simple, and are founded upon characteristics very easily recognized.

The first division of worms is the intestinal worms or *Helminthes*, which is their systematic name. They have been the subject of many speculations. How do they come to exist in the bodies of other animals? How can they be introduced into cavities perfectly closed? And if they cannot be introduced into those close cavities, how are they produced within those cavities? These were questions which were apparently answered in quite a satisfactory manner; and the reply—these worms originate where they are found. That was the common solution of these questions; and, in fact, it has till recently been believed that intestinal worms originated, in particular circumstances, within the bodies of animals, within the alimentary canal—within the surface of the abdominal cavity of animals in which they are found. But is that true? This statement rested merely on assertion; and no one ever made observations so as to prove that the animals had been produced where they were found. It was only because it could not be explained or shown how they were introduced, that it was quite generally admitted that intestinal worms originated where they were found. But recent researches have explained the way in which these animals are introduced into the cavity of other animals.

I will give the history of one of them, and then show what conclusions may be educed, and then give some details of other divisions of worms.



The history of the intestinal worms is most interesting, owing to the fact that they have been regarded as affording the most striking example of spontaneous generation. The mode of formation without apparent cause

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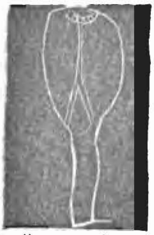
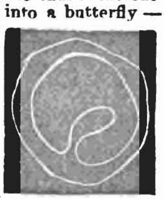
has been called spontaneous generation—the intestinal worms. as also infusoria, were considered as arising spontaneously either from a diseased condition of the alimentary canal, or from peculiar circumstances, without knowing how. Let this be the body of a common species of fresh-water shell. Steenstrup, the Swedish naturalist, disovered that at a particular season this shell had worms of



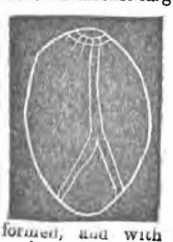
a minute size. These worms have this form: Here is a kind of sucker. Here the alimentary canal, dividing into two tubes in this way—a forked alimentary canal. At particular seasons these worms fix themselves upon the skin of this shell-fish and within the mucus which surrounds it. They swim in innumerable quantities in the water, till they fix themselves upon this mollusc; and there they form little cysts in which they bury themselves. Fixing themselves on the skin by means of these suckers, they produce a kind of irritation. The mucus is secreted in large quantities and accumulates around them, forming a kind of cell in which they are buried. They remain there curled up in such a sac, and may be found in great abundance in the skin after the mucus has been removed.

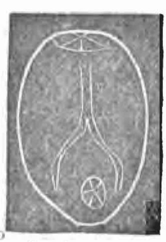
During time they are buried in that way, they undergo a metamorphosis similar to that of the caterpillar which is to be changed into a butterfly.— The tail is cast, and a circle of folds is formed around the head and we have then an animal of such a form which escapes from these little sacs. The animal then penetrates into the skin with these folds, which are harder than the outer portion of the animal. It bores its way into and passes through. the skin—



enters into the wall of the animal, and, passing across that wall, enters into the abdominal cavity, and reaches the organs contained in the abdominal cavity, entering even into these organs themselves.

These folds then disappear, and the anterior region of the animal assumes another form. Here we see a sucker—a mouth which is small. The intestinal tube still retains its bifurcated form. But here is another large sucker

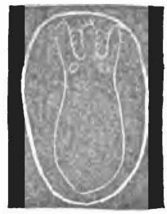




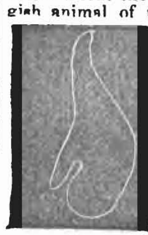
formed, and with these two suckers the animal walks over the inside of the abdominal cavity, over the organs, in a manner similar to the leech, and fixes itself upon the liver, which it penetrates, and we have there that common intestinal worm of the liver which has been described in the class of intestinal worms, under the name of *Distoma hepaticum*.

Several other worms are found to enter the abdominal cavity in the same way. I have lately seen some of those penetrating into the gills. One of the gentlemen now present, saw it within the flesh of the abdominal wall, penetrating through the flesh and reaching the internal organs. It had nearly gone through the whole thickness of the fish, and was about to reach the abdominal cavity when the fish was opened. So that, in the case of the distoma, the way in which these worms penetrate into the cavities of other animals is well known. I do not say that all intestinal worms are introduced in the same way into the alimentary canal; those are not found in the alimentary canal but found in the organs of the abdominal cavity. We shall see in what manner others are introduced into these cavities. What is still more curious is that this distoma, after it has been in the cavity of the body, will lay eggs, and these eggs have a very singular structure

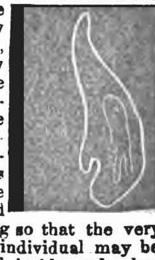
Within the egg, we see a young one formed which has this shape. The moment the shell of the egg



breaks the new individual escapes, and here there are numerous vibratory cilia by which it moves with great rapidity, in a manner so similar to some of the rotifera that I do not doubt for a moment that many of them are only embryos of these intestinal worms. But even within the egg we see through this shell another thing. It is very thin and transparent.— When the young escapes and begins to move, that faint body inside becomes more transparent —more prominent—always of this shape. At that time this free movable covering, with all these vibratory cilia, is cast. It is no longer a portion of the animal. It is like the skin of the caterpillar which falls away, and out of it comes a sluggish worm. moving very slowly, which grows and grows, and we see within that these extraordinary phenomena which, if not observed by several experienced naturalists, would be well deemed incredible.— The moment the skin is cast we have a very sluggish animal of this shape.

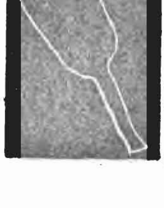


We now see eggs formed which become numerous and grow. We see some assuming a peculiar form. We see through this body new individuals formed inside, which have a form somewhat different from that. When ripe to escape, their form is like



this: And now they escape, and now they grow. We have, therefore, here a generation arising from the egg of the distoma, which does not produce animals of that form—a second generation.

Inside of this organ we see eggs form, and these growing so that the very form of the individual may be distinguished, inside and when these new young—the third generation——escape, we have this animal, the common Cercaria: the third generation from the egg of the distoma. (Applause.)



I have no part in these beautiful discoveries. I only relate them.

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(Applause.)—Here we have animals of successive generations undergoing in each generation a series of metamorphoses. We have three alternate generations each undergoing metamorphoses, producing individuals different from the mother, and so for three generations, till at last we have the form of the common intestinal worm, which reaches the internal cavity and there becomes a parasite.

How difficult to identify all the successive generations when each generation, in its metamorphoses, assumes such different forms! But when the *great grand-father* is reproduced in the fifth generation, all doubt must end.

What remains then of the theory of spontaneous generation? It is gone forever! Every one now who attempts to reason on spontaneous generation knows that he is reasoning on what has no existence. He is reasoning on a supposition which has been scattered to the winds. (Applause.) Because one such fact well-ascertained—as that has been, and you will see that similar facts have been well ascertained—is sufficient to destroy forever such a theory. Another case adduced in favor of the theory of spontaneous generation has been shown to be equally unfounded in fact. I allude to the infusoria. But the rotifera also lay eggs. I have seen some rotifera living in the snow at the hight of eight and ten thousand feet above the level of the sea, causing the snow of higher mountains to be as red as blood and presenting a most beautiful appearance. This red snow is only an accumulation of microscopic animals belonging to the class of rotifera among infusoria. I have seen some of these laying eggs. I have had the good fortune to have been able to trace some of the changes in these eggs, not all of them, so that I mention here an imperfect series of observations, because I can stand for that; but other observers—Ehrenberg, in particular, who has made that beautiful history; in fact created the natural history of Infusoria—have completed the researches on this subject. Ehrenberg has seen rotifera laying eggs an hundred times. He has seen the young form and grow within the egg. He has not only seen them grow, but he has traced them for a series of generations. Individuals which he grew from eggs he has seen laying eggs. He has seen them for three, four, six, ten generations. He has even seen individuals arising from a stock from which millions have been derived; and now, again, I ask, what remains of the theory of spontaneous generation? (Loud applause.)

But there are other intestinal worms for whose presence in other animals as parasites it is not so easy to account. These are found in the eyes of almost all fishes, and in other portions of the body. How they were introduced is a question which could scarcely be answered, were it not for the discoveries of a distinguished Professor of Natural History in Copenhagen—Prof. Eschrich. He traced them in fishes which were kept in a pond, so as to be able at a moment's notice to kill a sufficient number of fishes and examine the condition of the intestinal worms within each animal. He found that in the scolpin of the Baltic, at a certain epoch, there were always very large tænia in the alimentary canal, while at other seasons there were none to be found. He ascertained, for a series of years, that the presence of these tænia was periodical, and he knew at what season he could find them, and in what condition he would find them.—The moment that he ascertained this preliminary fact, which cost years of patient investigation, he went on tracing still farther the phenomena, till he discovered that these animals—which are exceedingly long, with a small head, a very slender neck and thin body, of extraordinary length, divided into transverse articulations—cast,

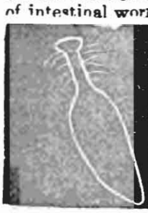
at certain seasons, the greater portion of their body, and that he could produce it by dividing this portion of the head, the articulations dividing and dividing till a great number were formed. When studying the anatomy of these links he ascertained that there was a continuous tube running through all—in fact, an alimentary canal, but branched in such a manner in every ring as to supply the ring with substance; these branchings of the alimentary canal being at the same time a sort of blood-vessels or organs of circulation. But he found, moreover, that in each ring there were several hundreds of eggs, each having the true character and three essential parts of an egg. When these bodies were cast, then of course innumerable quantities of eggs escaped into the water and were swallowed by the fishes with their food. This affords a perfectly clear solution of the manner in which those intestinal worms find their way into the bodies of these fish.

As to the terrestrial animals in whose cavities intestinal worms are found, the same process takes place. With the vegetables on which they live, there are constantly conveyed into their alimentary canal innumerable quantities of eggs. And now we can also explain the reason why some animals have one species of worms and others other species. The alimentary canal of some has an influence which the eggs of certain species cannot resist, and they therefore perish, while in other animals they grow and propagate.

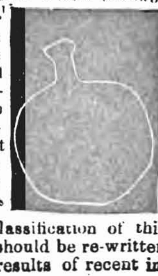
It has been still farther ascertained that these eggs exist in the blood cavity, nay, they have been found circulating with the blood corpuscles of certain animals—in the frog, for instance.

These researches of course require great patience and care, as they are attended with obvious difficulties; but they have been repeated by competent observers, and there can be no doubt of the accuracy of the results.

All this shows us how defective the old classifications must of necessity be. Even old divisions of intestinal worms can no longer be admitted.



This is only one state of an animal, so that it must be combined with that class instead of forming an independent division. So with others which belong to the distoma, which, as we have seen, undergoes many changes, but is still the same animal. Then we have the *Cystica* which perhaps are not real worms, but only the sacs in which the actual worms are found. All the classifications of them are yet to be changed.—The class Nematoidea of Cuvier and the families Aconthocephala and Frematodea, which last contain the Distoma, must undergo an entire revolution as the history of the animal becomes



known. In fact, the whole classification of this type of the Animal Kingdom should be re-written and made to accord with the results of recent investigation and discovery.

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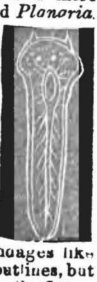
LECTURE VIII.

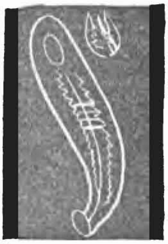
The Remaining Types of the Class of Worms....Its Divisions or Families—The *Apoda*, or Fresh-water Worms ....The so-called *Planaria:* the Leech and its Structure....Rudimentary Feet....Respiratory Organs of this Class—External Gills, or Ramifications of the Blood-vessels in the form of Stiff Hairs: the *Dorsibranchiata*.. . Another Group of Worms still more complicated—the *Tubulibranchiata*.—Articulations of the Body and very complicated Gills....The Singular and Interesting Metamorphoses of these Animals....Disappearance of the Eye....These Animals when young highly phosphorescent....Experiments....The Class of *Insects*—the most numerous Class in the Animal Kingdom—their Structure closely and extensively studied—Illustration of their Striking Phenomena....Structure of their Respiratory Organs....Structure of Wings....The Order of *Coleoptera*....The *Orthoptera*....The *Emiptera, Neuriptera, Hemiptera, Diptera* and *Aptera*....Their Structural Peculiarities have given origin to the designatory terms *Suctoria* and *Mandibulata*....The Metamorphoses of Insects ....The Class of *Crustacea*, and its subdivisions....Structure of the Eyes of particular Classes.

Ladies and Gentlemen: I know no greater difficulty which a lecturer is called on to encounter than that created by the necessity of crowding a great quantity of matter into a limited space. That difficulty I cannot avoid on this occasion. In this Lecture I must finish what I have to say on the worms, and introduce the insects and crustacea; in order to have some time left for the remarks on the higher animals, and for general observations on the phenomena of gradual or successive introduction of types through geological times, which will, I think, constitute a becoming conclusion to a course of Zoological Lectures in order to show how the succession agrees with the classification and structure.

I shall avoid repeating what I said in the last Lecture, and proceed at once to the remaining types of the class of worms. The families which we have studied are the lowest—those without any external appendages, provided only with transverse articulations or rings. The other worms are not parasitical; at least few them are, and most of them have shorter bodies composed of fewer rings than the intestinal worms. In one of the families which has received the name of *Apoda*, and contains a great number of fresh-water worms, we have that extraordinary type in which the alimentary canal is branched like a blood-vessel. It is a very beautiful sight to see through the transparent body, the stomach branching like a blood-vessel, contracting like arteries and the alimentary fluid running through the vessels like blood, to the periphery. Several are to be found in this neighborhood in ponds and rivulets, some of them being very beautiful. If they were not so minute I could have had the pleasure of showing some of these worms, as I have now several alive which were collected in the vicinity of this City. They are among the objects which will interest in the highest degree all who take the trouble of looking for them. They are usually found under stones in fresh water. Their form is that of the leech, and they are usually mistaken for leeches. The leech belongs to this type, but is more highly organized than these, the so called *Planoria*. Their form presents this appearance.



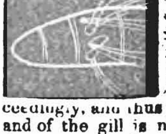
Usually they have two eyes—but sometimes a greater number—placed externally; and it is easy seen the eye has not attained in them the high value which belongs to it in the higher animals. Here we have the opening of the mouth, and there is the long alimentary canal, from which tubes branch off like blood-vessels toward the periphery in all directions. These vessels are usually of a darker color than the body itself. Some have appendages like tentacles, varying much in the general outlines, but all have this general form and are usually flat.—They fix themselves by this large mouth on the bodies on which they prey. The transverse articulations are scarcely distinguishable. A flat dentation on the margin is all that is seen of them. In fact, it has been doubted that they belong to the type of articulata, and if it were not for the structure of the nervous system these doubts would have some value. But it is owing to the very transparent nature of the tissues of the body that these articulations are so slightly marked. The



leech belongs to this type. It has a straight alimentary tube and also large jaws armed with teeth. Some have two jaws, others have a third, and thus the bite makes a triangular cut in the skin of the animal on which they fasten. The alimentary canal, now and then, shows dilatations, and these dilatations correspond to the articulations of the body. There is one point in the structure of the leech which must be considered; it is this: that the number of transverse ridges on the skin is not precisely in correspondence with the number of nervous ganglia. There are in several species three or four such ridges to one swelling. As very little in a physiological point of view can be learned from this species, I pass them, and proceed to the earth-worm. This class begins to have feet. But these feet are exceedingly slight and simple. If we have here transverse articulations, we will see that some of them are more prominent than others. Three or four or more are more prominent.

In every ring there are strong bristles or hairs, and these are the rudiments of feet—not articulated, only movable in their case, and it is by the motion of these stiff hairs that the earth-worms move about and burrow in the soil.

The respiratory organs here are little holes on the side opening outside, and with ramifications like blood-vessels inside. All these animals are terrestrial, but there are a great number of worms provided with feet living in the sea, and these have external appendages which are provided with little membraneous cells in which blood-vessels ramify and act like gills. These worms lie buried in the sand and are not seen unless the sand be disturbed. Some swim freely on the surface of the sea. Some of them are extremely beautiful and exhibit a great variety of color. Many, however, are very uniform. The principal and most interesting point in their structure is that their transverse rings, which are very distinct, are usually provided with two sorts of appendages. In the upper region we have usually blood-vessels ramified and forming an external gill extending toward the back, and these



stiff hairs sometimes in the shape of a brush; sometimes stronger and articulated even. Sometimes there are two such brushes of hair, one above and the other below the gills. In this respect the worms vary exceedingly, and thus the position of these stiff hairs and of the gill is not the same in two species of these worms. Owing to these differences and to the physiological interest of their structure, the story of these worms is one of high interest. For

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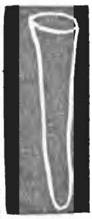
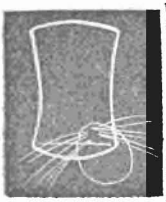
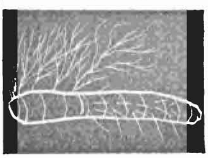
instance, we can see all possible transitions between such a complete gill standing out and forming paddles or feet, and a more simple structure which is observed in others where there is a kind of bladder standing out with a few blood-vessels; and these have some hairs also standing out above and below this vesicle. Now when we examine in detail all these complications, we see here only a little vesicle, the remnant of the large one, which has diminished in proportion as the blood-vessels came out and formed a gill. The group of worms which have such gills and such stiff hairs as organs of locomotion have been called *Dorsibranchiata.*

There is another group of worms still more complicated. Many of them form a tube of sand, by means of the sucker which takes in particles of sand which are fixed by the mucus secreted by their skin, and thus a solid tube is formed. Some more fix together fragments of shell and form a harder tube in which they conceal themselves on the approach of an enemy. These have received the name of *Tubulibranchiata.* Sometimes they have hard calcareous tubes. In other cases the tube is membraneous; others have tubes formed as I have said, of aggregated particles of sand. The distinction between these different classes is that the body has not gills upon every ring, but only upon the anterior rings.

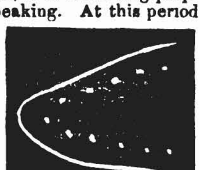


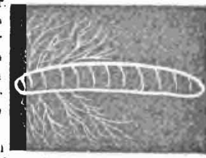
If this were the body articulated in this way we would have here only stiff hairs on these posterior rings; but here upon two or three of the anterior rings are very complicated gills, formed of blood-vessels extensively ramifying; or as many pairs of such complicated gills as there are rings, of peculiar form, behind the head; and here the head surrounded with appendages of a most extraordinary kind: usually very long, slender appendages, proceeding from the upper part of the head and forming a brush all round the head, and sometimes so extensive as to conceal nearly the whole of the animal. These appendages are singularly constructed. It is a thin membrane, folded in the centre, so that a transverse section would show such a position, and when entirely folded looks like a flat ribbon. It is as it were two ribbons folded into one, and when opened the animal walks in a way similar to the motion of the leech.





The metamorphosis of these animals is very singular and interesting. When young these worms are quite uniform; all the rings have precisely the same appearance, and there is a simple gill coming out from every ring. In fact, it is not a ring properly speaking. At this period the first ring has six or eight eyes placed in two series on the sides of the head. As the animal grows, the posterior gills disappear—the anterior grow larger and they gradually disappear in such a manner while the anterior become more and more complicated, so that several pairs will be formed, and in proportion as these posterior gills disappear the anterior grow larger. The eye also disappears, and in its place those long tentacles begin to grow, and it is with the tentacles that the animal moves and feels its position when it has lost its sight.





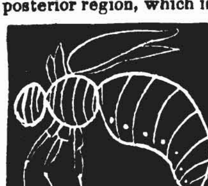
I recently made the unexpected discovery that these animals when young are highly phosphorescent. While examining one of these animals not more than two lines in length under the microscope, on the introduction of a drop of alcohol into the water, I perceived that the animal contracted and that light was produced. I thus perceived distinctly that these animals are phosphorescent. I had some doubt on that point, because I had seen in water some of the microscopic animals which are phosphorescent, and feared that the light might have been produced by their having fixed themselves on the worm. But this observation satisfied me that these worms were the cause of the phosphorescence—(Applause)—though, as I remarked in a former Lecture, there are various causes which aid in producing the phosphorescence of the ocean.

The class of Insects is the most numerous of all the classes of the Animal Kingdom. There are certainly between sixty and eighty thousand species already noticed by naturalists, and more than forty thousand species which have received names. We may then safely estimate the aggregate number of these species at some hundreds of thousands.

Their structure has been extensively and closely studied. But to give even the briefest abstract of what has been ascertained regarding their structure would be a task extending far beyond the limits of such a Course of Lectures as the present. I must confine myself to the illustration of some of the most striking phenomena: the metamorphoses of these animals, and the structure of their jaws—the organs of grinding the food—and the structure of the wings which exist in most of them.

As a class they are characterized by the structure of their respiratory organs, which are air-tubes opening outside at the lower portion, or rather at the lateral portion, of the wing, and communicating with extensive tubes branching in the interior of the animal.

What is most peculiar to insects, however, is the fact that they undergo extensive changes during the progress of their growth. They are born in the form of worms, and live in that form for a certain time, when, changing their skin, they assume another form, and usually terminate their lives in the form of a winged animal. In this class we have usually three regions of the body, well defined: a head, forming the anterior portion of the body—a middle region, which is called the thorax, and a posterior region, which is called the abdomen. On the last named region we have the wings. We have here the feet. These regions are divided by transverse articulations into numerous rings.—These rings are not always so distinct as they are represented here.—These appendages, the feet, are articulated, their



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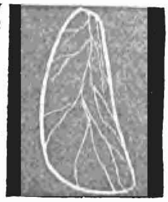
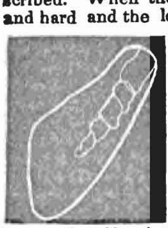
structure is complicated, and they usually terminate with a hook, by which they seize upon their prey.

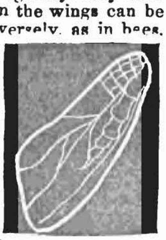
It is on the sides of these rings that the openings for respiration are seen. The number of joints in the body is well defined—three for the head, three for the thorax, and a number which varies for the abdomen, or posterior extremity

The structure of the wings varies very much. Some are transparent and have ribs branched in different ways. They have a very varied appearance. These are the remnants of blood-vessels. It has been ascertained that these ribs are hardened remnants of tubes through which the circulation was carried on in the earlier stages of life. In the perfect animal these tubes become hard, and the opening is obliterated. When the wings are very hard, as in the beetle, no trace of the ribs is perceptible. Usually, these hard wings answer the purposes of shields for the protection of the membraneous wings underneath and extend over the posterior portion of the abdomen. But in many insects the two pairs of wings are membraneous. Sometimes the posterior portion of the wing is softer than the anterior portion. These differences in the structure of the wing have been made the basis of the classification of many entomologists.

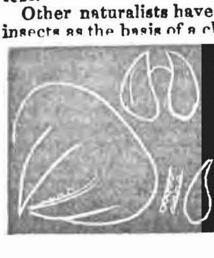


Where there are hard wings covering membraneous wings, as in the beetle, the insects have been called *Coleoptera.* They are the most numerous, and of them the greatest number have been described. When the external wings are straight and hard and the lower wings are also straight, though not so hard, they have been named *Orthoptera.* Grasshoppers belong to this class. When only the base of the upper wing is hard and the external end of it soft, they are called *Emiptera.* When the whole wing is membraneous, but when the "nerves" are arranged so as to form a network, as in the dragon-fly, they have been called *Neuriptera.* When the wings can be folded longitudinally and transversely, as in bees, they have been called *Hemiptera.* When only two pairs of wings exist, they are called *Diptera.* You see I have scarcely time to mention the fundamental principles of the classification. It would be interesting to enter into details about the structure of these wings but it is not possible in the limits of this course. Another group of insects has been called *Aptera,* or "wingless."





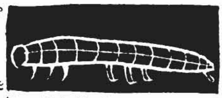
Other naturalists have made use of the jaws of insects as the basis of a classification. The beetle, for instance, has very powerful jaws, by which it can cut its food and divide it just as the carnivorous animals. These jaws are as follows: in the anterior portion of the head there is a strong pair of plates like a scissors, which have been called the "mandibles." The head of the insect should be viewed in profile, and then we have this appearance, which exhibits the mandibles and the mode of their articulation.

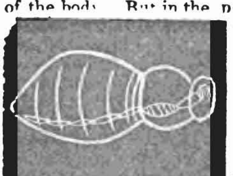


There is another class which have lateral appendages. These palpi are the organs by which the animal swallows and appreciates its food.

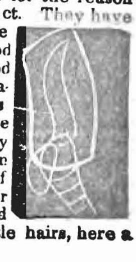
These structural peculiarities have given origin to the terms *Suctoria* and *Mandibulata* as designatory of these two classes of insects. But all the elementary works on entomology give so fully all these details that it is not necessary to enter into them more at length.

I will only add a few remarks on the metamorphoses of insects, and show what evidence we have for the systematic arrangement and appreciation of the value of different types of articulated animals. The caterpillar of insects is composed of a series of rings which are quite uniform. The three anterior pairs have feet of a peculiar structure, which are terminated by hooks, and these three pairs of hooks or feet correspond to the three rings which will form the thorax in the perfect insect. The seventh, eighth, ninth and tenth rings have other feet of a peculiar form like suckers—membraneous feet which are used as organs of locomotion—and usually the last ring has still a pair turned backward. Now the nervous system, alimentary tube and all the organs of respiration are perfectly uniform in all the rings. There is a nervous mass in every ring, so that the structure of such a caterpillar is very similar to that of any worm. The alimentary tube is a simple tube scarcely swelling in the region where the horny feet are seen, and quite uniform for the whole length of the body. But in the perfect insect, where we have the head well defined, the thorax distinct and the posterior region divided completely from the anterior portion, we have the anterior rings of the head still the same, but only one large nervous mass which results from the junction of these three nerves; and then in the abdomen we see again this difference. But when some of the rings come together we have a greater approximation between them. Here, though combined, the fundamental distinction of these swellings can still be observed. Here we see evidence that such insects with defined and distinct regions of the body must be considered as superior to those which have no such divisions.





The class of *Crustacea* is the highest among articulated animals, and we infer this for the reason that their circulation is quite perfect. They have a heart, from which proceed large blood-vessels, conveying the blood to all parts of the body. This blood is returned to the organs of respiration. In a lobster the organs of respiration correspond precisely to the thorax. They are in common chiefly formed by the junction of rings on the back and are above the base of the feet. Now if you will remember what I showed you in articulated animals, where we have here little hairs, here a



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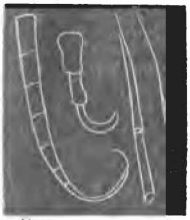
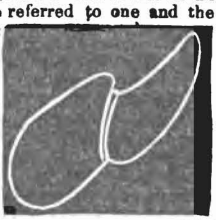
branching blood-vessel—here a vesicle with vessels ramifying in it, and if we trace the whole series of modifications in the type of articulated animals you will readily admit that in the Crustacea you have only in a higher and more complicated organization the blood-vessels seen in worms.

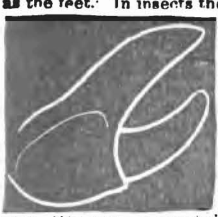
It is not a useless playing with forms to make these analogies. I will take my example from an actual species. We have in the earth-worm, simply stiff hairs as organs of locomotion, articulated at the base. We have in many of the marine worms these hairs not only articulated at the base, but also articulated at some distance from the base. We have that, for instance, among the *Aphroditæ*.—



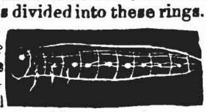
But take some of the insects and we have a foot with articulations and a hook at the termination—a foot formed of numerous joints and a hook at the end. We may trace all these modifications in certain families of the Crustacea. Here we have the last but one, and here the last joint. Now let this projection become a little more prominent and you see how little is wanting to make that a claw! Nor is this at all accidental. All can be referred to one and the same type—in fact, that all these complicated structures of locomotion from the heavy claw of the crab and lobster down to the single stiff hair by which worms move, are only modifications of one and the same type of appendages. (Applause.)



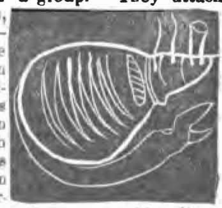
The jaws are the same as the feet. In insects the jaws are only modified feet; and if we wanted proof of that we have only to look at the jaws of Crustacea. In many of the crustacea there are not two pairs of such lateral movable appendages as in the insect, but there are as many as six pairs. The arrangement is thus: Let this be the foot of the crab. We can see how it is divided into these rings.



The anterior one has an appendage. At its end we find an eye. Then comes an appendage, as we see here—internal and external antennæ; and here the mouth. Here are the mandibles. Then another pair more slender; and a third pair still more slender. Then come three other pairs more complicated. So we have a series of appendages from the tail to the anterior extremity of the head. In the posterior extremity they are paddles, by which the animal swims. In the tail they are flat appendages; in the thorax they are feet; in the head, jaws; in the anterior extremity of the head, appendages by which the animals touch their food, and the first of these appendages terminates in an eye, and all these different appendages are only modifications of one and the same type. Nothing is more interesting than to trace these modifications through different families.



Among Crustacea there are a great many which are parasites and form a group. They attach themselves to the gills, skin and fins of fishes.—In these, some of the jaws and anterior portion of the feet unite together from the two sides and form at the junction a large sucker, by which the little animal fixes itself on the fish on which it lives as a parasite. These appendages, these sucker-like discs, are formed sometimes of the jaws, and sometimes of the anterior portion of the feet. The metamorphosis of these parasites is extremely curious.—They are free-moving insects when young, but afterward become fixed, and usually grow to a monstrous size, and change entirely their shape, so that they are frequently mistaken for other animals.—Many of these parasitical crabs have been described as peculiar genera, when they are only families which have long remained attached to other animals.



The form of these animals is extremely interesting, but still extremely obscure. The crustacea proper, which remain free-moving animals, are exceedingly numerous, and it is difficult to classify them. The most common division is that of *Entomostroca* and *Malamostroca*.

Their eyes, like those of insects, are exceedingly complicated. Of this complication you will form some idea from this diagram. The surface of the eye is composed of a great number of little eyes united, and to each of which a nervous thread may be traced, arising from a common nerve which proceeds from the anterior or upper swelling of the nervous system placed in the anterior portion of the head. The number of these eyes varies from hundreds to thousands. Some have ten thousand eyes united to form one single hemisphere, apparently one eye. The mode of vision in these animals is difficult to understand, and it is owing to this arrangement that the rays only which fall perpendicularly on that part of the eye can reach the nervous system, because every one of these little eyes is tubular, and has not a spheroid form as the eye of other animals.

Among the Crustacea we have a series of forms, similar to those which we see in the metamorphoses of insects. We have elongated types in which all the rings are similar, as in the shrimps. On the contrary, we have other types, in which the anterior region is very much complicated, while the tail is short and curved on the body. This is the case of the crabs. The latter stand highest, and those with elongated tail must stand next, and so down to those which are parasites.

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LECTURE IX.

The Structure of the Vertebrated Animals—Fishes....Vertebrated Animals characterized by striking Differences....Characteristics of Fishes—The Formation of their Vertebral Column....Connection of the Vertebræ....Fins and their Structure....Division of the Fishes according to the Position of their Fins....Formation of the Scales of Fishes....Restorations of Fishes....The Brain of Fishes possessing the same essential parts as those of higher Animals....Succession of Fishes, Reptiles, Birds and Mammalia, and in the last epoch only one type—Man, who stands at the head of Creation.

LADIES AND GENTLEMEN: This evening I intend to illustrate the structure and some points in the history of the vertebrated animals, beginning with the class of fishes.

The vertebrated animals, the higher group of the Animal Kingdom, are characterized, as I have already stated by striking differences. Their essential organs—the nervous system, comprising the brain and spinal marrow; and the organs of vegetative life, the stomach, the alimentary canal, the lungs, heart and blood-vessels, are contained in two different cavities;—the former in an upper or posterior cavity, according to the position of the animal, and the latter, the organs of vegetative life, by which the animal lives, in the lower or anterior cavity. These two cavities are formed by bones—a series of bones called the back-bone, having appendages curved upward and uniting on the back, forming the cavity which contains the spinal marrow. Other appendages are turned downward, sometimes uniting, sometimes terminating between the soft walls of the animal, forming a lower cavity in which the alimentary canal, the lungs, the heart and ether viscera are contained.

In these three skeletons on the wall you may see these general traits of the vertebrata, just as well as in any of the higher classes. You see that in these skeletons the vertebral column is undivided in its whole length and not divided by transverse articulations. Few fishes have such an undivided vertebral column. These belong to a peculiar class to which I shall soon refer. Generally the vertebrated animals have this column formed of divided bones moving upon each other. In those which have an undivided vertebral column we have a reminiscence of the condition of things when the animal was in the egg and the vertebral column was merely a cartilaginous string—the so-called dorsal cord, which is the foundation of the vertebral column in the new individual when very young within the egg; and this vertebral column remains soft in many fishes, and in those which must be considered as the lowest. These only in their full-grown state preserve the character of the embryo. It is a peculiar condition of things—a most extraordinary condition of things, which I regard as of high importance in attaining a correct understanding of the succession and gradation of types in geological epochs. I had the good fortune to notice, when investigating these fishes, that there are fishes which in their full-grown state exhibit, in their vertebral column, precisely the same state of things as existed in the fish when forming within the egg.

The first thing which is perceived in the fish when the substance of the upper layer of the egg is condensating—becoming divided into organs—is a series of lateral condensations, and between that there is a continuous string, which has received the name of dorsal cord. That is the foundation of the backbone or vertebral column. It is certainly cartilaginous in the embryo, and remains so in the sturgeon and in several cartilaginous fishes; and this is, most extraordinary to say, the natural and uniform condition of all fishes of ancient types. In the ancient strata—in the strata below the

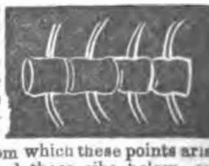
coal, at the beginning of the creation of animal life, when the fishes were first introduced in the waters, all the fishes had this peculiar condition of the vertebral column—bony appendages, but no ver-

tebræ—no division of the back-bone—a cartilaginous dorsal cord remaining throughout life.

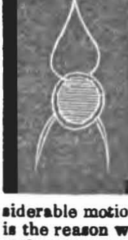
There are very many peculiarities in the structure of fishes which deserve to be noticed, in order to distinguish the class of fishes from the other classes of vertebrated animals.

It appears to be of little value, but it is one of the most striking characteristics of this class, that all are perfectly horizontal—all swim horizontally. There is a longitudinal diameter, running from the head to the tail, which is perfectly straight. Now you will find that in any of the other vertebrated animals—in the reptiles, in the frogs and salamanders, in the snakes—the head rises more or less. Even in those which have no legs, as the snakes, the head rises more or less from the horizontal position of the body. Another characteristic trait of the fish is to have no neck. The head and trunk are continuous; so that the fish cannot move its head upon the neck. The fishes move the head and the trunk together; they form a lateral curve more or less marked, but there is no possibility of an immediate motion of the trunk upon the neck. There is one single exception to this—and it is in this fish whose skeleton you see here.

The vertebræ of the fish are connected in this manner: Just take two of the vertebræ, with their upper and lower appendages. The surfaces by which the bones unite here, when cut across would have such a surface.



These singular surfaces, from which these points arise above and these ribs below, are not flat as in the Mammalia. They are hollow cones formed in such a manner,



and these hollow cones are filled with cartilage. These articulations do not allow any considerable motion between the vertebræ; and that is the reason why the fishes have general motion and cannot move one part of their body on the next or following portion. One type of fishes has articulations similar to those of reptiles. There is

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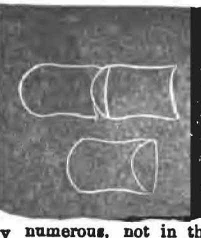
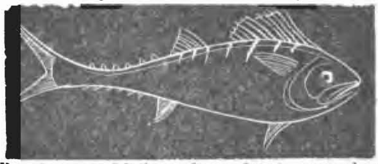
a fish of the Western waters, found also in the Northern lakes, which has vertebræ with hollow surfaces posteriorly and with hemispherical swellings anteriorly on the articulating surfaces. This fish is only a remnant of a numerous family, of which you have here some representa-



tions. They were very numerous, not in the oldest strata, but in the so-called secondary strata of the crust of our globe, and this living type, whose structure can be well studied, has that likeness to the reptiles that the articulations in its back-bone are movable by a ball-and-socket joint. This is a reptilian structure of the skeleton in this fish—a form common in many fishes at an epoch when reptiles did not yet exist. They are the next step in the fishes in their succession in geological epochs, and that is one of the first fishes whose vertebral column, instead of remaining cartilaginous, becomes bony—osseous. Now I had the good fortune to see one of that class of fishes alive last Spring; and my first thought was to see whether it moved its neck, and the first look at it conveyed the impression that it did. In this respect this reptilian fish, with this peculiar articulation of the vertebræ, has the faculty of moving its neck right and left,—though the neck is not divided; though there is no division, the head can be moved sideways.

Another peculiarity of fishes is found in the fins. Instead of legs, these animals have fins of a peculiar kind, which serve the purposes of organs of locomotion. The organs of locomotion in birds and in reptiles consist of a few joints. There is the shoulder—there is the upper arm—the fore-arm and the hand. They have similar bones in the posterior extremities. All these are detached from the walls of the animal. In fishes we have also a shoulder, arm and fore-arm; but the bones were detached from the body, only the hand depends sideways. The arm remains within the wall of the animal, and the fingers are numerous instead of being reduced to the number of five, as in the case of the higher vertebrated animals. None of the higher vertebrated animals, no reptile, no bird, no mammal has more than five fingers; there are many which have only two, three or four fingers; in horses there is only one: the hoof is the nail of the single finger. In fishes, I was about to say, instead of being reduced to the number of five, the fingers are many, and are united into many joints. I just stated that the higher animals have several fingers, and I might go on and show the beautiful adaptation of the human hand. In animals which have only four fingers, the first which is wanting is the thumb; then, in the next, where there are only three fingers, the little finger—the shortest remaining—is also wanting. In those which have only two fingers—which is uniformly the case in the ruminating animals—we have only the middle and annular, or fourth, finger; and there are usually two rudimentary fingers backward, corresponding to the first and fifth fingers, and which even have also rudimentary nails. Where only one finger is, left it is the medial finger, and that is the case in the horse. Thus, in proportion to the fingers, we may trace the gradation of the hand or foot in the whole series of animals. (Applause.) This is nothing but a common anatomical fact.

But, beside, the fishes have other fins. I will just mention their names. First: there is the pectoral fin, because placed on the chest; then the abdominal fin, on the abdomen—usually placed on the centre of that cavity, but in some we have the abdominal fin just below the pectoral, and in them it is even more forward. So it is in the cod, where the ventral fins are placed under the head in front of the pectoral cavity. The other fins are placed verti-

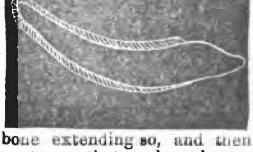


cally above and below these bony appendages, rising from the vertebral column According to the position of these fins, they have received different names. The one on the back is called the dorsal fin—that below the tail, the anal fin—that at the termination of the tail, the caudal fin.

These fins vary very much in their form and even in their number Sometimes the dorsal, caudal and anal fins are united into one continuous fin, beginning at the neck and continuing till it terminates in the tail. Such is the case in the eel. This condition of fin we find in every embryotic fish at the beginning of its formation in the egg. All these have a continuous fin. As the fish grows, more or less dentations are to be seen, and the fins at length divide, as we see them in the full-grown fish.

But what is most extraordinary is, that young fishes have the vertebral column not terminating in a straight line, as you see here, with a regular bilobed medial fin. That is only seen in full-grown fishes. Young fishes always have the vertebral column terminating in the following manner: The white-fish, common in Lake Superior and other Northern Lakes, has its medial fin as deeply emarginate as this.

We have one in our Swiss Lakes quite similar to the white-fish of these Lakes; and, indeed, it cannot be readily distinguished from the latter, unless by those who have made Zoölogy a very serious study. In this fish I had the chance of examining the egg, and of tracing the succesive changes which occur there. I could observe in the young fishes the following outline: Lines beginning here and extending so all round the animal, the back-



bone extending so, and then terminating in the centre, so that we have here a regular termination of the vertebral column. Now when the fish grows larger this is diminished; the lower extremity becomes more prominent, and after the fish has been hatched it changes its form so as to present that appearance.—This is only that exaggerated. But you will easily perceive how readily it may be changed, and even the vertebral column become regular and only a little remnant of that irregularity remain in the curve of the very last part of the column.

This is observed not only in this fish, but in many other fishes—in fact among all those bony fishes whose young have been observed within the egg. Now we will see that that same form of tail is seen in these bony fishes of ancient types. All fishes in the coal and below the coal, which have a bony skeleton, have such a termination of the tail;

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and it is only in the secondary strata, in the intermediate epoch of a succession of animals, that we find the tail becoming more and more regular. In one of my drawings here there is only a slight obliquity left. It is a fish from the chalk. Among the fishes of our day we have only the sturgeon which has this cartilaginous vertebral column, and in the tribe of cartilaginous fish at large, those whose skeleton never becomes bony—the sharks and skates—we have also that irregular prolongation of the vertebral column.

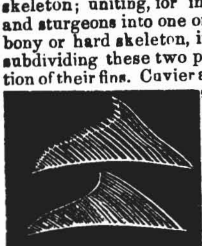
It is a matter of surprise even now, and of course was more surprising when first discovered, that there should be such a strict correspondence between the form of ancient fishes, which alone possessed the waters of former days, and the changes which we now see going on in all the young fishes within the egg. These changes correspond precisely to the order of succession of fishes in geological epochs, so much so, that more than once I have been able from this to establish the species and even the geological epoch to which fossil fish belong. In this country there is a full series of strata, containing fossil fishes which all show in their structure such a position of their tail—an oblique termination, not this symmetry—whose era must be between the coal and the oolitic series. I have seen a beautiful series of these fishes in the collection of a scientific gentleman in this city—the most beautiful, indeed, that I have ever seen.

This correspondence of structure between the egg of fishes and the growth of the embryo, is one of the matters which can be established, perhaps, only in a class of animals whose structure has been fully ascertained. I could show some examples among the acephala of the Mollusca, because they have been better studied than other types. But the fact being that there is such a strict correspondence between the phenomena observed in the growth of individuals and the succession of geological epochs, I venture to maintain what I have already asserted, that all classifications in which we should not find such an agreement must be defective, and can have been constructed only on account of want of information. In Nature, when we have ascertained a rule of such an extent, we are safe in regarding it as the general rule, because there have been observed no such exceptions in organic life.—(Applause.)

I see this favorite subject of mine has already led me beyond the limit of time to be devoted to this class of animals. I must, therefore, abridge what yet remains to be said of fishes, in order that I may be able to go through that class in this evening's Lecture.

There is one point in the structure of fishes to which I must allude, as it is important in its bearing on the study of fossil fishes. I refer to the scales of fishes.

Naturalists have usually classified the fishes by their fins, uniting first the fishes which have a bony skeleton and those which have a cartilaginous skeleton; uniting, for instance, the skates, sharks and sturgeons into one order—then all fishes with a bony or hard skeleton, in another order; and then subdividing these two primary groups by the position of their fins. Cuvier adopted these primary divisions, and arranged the fishes into two great groups—those with only soft rays in their fins, and those which had not only soft rays, but spines also rising as you see here—hard spines on the anterior of the dorsal fins and soft rays backward.

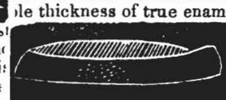


Linnæus adopted another mode of classification. He divided the fishes according to the position of the pectoral and ventral fins. He named "abdominals" all the fishes whose ventrals are placed in the middle region of the abdominal cavity.—The next he called "thoracici," those with ventrals on the thoracic region. Then he named "jugulars" those whose ventrals are in front of the pectorals, and then he had in another class those whose fins are continuous, as in the eels. But such a classification, though readily learned, is not at all natural, and does not bring the fishes together as they are really related. The classification followed by Cuvier, in which the hardness or softness of the rays of fins is the principle, is not any more natural than the other, which is beneath criticism.—If, instead of taking the hardness of the rays, the structure itself were taken as the basis of classification, it would be much more natural. Then we would have fishes which have, in the dorsal, simple rays in front and articulated and divided rays in the posterior. When these rays are divided. not only longitudinally, but also transversely, the distinction has, I think, some value.

I will show that by referring to another difference. Studying the fossil fishes I could not satisfy myself with the classifications, because they scarcely ever showed their general form. We find too rarely a complete fossil fish to be able to ascertain by the structure—by the form of the fish—to what family it belongs. But the scales were frequently found in an excellent state of preservation; and when investigating the subject I tried to find in the scale some characters by which I could recognize the fishes, or by which I could classify them.

One preliminary fact was then ascertained: that those fishes which had some likeness to the ancient fishes had scales of peculiar structure. The structure of a common scale is this: Layers are formed successively on each other in a manner very similar to the formation of a shell. These scales are of a horny structure. I make now a section of this scale. Such a

scale is a coil of layers piled up, the oldest being uniformly below, and is covered with a mass of considerable thickness of true enamel, as hard as the hardest enamel of the teeth, and the lower portion of this scale is bony substance



showing all the characteristic peculiarities of bony structure. Here we have two varieties of scales, of very different structure. Now all the fossil fishes, without any exception, have such enameled scales—the lower layer of bony substance and the upper of enamel of considerable thickness. This afforded a sufficient reason for the union of all these fishes in one order, especially as they differed so completely from the common fishes.

Recent anatomical investigations have led even those who at first ridiculed this mode of classification to adopt it themselves. Johannes Müller, for instance, of Berlin, who at first laughed at this singular desquamation, as he was pleased to term

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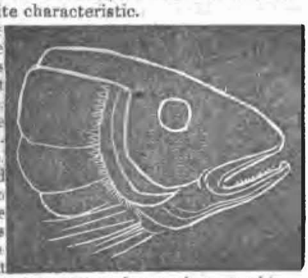
it, has himself acknowledged that it was the most fortunate hit I made in Ichthyology. (Applause.)

Every animal is cartilaginous at the beginning. Even those animals which have the hardest bones have a cartilaginous skeleton in the embryotic state. It is only at a later period of life that they become bony. That, then, gave me the basis for a classification, and I think that from that time I made more rapid progress than before in Ichthyology. After I had ascertained these analogies I went on, and found that sharks always had scales of a peculiar character, formed only of enamel without bony substance below. All those protuberances on the skin of the skates are of enamel, but they are not arranged in layers on a bony basis, and, therefore, they form another type. Then among the fishes with scales of horny substance, deposited in layers I found that these were two types: one type in which the scales are simple layers with regular outlines; and another in which the scales had dentated outlines, so that every one had teeth in its posterior edge, and that as the scale grew larger these dentations became more numerous, and the surface of the scale became gradually rougher and rougher. Now we have that in the perch. The mere touch of that fish discovers this peculiarity, while the fishes whose surface is smooth have the scales formed in simple layers.

A singular coincidence is this, that fishes, with few exceptions, which have such dentations on the posterior margins, are just, those which have the hard bony spines on the anterior portion of the dorsal fin; and more than that, the head of the fish has something quite characteristic.

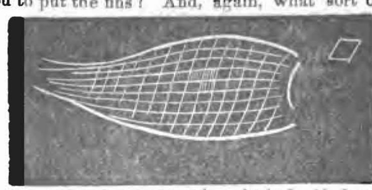


Here we have a bony plate which covers the gill. That will be the eye. We have here a crescent-shaped bone, movable, and behind which there are three other bones movable upon it, and that joins with the lower jaw here, also movable.—These four bones here have been called the operculum.

Having ascertained such a connection between the hard parts of the animal, I became more and more convinced of the value of scales; and I then endeavored to ascertain to what families belonged those of which any scales had been found, and to classify the whole of fishes according to the structure of the scales. I put in one order all the fishes which have only enameled granules on the skin, and called them *Placoids*. All those which have scales covered with enamel I called *Ganoids*. All those which had dentated, serrated scales, with hard bone in the back-bone and serratures in the opercular bones, I classed together as *Ctenoids*; and those which had simple head-bones, soft rays and soft scales, with simple outlines, I classed together and called *Cycloids*.

Of course, when studying the different families, I found the similar relations in the details which enabled me to find correspondent adaptations between the higher characteristics by which we distinguish genera and species.

Now, I was enabled to "restore" a fish from isolated scales. So much has been said about that that I will show how possible, and indeed how easy it was for any one who took the trouble first to investigate these relations. I have shown how the different modifications of the structure of the head-bones are related to the structure of the fins and the structure of the scales. I will not try your patience by going into details, but I will only show you how easy it was, from the knowledge of these relations of the scales to other portions of the animal, to give the probable and approximative outline of a fish when you have had only a single scale as a starting point. (Applause.) Let me draw a scale. A great many fossil fishes have angular scales of this oblique form. That portion which is here encased by enamel is covered by a scale which proceeds so that I am allowed to draw my outlines of merely of the enameled portions without drawing the portion which is covered. I will make the scale of a size which will enable me to give the whole thing on the board. Let that, then, be the outline of the scale. Now we know that there are usually forty, fifty or sixty scales in one longitudinal series from the head to the tail. We know that fishes which are about as thick as long have these scales higher than they are long; and that those which are longer have their scales longer than they are high. These are preliminary facts easily obtained by investigation. We now find a scale which is about as long as it is high. You see then what an easy task it is to draw scales of about the same form, perhaps forty in that line, and you will have to make a fish about as high as it is long. You at once draw your outline and when placing your scales you will find that they fit easily, and you draw them with as much precision as if you had the living model before you. But you have now got a fish without fins! The question is where are you to put the fins? And, again, what sort of a



head are you to put to such a body? (A laugh.) A fish which has a flat, ovate form like that will be a fish of not very rapid motion; and we know that all fishes not possessed of powers of rapid motion have rather elongated dorsal and anal fins, and that the caudal fin is not forked. Those that swim fast have the tail forked, and these fins act as a paddle. The fishes which have a broad, flat body, are not voracious; therefore they cannot have a prolonged snout. They will have a short, round head, and so in that way you terminate your drawing. (Applause.)

That all that can be done with precision I had the good fortune to be able to demonstrate in a rather striking manner. In the year 1833 I delineated in the first number of my work on "Fossil Fishes," a scale of a fossil fish sent me from England, and from it drew the fish to which I considered it to belong. In the following year, 1834, the whole remains of the fish were collected, and the drawing was given in the third number of my work. I have the satisfaction of saying that the two delineations do not differ in any essential way, even in the details (Loud applause.)

These restorations have been repeatedly made. They have been made in other cases where the process was still more difficult. Cuvier was the first

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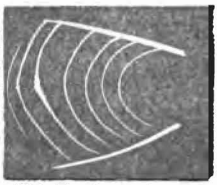
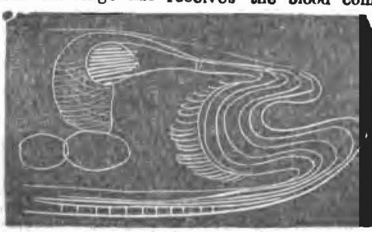
who made these restorations from single bones of those fossil mammalia found in the gypsum near Paris. He restored several genera. He gave not only the whole skeleton of these animals, but even the outlines of their forms. Thus far he could go, and thus far he did go, and gave entirely satisfactory details to his figures. Some imitators followed and went farther than he—giving even hair to these animals and dots to their colors! They accomplished all that, but there were as many lies as additions to the figures. (A laugh.)

The structure of fishes is in general the same as that of the higher vertebrated animals, except perhaps as far as regards the organs of respiration.—All fishes do not breathe by lungs as the mammalia, birds and reptiles. They breathe by gills, organs placed in the sides of the head under those large covers which protect the sides of the head. These gills have the following structure: Let that be the posterior margin of the head. Here we have in the opercle three, four and sometimes more, arch-shaped bones, usually three or four, to whose posterior margin we see attached small bony appendages, along which blood-vessels run in great abundance. These are the organs of respiration. The blood comes to them immediately from the heart, which is placed here below and has this form. A large sac receives the blood coming



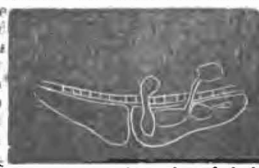


from the body, which is the auricle, and empties into another cavity called the ventricle; and that empties through a tube which has received the name of aortic tube; and here arises a large blood-vessel, under the name of aorta, which branches into as many branches as there are arches in the gill. There is no continuation to this great blood-vessel. The blood goes directly to the gills and then comes back after it has reached the termination, through a sinus, and all these veins unite, forming another large blood-vessel by their junction, which runs to the back-bone and along this cavity beneath it, whence it is distributed to all the viscera of the abdominal cavity. The blood, after it has reached all parts of the body, returns through these veins and is emptied into this large sac, so that the venous blood comes into that cavity and is propelled into the gills, where it is converted into arterial blood.

Such a circulation is called "a simple circulation." But beside these organs of respiration we have in fishes a curious organ placed in the upper portion of the abdominal cavity—a large air-sac called the air-bladder, which opens into the alimentary tube above. This is a rudimentary lung. It is the first indication of the formation of a lung in vertebrated animals; and when tracing the formation of the organs within the egg we may ascertain that in its position and formation this air-bladder is similar to the lung of higher animals.

The mouth opens into the gills, which form the arches on both sides. The food passes between these arches, and moves on into the stomach which is very uniform. The alimentary tube is scarcely more slender than the stomach, and is very short in most fishes. There is also a large liver and gall-bladder, so that in the structure of the viscera the fishes do not materially differ from the higher animals. All of them lay eggs in innumerable quantities. There are species which lay as many as fifty thousand eggs. This extraordinary fecundity affords a ready explanation of the great number of fishes, and the non-disappearance of any of the types notwithstanding the voracity of these animals.

The brain in fishes has the same essential parts as that of higher animals. We have also nerves proceeding to the eye, the nose and the ear, which has no external outlet but is yet quite complicated. Here is another striking analogy with the higher animals. All belong to one and the same plan, and the order of their structural arrangement precisely corresponds with their succession in geological times. There was an epoch when there were no fishes, no reptiles, no mammalia. First come the fishes, and fishes only exist. Then appear the reptiles—then the birds, and lastly the mammalia; and in the last epoch only one type is introduced—Man—who stands at the head of Creation.



LECTURE X.

Geological Succession of the Class of Fishes....The Vertebral Structure of Fishes—Peculiarity of their Teeth.... The *Placoids*—Sharks and Skates—Fossil Remains of the Shark....The *Ganoids*—The Gar-pike: its Hard Enameled Scales....The genus *Lepidosteus*—Their Vertebral Structure....The Alligator....Peculiarities of the most ancient Fishes—their Analogy to the Reptiles....The Ctenoids....The Sparoids....Position of Flat Fish in Swimming—Peculiarity in their Eyes....The Herring....The Trout....The Codfish....The Class of Reptiles—Apparent dissimilarity in their Structure—Snakes Lizards without feet—The Turtle similar to the Lizard—The Frog—Structure of the Heart in Reptiles—Division of Reptiles into four Orders: Turtles, Lizards, Snakes and Frogs....Scales of the Tortoise nothing but extended Ribs....Brain of Reptiles small.....Date of the existence of the Turtle not very ancient....Crocodiles a Remnant of the Ancient Type of Lizards....The American Crocodile....Fossil Remains of the Mososaurus....Characters of Ancient Types determined by Comparison of the Vertebræ....Extensive Discoveries yet to be made on this Continent....Lizards without Feet and Snakes with Rudimentary Feet....Difference in the Structure of the Jaws in Snakes and Lizards—Enormous Distension of the Jaws of Snakes....Fossil Snakes found in the London Clay....Batrachians.

Ladies and Gentlemen:—Through the kindness of Prof. Watts, I have been provided with a series of specimens from the College Museum, which will enable me to show several facts of interest relative to the structure of Fishes and Reptiles. Having gone through the examination of the anatomical character of fishes, we have the means of understanding more fully the order of succession

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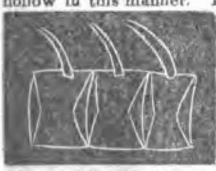
and the mode of introduction of the different types in geological epochs.

I will now advert to some of the peculiarities in the families of Fishes. I have already stated in my last Lecture that the class of fishes is divided into four Orders, from the structure of the scales. But these peculiarities in the structure of the scales are not the only characteristics by which these Orders are distinguished. For example: in the first group, the Placoids, which is covered with enameled tubercles spread over the skin, we have a skeleton constantly cartilaginous. This, though sometimes hard, is never bony as in other fishes. Again, the vertebræ on the central portions of the back-bone are also separated from appendages which stand above and below, so that the vertebral column can be taken out of the body like a stick.—Here is a specimen. You see plainly on these surfaces the prominent characteristics of all fishes that have the whole surface articulated. You observe this cavity and, opposite to it, a similar one. You see several vertebræ, one above the other, and these holes form biconical cavities. For the sake of a clear understanding I will repeat what I have before explained. Such a portion of the back-bone of the shark is divided into a series of cylinders which are hollow in this manner. These hollow

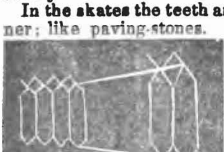


cavities in contact with each other are filled with cartilage. So there are here the hard portions of the vertebræ, and above them the appendages of the vertebral column, but separate from the back-bones themselves, and articulated in such a manner that they easily fall off.

Another peculiarity of all cartilaginous fishes, is to have their teeth loose, without sockets, and only attached to the jaw by the skin. They are not inserted in deep sockets as those of other fishes and higher orders of animals. This mode of insertion renders the teeth movable, so that the shark can erect its teeth. The shark has not a single row, but five, six or seven rows behind each other, and the first erect teeth are placed thus.

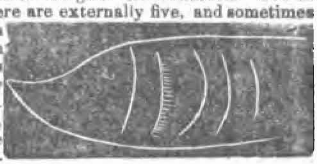
On the edge of the jaw we have an erect tooth, and back of it numerous teeth whose point is turned backward. As often as such a tooth is destroyed, the next tooth will take its place, so that there is a constant supply. The rows of teeth are not always as distinct as in this instance. In many the teeth are united so as to form large plates by their junction.

In the skates the teeth are arranged in this manner; like paving-stones. This being the anterior



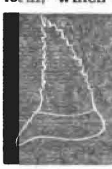
margin of the jaw, there are constantly new teeth forming at the back as often as the front ones fall off. There are sometimes as many as twenty or thirty in one row, all of which are renewed in the same manner, and as the animal increases in size the series of teeth grow larger. The series of teeth are oblique, and as they fall off, those which come to supply their place will fill up the whole margin of the jaw.—Those back teeth are formed on a larger scale than those in front.

The order of *Placoids* contains two families—sharks and skates. These two families, though very different in form and structure, have this in common—their gills are merely covered by strips of skin. There are as many openings as gills. In the common fishes there is only one opening in the gill and a series of flat bones covering the whole cavities in which the gills are contained. But in the shark there are externally five, and sometimes six or seven fissures, each of which is covered by strips of skin. In the skates, which are flat, the fis-



sures open under the heads—in the sharks, on each side.

A knowledge of the details in the structure of the shark is very interesting to geologists. The great number of their teeth found in a fossil state, renders it quite necessary for the geologist to know what differences in their structure the teeth indicate. Their skeleton, being rather soft, is not often preserved in a fossil state, but the teeth being exceedingly hard, are very common in geological strata. In the tertiary strata some are found exceedingly large. In this shark, which is about twelve feet in length, the teeth are nearly an inch long. Some are found, having the same form, which are several inches in hight and as



much in width. In Malta, teeth are found seven inches long and four and a half broad at the base. One would suppose that the shark from which it was derived must have been exceedingly large. Such is not the fact. They probably did not exceed some living ones, being about twenty-five or thirty feet in length. It has been pposed that they were sixty or one hundred feet long; but such is an exaggeration, caused by want of a proper knowledge of the corresponding living species. Sharks of the greatest size have not the largest teeth, but on the contrary, those having the smallest body have the largest teeth, and it is to this tribe of sharks the fossil species belong. So then we have no right to infer that the teeth belong to an extraordinary sized species.

The next is *Ganoids*, of which I have explained the character from ancient strata. This drawing represents the one which I had the pleasure to "restore" from a single scale some years ago, and I here exhibit the outlines of that taken from the specimen itself. You will observe, on comparing this specimen with the first outline I gave, how closely it agrees. They have not only enameled scales, but they are rhomboidal in the same way as the Ganoids.

You have here one of the few remnants of these ganoids, the gar-pike of Lake Champlain—found also in the Southern rivers. It is provided with sharp

conical teeth, and is extremely voracious. You can find all the peculiarities which I mentioned, about the position of the dorsal and anal fins, in the voracious fishes. In those which have a short body, the dorsal fin is usually on the back and is of a larger size. The head is proportionably shorter and rounder. The scales of the gar-pike are so very hard that it is utterly impossible to pierce them with a nail. They are covered with the hardest enamel. The fin likewise is protected on either

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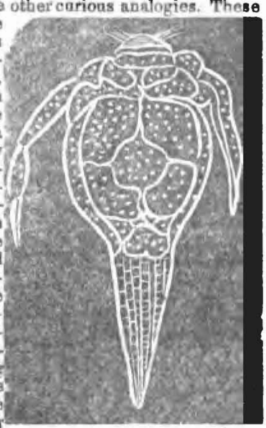
edge with similar hard scales, which prevent the breaking of the rays. Only a few similar fishes are found.

This genus *Lepidosteus* is peculiar to North America. It is found in rivers emptying into the Gulf of Mexico and the St. Lawrence. A genus is also found in the Nile and Senegal called the *Polypterus*, which has numerous rays on the back.—The sturgeon is allied to this genus. Fossil fishes, of which a few smooth scales are found, differ from them by the position of their fins and the form of the head and teeth.

I have alluded to the peculiar structure of the vertebræ in that genus where we have articulating surfaces of the back-bones, rounded on the anterior, and hollow on the posterior extremity. I have shown you a series of vertebræ of the back-bone from one of these fishes. Though it is from a large species, it is so small that you will scarcely be able to examine it at a distance. I show it to compare the form of these vertebræ with those of other fishes—the shark and codfish for example. In the form of their articulating surfaces they resemble those of the crocodile.

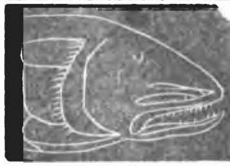
I have here the vertebra of the alligator. You see these rounded articulating surfaces. There is a hollow socket in which the succeeding vertebræ can fit, and the manner in which the two vertebræ move is like a ball-and-socket joint;—precisely the mode of articulation in the family of the Ganoids. This peculiarity is more interesting, as these fishes are the only vertebrated animals existing at an epoch when reptiles had not yet been called into existence. And after the reptiles began to exist, those types of fishes became so diminished that they were almost extinct, and at the present day we have only a few remnants of them—in fact only two genera.

It is not the place to speak of the types of those ancient fishes, and I would only allude to some more peculiarities of the most ancient ones, to show that they are somewhat analogous not only to reptiles, but have some other curious analogies. These animals, with these curious flat bones on the head and behind the shoulders, have in their form some resemblance to tortoises, but of a small size. They have also some resemblance to certain crustacea.—They have been mistaken for the former by some and for the latter by others. It is only since I had an opportunity of studying minutely their structure, and finding some of their types more fish-like in the structure of their vertebral column, that I could ascertain that this as well as that form belonged to the class of fishes. The analogy is so striking that it is possible to satisfy any one that this type will follow that, and that being a true fish, we must necessarily consider this extraordinary form as belonging to that class.



At the first appearance of the class of Vertebra they bore such a resemblance to types entirely different from the fishes now in existence, as to exhibit a most curious phenomenon in Nature, showing us how that from the beginning all types were contemplated by the Creator, but only called into existence gradually.

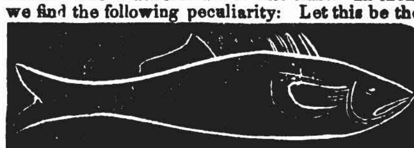
The ordinary bony fishes are divided, by the peculiarities of their scales, into two Orders. First, those with hard, rough scales, called the *Ctenoids*, to which the Perch belongs. They have not only spines on their backs, but dentations on their scales, and have been divided into numerous families, according to the structure of some of the head-bones. They are not found in general works, which may be an inducement to some to study them. We have here a preöperculum which is dentated or serrated. Then the operculum which is the next lower is usually dentated and provided with spines, and two other bones below the serratures. That is the character of the perch families. Beside that, the perch have teeth in the upper and lower jaw, and upon the palatal bones inside the mouth, as well as the bones of the skull. It is a most extraordinary fact that the bone which is known by anatomists to form the division of the nose in higher animals, called the *vomer*, rests upon the bones of the skull in fishes which have no such deep cavities in the nose. The *vomer* forms part of the palate in the perch family, and is covered with teeth.



Another family allied to this, the Sparoids, to which the "sheep-head" belongs, differ in having no serratures along the edge of the preöperculum. This and two other bones are smooth in their edges, but the operculum has spines, the back fin has spines, and the scales are rough. The *Scienoids*, to which the weak-fish belongs, has the same characteristic of the opercular bone, and no teeth on the palatal bones.

One most extraordinary family belonging to this group is the flat fishes, for it is the only family that is unsymmetrical in the vertebral column. The two sides are not equal. The one is flat and colorless, while the other is swollen and colored. Instead of swimming vertically, they swim flatwise, on one side. They are distinguished by the fact that the two eyes are on the side that is colored. When young, in the egg, they are symmetrical, but when they grow larger, and even very early, one of the eyes turns to one side—sometimes to the right and sometimes to the left. The eye turns the moment the fish begins to grow. That side which is exposed to the action of light is the only one colored. Though these fishes have soft rays, they have radiated, serrated scales, thereby making an exception to the general rule that there is a correspondence between the hardness of the rays and the structure of the scales. The flat fishes form an exception to the whole type of vertebrated animals, in their want of symmetry. The name of the family is *Pleuronectes*.

The fishes with smooth scales are more numerous than any other types, and are the type belonging to our day. Some have had rays upon their backs. The Mackerel are of this class. In them we find the following peculiarity: Let this be the



body: we have here hard rays in the same manner as the perch. Numerous branches arise and even divided rays. According to the rule I gave, this fish should have smooth scales. On the contrary it has serrated scales, but only on some parts of the body—the other portion is covered with smooth scales. It is, in fact, an intermediate type between the herring and the ctenoids.

The family of the herring, of trout and of codfish, all have the same scales and soft rays. The family of Codfish is distinguished by having numerous divided fins—sometimes three dorsal and two anal fins, all of them with soft rays and smooth scales.—The family of Eels has the fin continuous with the body.

Then we have the families of Herring and of Suckers, which differ in the following manner. In the family of herrings the body is provided with a single [redacted] whole class of Fishes. I will show a specimen containing three fossil fishes. The scales in the fossil fishes are precisely the same as in the living garpike. The specimen is from this country—one from the collection of Mr. Redfield.

I have now to introduce the class of *Reptiles.*—They are animals very dissimilar in their structure and appearance. At first one can scarcely understand the likeness existing between a snake and a turtle. Their skeletons in their external form are so totally different that a common characteristic is by no means easy to perceive. It seems almost impossible that such heterogenous animals as frogs, snakes, lizards and tortoises should belong to one natural division; nevertheless the class of reptiles is the most natural group of the Animal Kingdom. The extreme differences we notice between the groups just named, disappear more and more when we examine the distinct types of those animals which lived in former epochs and are now extinct. We have now some animals which, by their form, stand intermediate between lizards, or crocodiles, and tortoises. We have other forms even intermediate between the snakes and lizards. The common snake has no feet; numerous ribs extend the whole length of the body. The numerous vertebræ have each a pair of ribs, and the structure is so uniform that in a transverse section in any region of the body, we see precisely the same arrangement of the bones and soft parts.

Some lizards, like snakes, have no feet. In some there begin to appear on the sides and underneath the abdominal cavity rudimentary feet, or ribs, at the extremities of which there is a hook. First we observe these enlarged—then there are two fingers—then some rudimentary feet on the sides of the head with one, two, and afterward three toes, until we have the common form of feet with five distinct fingers. All possible intermediate states between the existence of feet and the complete want of them is known among the living reptiles—snakes and lizards. The length and proportion of the body vary. Some are of extraordinary length; in others, in which the body is shorter, the tail is more separate from the body and forms a long, tail-like appendage.

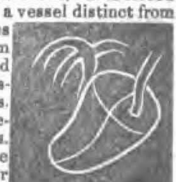
There is no longer any difficulty in tracing this form in that of the turtle, in which the body is broad, flat, with very short tail and neck. Here we have a type where the tail is very long and very similar to a snake's body, and here we have feet of considerable size.

Again, in the frog the legs are of extraordinary length, being in many instances longer than the body. The medial region is broad, flat and short as in turtles, so that the external form, where we trace all intermediate forms, should no longer be an objection to the union of all these animals in one group. But in the intermediate forms we have positive characters by which they all agree and therefore must be classed together.

These characters are—first: the structure of the heart. In this injected heart of a turtle you see two red cavities in which the blood comes from the lungs, and this black cavity from which the blood is forced into the lungs and other parts of the body. The heart of reptiles is divided into three cavities.

Let that be the ventricle or heart proper: from the auricles arises a large blood-vessel proceeding into the body of the animal and also sending two vessels to the lungs. A large trunk arises from this cavity sending branches to the respiratory organs. The main trunk, which carries the blood into the body, divides into numerous branches, supplying the head, anterior extremities and alimentary organs, and also the viscera in the posterior extremity. That blood returns and enters one of the auricles, while the blood which goes to the lungs will enter this other auricle, so that the blood from the body is mingled in the common ventricle. Thus we have, going to the body, blood of a mixed nature. That which has become blood and has lost its vital properties by being used in the body, returns to one of the auricles; and the blood which has become oxygenated in the lungs comes back to the other auricle. The venous and arterial blood then empty into this common cavity, the ventricle, and are forced thence into the body, as well as the respiratory organs. Such a circulation is that which is fonnd in all cold-blooded animals.

In the higher animals the blood which comes from the body into this cavity passes into that, and does not unite with the arterial blood, but is forced into the respiratory organs by a vessel distinct from that, and from the lungs comes back into this cavity, and from this into that, so that the blood coming from the body and respiratory organs never mingles. This is a double circulation peculiar to warm-blooded animals.



Reptiles are cold blooded, the temperature of the blood never rising higher than that of the

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surrounding atmosphere. Their temperature sinks with that of the atmosphere, and when it is very low the animal becomes torpid and remains so during the cold season. Turtles, snakes, lizards and frogs sink into this state during the Winter, and their circulation is very much diminished.

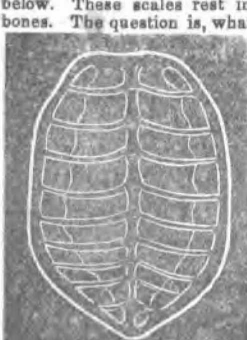
All reptiles breathe with lungs, which are of a very peculiar appearance. I have here the lung of the snapping-turtle—it is sponge-like and full of large air-cells. The air enters into tubes or air-pipes, which unite in one tube opening into the mouth and communicating with the nose.

Here is the lung of another reptile, the boa-constrictor, in which the cells are beautifully seen, similar to the former, but more numerous and not divided into larger cells. These two reptiles have such organs of respiration. We have seen in fishes only a rudiment of a lung—the air-bladder. Here we have the lung of a reptile, into which the air is constantly introduced, moving in and out as often as the animal requires air: but the inspiration is not so frequent as in warm-blooded animals, and the quantity of oxygen consumed is much less.—These two characters are sufficient to distinguish reptiles from all other animals, and to show that, notwithstanding their extraordinary diversity of form, they are a very natural class in their structure.

Without entering into any more anatomical details, I would mention some peculiarities of the different organs.

Reptiles have been divided into four orders—*Turtles*, *Lizards*, *Snakes* and *Frogs*. The first are named from the Greek *Chelonias*, the second *Saurians*, the third *Ophidians*, and the fourth *Batrachians*. These terms simply signify the same as the common name, and are only used for the sake of a common understanding in different languages. The common name is just as good, only it would sometimes create mistakes. For instance: here is a fish called the gar-pike, which has a namesake belonging to a different family. So it is necessary to have scientific terms derived either from the Greek or Latin—for scientific men of different nations speak different tongues, and it is essential to a thorough study or knowledge of the different types of the Animal Kingdom that there should be a fixed Classification, as the names in common use among us would necessarily change with different languages.

The order of Chelonians is peculiar from the singular form of the body. The common turtle is covered with large flat cuirass-shaped scales, both above and below. These scales rest immediately upon the bones. The question is, what are these bones?—



Turtles have been considered as animals of a peculiar order, constructed on a different plan from other animals, in having their skeleton outside, and having bones analagous to no other animals.—But it is easy in comparing to find what the broad, flat bones are. Here we have the indication quite plain: the whole space between the scales is not filled up. In all marine animals the ribs do not enlarge the whole length but are only united near the back-bone. The large, broad disc is nothing but a series of ribs, and when looking internally they present precisely the same relations to the central back-bone as in common vertebrated animals.

In the philosophical comparison of animals the mere disc is not sufficient, but will lead to frequent mistakes. On the anterior portion of the animal we have a similar series of bones something analogous to those of the crocodile. The anterior extremities of the ribs unite in a series of middle bones, called sternal bones. The lower cuirass of the turtle is nothing but a series of those bones formed in the same manner as ribs. The whole middle region of the body is thus immovable between them. There is no possible motion of the ribs or sternum. In some turtles only the anterior and posterior portions are movable, and the animal has a head of most extraordinary form.

Here is a head of a large green-turtle. From the cavities in it one might suppose the animal had a large brain—but it is not so. Here is a little hole through which the spinal marrow passes. These large covered cavities are only to protect the large muscles which move the lower jaw. So that we have a covering formed by the skull to protect the lateral muscles which move the lower jaw. The head is large, but the space for the brain small. So in reptiles, the brain is not very large, and we have in this class the same relative position of the different parts of the brain. The little quantity of brain remains uncovered by the anterior lobe. The only

progress in the form of the brain is that the anterior lobe of the brain is larger than the other, but the posterior part is still uncovered by it.

These turtles form a natural group. They did not exist very anciently—we do not find them beyond the oolite period, but we find the next order, the Saurians, at an earlier age, immediately after the coal era. The question arises, Are the saurians, which are found below the oolite and above the coal, real lizards? They have been so considered, but I think the analogy with lizards has been exaggerated. In fact all the reptiles found in the strata below the chalk have a peculiarity which the actual lizard has not:—the teeth are inserted in cavities. Lizards have teeth united with their jaws, but these ancient saurians have teeth inserted by a long root into a cavity; and we have the same structure in the crocodile; so that the analogy between the crocodile and lizard which was considered so natural and close, is, I think, rather exaggerated. I consider crocodiles as one remnant of those ancient types of large lizards having, like reptiles, teeth inserted in the hollow cavities of the jaw. You see in this head of an alligator the character of their teeth very plainly. Most of them have fallen out, but in the few remaining you see a long root projecting above these cavities. Among lizards we have teeth which unite with the head and there are never any such cavities for their reception. These reptiles should be called *Rhizodonts*—having teeth with roots.

I will mention the distinguishing characteristics of the alligators of the South, from the crocodiles of the East. You see the teeth of the lower jaw come within the up-

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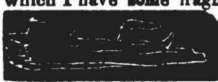
per jaw, and when the jaw is closed they unite in such a manner that only the teeth of the upper jaw are seen outsideof the lower. In the crocodile proper you have the teeth closing in a different manner, crossing each other, so that on a side view you see two sets of teeth—those of the lower jaw coming outside those of the upper. It is a fact for which we cannot account that all the crocodiles of the Old World have teeth varying in this manner from the alligators of this continent. There is one species, however, in the West Indies constructed on the plan of the Eastern crocodile.

With this type we have to combine fossil reptiles, of which portions only are known.—They have been described chiefly by Conybeare, Prof. Owen, and other British Naturalists. It is in the oolitic series of Great Britain that they are mostly found. They are truly gigantic, some of them exceeding in size the largest terrestrial mammalia. Only parts have been restored. They are described under the name of *Plesiosaurus* and *Ichthyosaurus*.

I will only allude to another of these types, of which I have some fragments, the precious gift of



Dr. Torrey. Here is a fragment of a tooth, portion of the jaw, and some radimentary teeth coming insideways. These teeth are larger than any of those in the jaw of the living crocodile. You see the portion of the tooth is larger than the whole of the other. Therefore we are allowed to infer that this animal was much larger than any of the largest alligators of this country. This would be one of those large reptiles. It belongs to the genus *Mosesaurus*, found in the cretacious strata of Europe. The peculiarity of the teeth is this: Let that be a portion of the jaw. Here is a large cavity for the teeth, which are gone. Here is a root of a tooth broken away, but the root

is united with the bone so that it is not fully separated from the bone; but that it was, at the time

when the tooth was formed, we see by the fact that so much of the tooth is preserved. Back of this there are the small teeth coming out whose peculiarity is to take that form. They have two sharp edges. This is a transverse section. The vertebræ are of considerable size. Here you have one of the backbones. The appendages aboveand below arebroken. The back-bone of the fossil is twice as large as that of the largest crocodile. How can this be ascertained to be a reptile? It is easy. You have these hollow surfaces. So this simple bone can be referred to the class of reptiles simply by the character of the articulating surfaces of the vertebra. That it is a reptile and not a fish is ascertained by the fact that the appendages were united to the vertebræ, as is seen by these fractures. We may ascertain to what genus it belongs bythe peculiar form of the joints of the vertebræ, which [as seen in the next diagram] are obtusely triangular. The articulating surfaces, though concave onone and convex on the other side, are usually triangular, and that is the peculiarity of the genus *Mososaurus*.

It is by this simple process of comparison that the characters may be determined, and if any one will investigate all the relations between such bones and skeletons of a reptile, he will himself be able to restore the entire animal, giving the whole outline with great accuracy.

The number of fossil bones coming to light every year is so great that there is a greater field of investigation than there are students to enter it, which should be an inducement for many more to begin such studies. In this country, fossil bones have been studied but very imperfectly. The Mastodon has been discovered here, and I have no doubt there are as many bones remaining undescribed as there were several years ago in many countries of Europe, so there is ample room for investigation. Owing to the before-mentioned peculiarities in the structure of the crocodile—the form of the teeth and modifications in the vertebræ—those ancient types should form a peculiar order by themselves.

The order of lizards, so numerous in our day, is of little geological interest, because so few fossils have been found to compare with existing types.

The next order is *Ophidians*. Having shown how gradually this order passes into that of lizards by the formation of the feet, the inquiry arises, By what are snakes distinguished from lizards? for there are lizards without feet, and snakes have rudiments of feet. In lizards the lower jaw is movable in its articulation on the temporal bone, and can only move up and down. In the snake the same motion is possible, but the two jaws in front can also move sideways, so that the jaw can be separated considerably, and thus the mouth can be enlarged indefinitely. This is the reason why snakes can swallow animals of a larger diameter than their own body. Not only is their mouth enlarged in that manner, but the posterior articulation of the jaw with the head is such, that the jaw can slide on the side of the head, and thus enlarge in that direction. The temporal bone is detached from the skin, and forms the joint of the lower jaw, which joint is movable right and left, allowing the snake to distend its mouth enormously. But the upper jaw is also movable, and in some, as in venomous serpents, there are movable teeth, uniting with the sac containing the poison which they inject through the tube of the tooth into the wound made by the bite of the reptile.

Snakes have existed in former times. Prof. Owen has ascertained that in the London clay, fossils are found allied to the boa-constrictor, as early as the deposition of the most ancient tertiary bodies.

The last family is the *Batrachians*, which is so interesting in its geological bearings, and also anatomically from the extensive metamorphoses it undergoes, that I beg leave to pass by the class of birds which is so well understood and is of less interest, and take up the order of Batrachians for the next Lecture.

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LECTURE XI.

Examination of the Order of Batrachians—Their Metamorphoses the Key to a proper Classification of Animals in the Scale of Being...The importance of this key or principle never as yet known and applied....Fossil Batrachians illustrate this principle....Birds and Mammalia—Difference in their respiration....Cause of the power of flight in Birds....Peculiarity in the Toes of Birds—A Clue to the Discoveries of Ancient Forms by their Footprints....Pres't Hitchcock's discovery—His opinion sustained...Diversities in the class of Mammalia.... Whales as order of Mammalia—Fossil Whales....The Hydrarchos...Herbivorous and Carnivorous Animals—Difference in their alimentary organs....The teeth of *Rodentia*—The jaw of the Badger....Motions of the jaw in animals—Teeth of the Barbaroussa....The Pachydermata....Remains of a species of the Elephant in Frozen regions with the flesh preserved....Sudden change of climate in the Frozen Regions....The Mastodon of recent date—The *Ruminantia*—The *Rodentia*—The Singular character of the *Didelphides*—The *Carnivora*—Seals: Carnivora proper....The *Quadrumana*—Difference between a man and monkey.

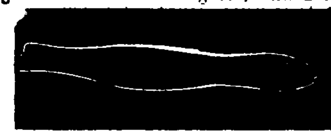
Ladies and Gentlemen: In the examination of the class of Reptiles, we have already gone through four orders—viz: that of *Rhizodonts*, containing those gigantic fossil extinct types and the now living Crocodile; second, the *Chelonians* or Turtles; third, the *Saurians* or Lizards; and fourth, the *Ophidians* or Snakes.

We have to-night to examine the order of *Batrachians*. These animals are very numerous, and of a singular character, owing to their mode of growth. They differ from the other reptiles in this—that their body is naked, without scales, and the skin is soft. But what is the most striking feature in their character, is that they undergo a series of changes during their life after they are hatched. The young batrachians all have a long tail, like lizards; even frogs and toads, when young, have this appendage.

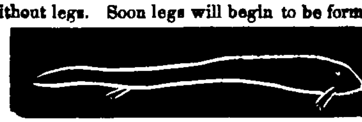
The order of Batrachians contains *Frogs*, *Toads*, *Salamanders*, and many other animals allied to Salamanders. There is an extraordinary difference in their external form, though all agree in this, that after they have escaped from the egg they have a long tail circumscribed by a fin, and in their early stage they have no feet. Soon after they are hatched, the feet begin to appear, and in some the tail disappears, and they assume the short, compact form of the frog and toad—while others retain their tail. Again, when young they all respire through gills, which some lose, in later life, and breathe through lungs like other reptiles.

In these few facts we have a most important indication of the value of *character* throughout the great division of the vertebrated animals. If my object was not to illustrate the principles of Zoology, I would enter into more details in the examination of the different species and their external characteristics; but these can be learned from books. In these facts of the structure and characteristics of the Batrachians, we have illustrated some fundamental principles of classification—and, in fact, a new principle which I consider as most important for that object. Animals have usually been classified by the difference in their structure, which principle is perfectly correct; but the difficulty is to ascertain by a knowledge of their structure which combination of organs—which structure—belongs to the higher and which to the lower order. We have had no test for ascertaining this. The good opinion men have of their own superiority over the rest of the animal creation, has induced zoologists to consider those animals more nearly allied to Man to be the higher order, and those that differ more widely from this type to belong to the lower orders. But the actual scale by which we measure the degree in the gradation of animals is found only in their metamorphoses; and unhappily this test has not been introduced into our classification as it should have been. The facts we know already in relation to the structure of Batrachians and their metamorphoses are sufficient to give a perfect key to the classification of the two lower classes of vertebrated animals and the succession of any order even with the most minute details.

In this diagram I will sketch not any one particular animal, but the general outline of a group. When the young batrachian escapes from the egg the general outline is elongated, with a tail, but



without legs. Soon legs will begin to be formed—

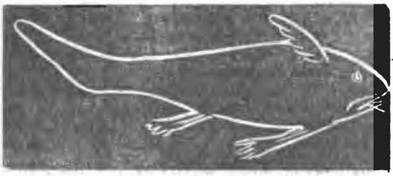


and we then have the form of a Salamander. Then the legs will increase in size and the tail will disappear—and we will have the form of the frog and toad. In the beginning there are external appendages for respiration—the gills. These disappear entirely in the salamanders, frogs and toads, and remain permanent in the others. The earlier stages

in the growth of the animal will be considered to be very analogous to the lower grades of animals—and in the full-grown state, to the higher. Let us see what are the relations of these to other vertebrated animals. Is it among birds and mammalia that we find an analogy to these animals? Certainly not. It is among the fishes we have a similar structure. Therefore we shall consider fishes as lower than those reptiles which begin with the characteristics seen in fishes, and progress to a higher development. Here is evidently a test by which we know that the class of fishes should stand lower than reptiles, which, otherwise, might be doubted. The fact that some respire by gills, is not of itself sufficient evidence that they stand lower or higher. There are some reptiles that breathe by gills their whole life. The fact of the fish-like forms in the young batrachian is sufficiently indicative of the position which fishes should occupy with reference to reptiles and other vertebrated animals.

Let us again examine the different families in the order of Batrachians. We have some families in which the form is thus:

First external gills, and, having lost them, a very minute fin appears, and afterward ill-shaped, imperfect feet. Then in some, whose body is larger, we will find the fingers more complete and the legs more developed, and larger and more complicated



feet. In others the tail will gradually shorten, and the fin circumscribing it will gradually disappear. The gills at length will disappear, and the legs attain such a size as to become the main organs of locomotion.

Here, then, we have—in such a series and gradation of forms, and in such a relation between these forms and the changes which the frog undergoes—the actual indication of the order of classification in the arrangement of all the families. And wherever Embryology—the knowledge of the changes in the young animal—has taught us the successive forms, we may have in these changes important hints as to the classification of types. Therefore I think the principle of metamorphosis, as a foundation for classification, is the best and most striking guide a zoölogist can take. But, as I have said, this principle has been very imperfectly understood, and in fact never applied as one upon which classification in general could rest.

There are several fossil Batrachians, and what is again interesting, is that the larger ones and those which have appeared earlier, belong to the older tertiary strata. It is in the more recent tertiary beds we find those which show a closer affinity with frogs or tailless batrachians.

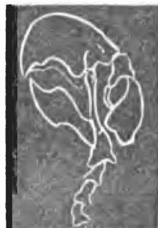
I will not enter into farther details. My object in speaking of the Batrachians was to illustrate the principle of classification, derived from a knowledge of the metamorphoses in any portion of the Animal Kingdom. In another Lecture I shall show that this principle will be of direct application in the order of succession of the different types of the Animal Kingdom. Though we have not investigated all classes, there are sufficient facts obtained to show, even now, that this is a fundamental principle upon which classification *can* rest, and that this same principle is the one in the order of succession of types in all geological ages. (Applause.)

The next class is *Birds*, and next the *Mammalia*. These two classes have certain characteristics in common, of which I will first speak. They are both warm-blooded animals, and they both breathe with lungs. Birds, as well as Mammalia, have large air-sacs called lungs, which open externally through the mouth as well as the nostrils, in the same manner as reptiles; but there is this fundamental difference between reptiles and birds and mammalia. The latter two classes are warm-blooded. The difference in temperature is undoubtedly owing to the greater amount of oxygen consumed in respiration.

Mammalia and birds agree again in the large size of their brain in proportion to the body. It is so much greater than in reptiles as to be quite striking. In comparing, for instance, the brain of the sparrow with that of the largest sea-turtle, that of the sparrow is found to be about half the size of that of the turtle. The difference in proportion to the size of the two classes is as 100 to 1.

The peculiar characteristics of the class of Birds are that the anterior and posterior extremities are entirely dissimilar. The former are wings—the latter legs. Nevertheless the structure of the wings and legs in birds is precisely the same—the bones exactly correspond, and the true difference is owing to their arrangement. The large thigh-bone, uniting with the back-bone, corresponds to the shoulder. The thigh-bone corresponds to the humerus—the leg proper corresponding to the fore-arm—then the foot and fingers correspond to the hand. These parts are covered with feathers, and the difference which is obvious in the bones entirely disappears in the external limbs. This analogy in the anterior and posterior extremities can be traced throughout the great type of the vertebrated animals. The short fingers on the foot of the bat, correspond precisely to the long fingers of its hand, even to their arrangement and number of bones, and the difference is only in the manner in which they unite together by membranes.

There is no class among vertebrated animals so uniform as birds. What I have said applies to the

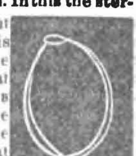


whole class—they differ only in the shape and form of the bill and the fingers, and in the proportion of their bodies. In the parrot, which is widely different from the ostrich, you will find the same neck and back bones, the same arrangement of the wings and even the same number of articulations in the toes.

In their respiration, they differ from Mammalia. Birds, in order to fly, must necessarily be very light. To obtain this, they are provided with a large air-sac, extending from the lungs into the abdominal cavity, and even into the bones. The bones of the arm in birds are hollow, communicating with the air-sacs of the lungs. The reason why a bird falls when its wing is broken, is because the air within the cavity no longer resists the pressure of the chest. If you sever the bone of the wing, you will hear the air whistling through the broken

bone. It is owing to this arrangement that the specific weight of birds is so much diminished, and they are enabled to soar through the air with such ease.

Only a few birds are deprived of this faculty—such as the ostrich. In this the sternal bone is quite flat and without the peculiar projection which is seen in other birds, to which the large muscles are attached that move the wings. I will draw a transverse section of the breast bone



of the ostrich. The surface is entirely flat and here is the cavity for the lungs—here are the ribs and here the breast-bone entirely flat. In other birds there is the same arrangement of the ribs and breast-bone, and there is a large ridge rising from the middle, and to it are attached the broad muscles which move the wing. These muscles are well known as the white meat of the fowl. There is a constant proportion in the extent of this bone and the power of flight in all birds. I will enter a little

farther into details. Let this diagram represent

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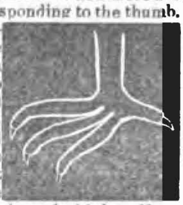
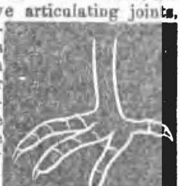
the backbone and ribs attached to it. There are additional bones not found in other birds, passing from one rib to another, preventing the compression of the chest, which would otherwise modify the respiration, by diminishing the quantity of air inspired.

I have mentioned that the fingers, or rather the toes, were similar in all birds. I will pursue this point, as it is the only one upon which birds have acquired a geological interest. Many years age Pres. Hitchcock of Amherst College discovered curious tracks upon certain rocks in the Connecticut Valley. He examined these impressions and published some diagrams of them, maintaining that they were the footprints of birds. I believe this assertion was received with as much incredulity in this country as in Europe. He has for years been struggling against opposition in reference to his assertion. To himself, as well as to a few individals who had confidence in the fixity of the laws of Nature, the evidence was satisfactory. At length his views have been fully borne out. It can be proved with as much certainty that birds have existed as early as the deposition of the new red sandstone, as if we saw them—though only the tracks remain, like those left on a sandy beach.—These tracks were made long before Man was created, and the evidence is beyond the slightest doubt. (Applause.)

The evidence is this. The toes of birds are always two, three or four in number. When there are four there is one behind corresponding to the thumb. Let this represent the foot.—



In the posterior finger there is one bony articulation and a nail—in the first finger, two bony articulations and a nail—in the second, three articulations and a nail-joint—and in the third, four articulations and a nail-joint. There is not another animal in which the number of articulations is such as in birds. Here we have only three fingers. The first has three, the second four, and the third five articulating joints, including the nail-joint.—

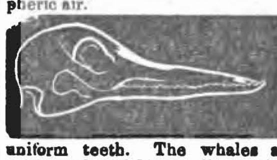


In the only bird which has two fingers, the African ostrich, the first finger has four and the second five joints.—Now in the new red sandstone of the Connecticut Valley, the impressions left show plainly the joints of the toes and number of articulations, which correspond precisely to the foregoing arrangement. This is satisfactory evidence to every anatomist that the impressions were from birds only. I do not maintain by this that President Hitchcock has shown that they were all birds' tracks. There were also impressions of other animals whose tracks do not agree with those of the birds. But there are tracks of birds running over wet sand, that have been preserved by a deposit of mud upon it, which is enough to prove conclusively to the mind of the geologist the existence of animals—though there are no remains at all. These results are satisfactory, because they promise more information concerning the true history of geological succession on the surface of the globe. Since the ripple-marks of the ebbing tide, and the slightest impressions of the feet of animals can be recognized, we have evidence that the time will come when we shall know all that has transpired on the surface of the earth, at a period when Man did not exist, and we can reconstruct the form of the whole Animal Creation only by these slight evidences.—(Applause.)

The last class of vertebrated animals of which I have to speak, is the *Mammalia*. It is a class in which the types are almost as diverse as in reptiles. We have, in this class, animals provided with fins, others with feet, and others with wings. There are some which have external horns of large size, some with smooth skin, and others covered with hair. Though their external appearance is extremely different, they all agree in this respect: they have warm blood, like birds. But they have no air-sac extending into other cavities of the body. The breast is divided by a large partition called the diaphragm, which separates the respiratory cavity from that in which the other viscera are contained.

Birds lay eggs, while the Mammalia bring forth living young. It is upon this most important difference in their character that the reünion of so many animals so widely different has been determined. For example, the *Whales* as well as bats bring forth living young and nourish them with milk. The similarity of their general structure is closer than would appear—owing to this peculiarity. The internal structure of the whales is the same as the higher Mammalia, and though they have been considered as fishes they have no affinity, but only an external analogy to that class. The whales are really much more allied to *Man* than to any of the fish tribe.

The distinction between analogy and affinity is, that the former indicates only an external similarity; but the moment we investigate the internal structure of the whale we find such a striking resemblance to the Mammalia that we call it affinity. So then whales are analogous with fishes, but are truly Mammalia. Even this analogy wtih fishes is much less than it might appear. They have fins, but for a different use from fishes. In fishes the large fin at the end of the tail is placed perpendicularly, and cleaves the water from right to left, producing a forward motion only—while in whales this fin is placed horizontally, and its motion causes the animal to rise or sink at will. And this arrangement facilitates their respiration, for they cannot breathe except in the atmosphere. Fishes can rise and sink, but only slowly, on account of the perpendicular position of the tail; but whales can rise rapidly to the surface to breathe the atmospheric air.



This is the skull of a dolphin, one of the whale tribe. It is widely different from the class of fishes and is provided with uniform teeth. The whales are, however, the lowest order of Mammalia, as is indicated by the structure of their other extremities. They have anterior feet, but no posterior. They have fingers, five in number, as in other Mammalia, but united by a thick membrane forming a fin. The structure of the caudal appendage, and in some of them the existence of a dorsal fin, shows some relation to fishes, which puts them in a lower grade, but still their true affinity is with Mammalia.

Whales have existed in former times. Most extraordinary sized fossil types are found in the Southern parts of this country. In Alabama large specimens have been discovered, which unfortunately have been described by an ignorant German naturalist as the remains of reptiles, and this discovery of so much importance, has been lessened in interest by the unscientific manner in which they were described. But lately Prof. Wyman, a young nat-

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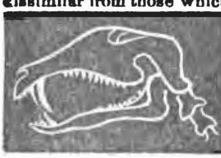
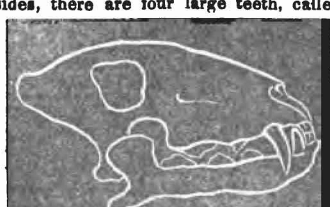
uralist of Boston, and Dr. Gibbs of South Carolina, have given a scientific description, showing their essential structure to be that of Mammalia. And still later, since their proper place has been assigned, a skull has been discovered, showing the peculiar rounded form of the posterior part of the head, giving another evidence that the remains are those of a species of whale, and not those of a reptile called the *Hydrarchos*. The existence of whales dates as far back as the cretaceous epoch, and many have been found in the tertiary strata. There is a difficulty in determining the species of these fossil cetaceans, on account of their large size. It is much easier to compare smaller specimens.

The Mammalia are divided into two other large Orders beside that of whales: the *Herbivora* and the *Carnivora*. There is a difference in those which live on vegetables and those which devour animals for food. The form and structure of the teeth for grinding vegetable food and for cutting and devouring living animals—as also the alimentary organs for digestion, which require the food to undergo a process of assimilation—are very different in the two Orders. The difference between the food and the substance of the body of an herbivorous animal and the modification it has to undergo to become assimilated, render the digestive organs much more complicated in the herbivorous than in the carnivorous tribe.

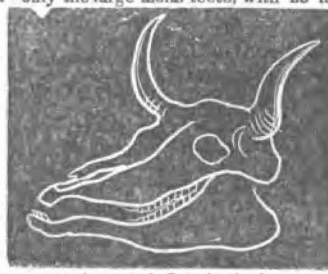
Again, the food of these two orders is so different in the various *families*, that we find numerous farther modifications in the operations by which the food is prepared before it is swallowed. We have, for instance, in the *gnawing* animals teeth entirely dissimilar from those which act upon the surface of the jaw. This is jaw of the beaver. You see the two anterior teeth, both in the upper and lower jaw. Then there is a space deprived of teeth, and in the posterior portion of the jaw we have the grinders. Animals with such jaws, and they are very numerous, are called *Rodentia*. Rats and squirrels are of this group. Rabbits and hares have two anterior teeth in the lower jaw. and four or five grinders on the right and left side of the posterior part of the upper and lower jaws. The first are called *incisors* and the second *molars*. We find such only among herbivorous animals, while in the carnivorous we find a third kind of teeth: In the jaw of the tiger you have in front the incisors, and in the posterior part the molars; but beside these, in the anterior position and on the sides, there are four large teeth, called the





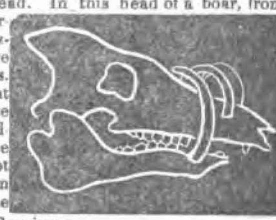
canine teeth. They are those with which the animal seizes and retains its prey. In the badger the articulation of the lower jaw is so powerful that the jaw cannot fall. There is a groove into which the enlarged end of the lower jaw is introduced, and closed by the upper so strongly that they are kept in their natural position, and even after the soft parts are removed, the jaws cannot be disjoined.

All carnivorous animals can make only upward and downward motions of the jaw, with a very slight lateral movement, while those which live upon grass have, beside these, a lateral motion.—This is especially evident in ruminating animals. All the herbivorous animals which have a complicated stomach, from which the food is returned to the mouth to be ground over again, have no canine teeth—only the large molar teeth, with no incisors

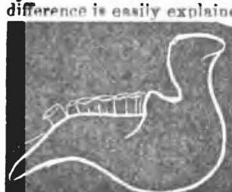


in the upper jaw and five in the lower. Deers, elks and cows are of this family, having no incisors in the upper jaws, and no canine teeth at all.

When I say no herbivorous animals have canine teeth I suppose many have thought of the extraordinary tusks of the elephant, which are placed in the same position as canine teeth in other animals. In this head of the Barbaroussa appear canine teeth of extraordinary size, but you will readily perceive the difference between these and the canine teeth of carnivorous animals. They are not used to seize the prey. They are curved upward, and are used for other purposes, beside being an ornament to the head. In this head of a boar, from the Island of Borneo—the *Barbaroussa*—they are curved like horns. In the elephant they become large tusks, corresponding to the canine teeth, but are not used to perform the office of canine teeth as in the Carnivora.



Among the Herbivora we will first distinguish the large family of *Pachydermata*, in which the fingers are covered with a hoof. The horse, the elephant and the rhinoceros belong to this family. They have grinding teeth of a large size. Some have many and some very few. The elephant, the largest of the Mammalia, when full grown has only four molar teeth—two in the upper and two in the lower jaw. The young elephant has twice as many—four in the lower and four in the upper. This difference is easily explained. The new teeth are not formed under the old ones, but behind, and as they grow they move forward, first the anterior portion of the tooth appearing above the bone of the jaw, the posterior portion being still covered with bone. As they



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come forward they displace the other teeth, the anterior portion successively falls away and the posterior comes in gradually. In the full-grown animal there are only four maxillary teeth in the whole jaw and two tusks, making six; but these are renewed constantly, so that after the second pair has taken the place of the first, another will be formed behind. So it is not true that the full-grown animal has only four teeth, for there are new ones constantly forming behind. They have now eight and now four teeth, and when full-grown there are only four left.

The family of *Pachyderms* is highly interesting, because it is to them we must refer many of the gigantic terrestrial animals found in the tertiary strata. They are quite numerous, and it is these which have been for the first time reconstructed and

illustrated so admirably in the immortal works of Cuvier. We have here the remains of the *Palæotherium*, an animal allied to the Tapir in the form of its head, and grinding and canine teeth.—This animal, the *Anaplotherium*, is similar to the Palæotherium—but of a slender frame, and the body indicates an animal of quicker motion, while the former was more heavy and slow.

The main difference is in the arrangement of the teeth. There is no vacant space between the incisors and canine and molar teeth of the latter, but in the former you see the canine can cross each other and fill the vacant spaces when the jaws are brought together. These animals have never been found entire, but the skeleton has been drawn from related bones. Never was even a complete head found of a Palæotherium or Anaplotherium. They have been reconstructed even from much more imperfect fragments than are now contained in the Museum of Paris. The difference in the animals is not only in the teeth but also in the feet; the Anaplotherium has three fingers, the middle finger being much larger than the lateral ones, while the other has two fingers only. The older pachydermata found in the gypsum are not of gigantic size—the largest is not greater than the horse, and some are as small as an ass. But in the more recent tertiary beds, other genera of this animal have been discovered, such as the Hippopotamus, showing the same characteristics in the canine, incisor, and molar teeth. And not only isolated teeth are found, but in the Val d'Arno, near Florence, complete skulls have been found larger than the largest specimens known to naturalists, and most of these are preserved in the Museum of Paris, which contains the largest and most complete collection of fossils.

Several species of the elephant have been found—and what is most remarkable, they lie in the coldest regions of Siberia and the most arctic portion of this continent. The species is similar to the Asiatic and African elephant, so that we cannot doubt that they lived in a much warmer climate than that where they are now buried—thereby proving extraordinary changes in temperature in those regions, and more particularly as it is evident that they are buried in the countries where they lived. The best evidence of this is the fact that one of these elephants was found so well preserved that after disinterring the body, the flesh was actually devoured by wolves. These well-preserved remains are numerous in the North of Asia. Parras, and more recently Admiral Vrengel, when visiting the White Sea, says he had to travel for days over remains of these fossil elephants and rhinoceri and hippopotami, gathered on the beaches so as actually to form hills. It is in the frozen region of Siberia that the soft parts have been found. The hairs, skin and even the muscles which are known to exist, show plainly that they must have been suddenly buried after their death, and could not have been dragged from the tropical regions.

There is a genus of Pachyderms, the *Mastodon*, which is entirely extinct. It is sometimes called the *Mammoth*, but improperly, as that name should be reserved for the fossil elephant of Northern Asia. Several species of the mastodon are found in this country, Europe and tropical America. The largest species is common in this continent and appears to be of recent geological date—so recent that few geological phenomena can have taken place since its extinction, so that it is even a question among geologists whether this species has not lived within the existence of mankind. This is a pendant question upon which evidence is not sufficient to determine the facts. All this shows how recently such animals inhabited this continent, and how stupendous the changes that have occurred on the surface of our globe.

Next to the Pachyderms comes the family of *Ruminantia*, of which the Northern Elk is one. The horns of the elk are flat on the internal margin and with projections on the edges. All the ruminating animals are characterized by the want of incisors in the upper jaw. There are two groups: those which have compact horns which fall off every year, and those which have hollow horns which are permanent. These horns stand upon a bony projection formed of a horny substance, but different from the enamel-like substance composing the horn of the deer. A species of very large size has been found.

The family of *Rodentia*, containing many minute species, among which the beaver is the largest, have only two upper and two lower incisors.

One type in the class of Mammalia has puzzled naturalists exceedingly, being similar in one respect to mammalia, and entirely dissimilar in many others. It is the family of *Didelphidæ*, containing the kangaroo and opossum. This family has one peculiar character: they bring forth their young in a very imperfect state, and they are afterward introduced into a large pouch under the skin, where they remain till they can provide for themselves.—But, except this common character and the fact that they have a common structure of the brain, they differ widely—some having the structure of the teeth like carnivorous and others like herbivorous animals. Some are, in fact, carnivorous and others herbivorous, and it is probable that a higher consideration than that of food will prevail to make these a natural group. The whole family of these Didelphides, except the genus opossum, is peculiar to New-Holland, where also numerous fossil species are found. The opossum is the only species which is a native of this part of the New World. There are some few species in South America. In New Holland the species are quite numerous and extremely varied in the structure of their teeth and alimentary organs. The fact that the fossil species are numerous also in New-Holland, shows that the opossum has a relation to that type, as among fossils in that country we find almost none but the Didelphides. Only one has been found in the plaster of Paris, and no one elsewhere.

The next group is the *Carnivora*. In these we observe distinctly the cutting canine teeth and the slender claws adapted for seizing the prey. This

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characteristic is particularly strong in the cat tribe. The claw which terminates the toes is arched and sharp so as to be used as a fang.

The order of Carnivora contains families sufficiently different to be distinguished. We have first the family of *Seals*, which have all the structure of Carnivora except that their fingers are united to form fins and the posterior extremities are exceedingly far back.

Next the Carnivora proper, which have the fingers divided, the legs long and the cutting teeth most strongly developed. These carnivora have been numerous in former ages and do not differ so widely from living carnivora as fossil herbivora do from the corresponding living group, and when speaking of the order of succession in the next Lecture I shall show that the nearer we come to the actual types which prevail upon the surface of our globe, the less numerous are the corresponding fossils.

Another family is the *Bats*, and differ chiefly by the form of the anterior extremities. They have four fingers which unite by a membrane, while the thumb is separated and is used as a means of suspending the animal in caves, and for the purpose of crawling. During winter they suspend themselves by their hind feet.

The last family, the *Quadrumana* or Monkeys, begin to approach so near to Man that Linnæus could not find a common character to separate the monkey from Mankind. (Laughter.) It is singular that the first naturalist of the past century, the one to whom we owe all our principles of modern classification, was incapable of distinguishing by characters expressed in words the true difference between some of the higher monkeys and Man, but has even placed one species—the *Chimpanzee*—in the same genus as Man, under the name of *Homo-lar*. It is only by close anatomical investigation we can learn the difference. Now it is easy to understand it so as never to mistake a monkey for a man again. We have two hands and two feet.—Monkeys have four hands. But, some will ask, what difference is there between the hand and foot? It is not merely the length of the fingers—for the fingers of the hand of the fore-arm of some monkeys are shorter than those of the foot. The difference is here: We can open and close the thumb with each successive finger, which we cannot do with our toes. (Loud applause) It is to this characteristic in the human hand and foot that Man owes his superiority over the lower creation. The fact that we have two feet allows us to stand upright, and while standing to use those delicate organs—the hands. Again, this upright position enables Man to move the head freely in all directions. The very fact that we have not four hands, and that we stand upon our feet, and in that position our hands and head are in equilibrium on our vertebral column, moving in all directions, gives to Man all his superiority over the Brute Creation, both mentally and physically.

LECTURE XII.

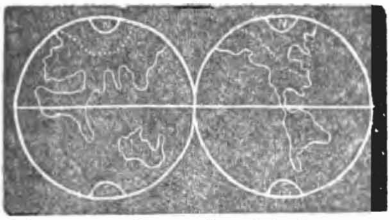
The Geographical Distribution of Animals—Animals all limited in their habitation—Fishes on both shores of the Atlantic perfectly distinct—Species more identical near the Poles, but the identity lost as they approach the Equator....Peculiarity of the Didelphides of New-Holland....Modification of Types not caused by climate....A group of Fishes peculiar to the Indian Ocean....Different varieties of Men circumscribed in the Natural Boundaries of Animal Groups....The Order of Succession of Types in Geological Times—Strata of different ages contain different species ...The results of observations of Geologists and Zoölogists—The Primary Rocks....Secondary Strata....Tertiary Beds....All contain different Species....The Opinion that Animals succeed each other in regular gradation entirely false—In view of this fact some deny all order of succession—Illustration of the Order of Succession....All the Invertebrated Classes and one Class of Vertebrated found in the beginning—Illustrations of this fact....The first types the highest in themselves....Reptiles which first existed assume all characters....A true gradation in the Vertebrated Animals which is not found in the Invertebrated....Man the last type intended—No farther progress to be expected.

Ladies and Gentlemen: Before proceeding to the consideration of the subject upon which I intend to speak this evening, I will limit myself to a very few remarks upon another subject, which I would gladly have introduced before this time, if it were not so extensive that I could give no notion of it without entering into very minute details. I mean the subject of the *Geographical Distribution of Animals*. It is, perhaps, necessary to know something of it in order to understand fully the relation, the distribution, the structure and the order of succession of types; and, as I have to introduce the subject of the order of succession of types into this Lecture, I will merely mention the general results of the recent investigations upon the geographical distribution of animals, without giving the facts upon which these results are founded. I beg you to accept them as resting upon investigation as accurate as any that can be made in the department of Natural History.

Animals are all limited in their habitation to some particular spot on the surface of our globe.—There are few species existing over the whole extent either of land or water. These few species belong to genera in which it is very difficult to perceive specific differences, and it is still possible that those species which are thought to be so widely dispersed, are nevertheless to be limited to some particular spot, when the minute differences shown in their characters shall have been fully ascertained and established. Again: Some which appear to have been originally so widely diffused have been scattered over large areas under peculiar circumstances, which are not natural to the species. But leaving those few species out of consideration, we can with correctness assert that all species have a limited habitation, and that mankind only are diffused over the whole extent of the surface of the globe. There are varieties of species in the coldest climates of the arctic regions, as well as under the burning sun of the tropical zone, while there is no animal type which is distributed in a similar manner to the type of Mankind, all over the earth. The ocean, which is the most convenient mode of communication for Man, has not been an easy medium for the diffusion of animals from one shore to another. What will perhaps astonish some of my audience is nevertheless perfectly evident from recent investigations;—fishes on both shores of the Atlantic are perfectly distinct. There is not one species found in the Mediterranean which occurs on these shores: not one species occurring on the shores of France is found south of Cape Cod; I do not maintain that there is not one species in the northern shores of Europe *identical* with those of Cape Cod. The farther north we proceed, the more species we find identical in both Continents, from causes which I am now about to relate.

There is a certain extent of land in which all animals in the different regions of Europe, Asia and North America are found to agree. In America they occur lower south than in Europe, where we have at the 70th degree of north latitude, the same mean annual temperature of 32 degrees Fahrenheit, as in America in latitude 50 degrees—20 degrees farther south.

This is the northern portion of this continent,



and the corresponding portion of the Eastern Continent. Within these boundaries [the dotted lines in the upper part of the diagram] the animals are identical; even the aquatic animals in the seas are also identical, and extend farther south than the land animals. For example, we have the fishes of Baffin's Bay extending along the shores of Norway, Scotland and Ireland to a lower latitude than that in which the identical land animals in the Asiatic and American ice-fields are found. Indeed, we have some of these arctic fishes coming as far south as Cape Cod, and occasionally still farther.—There is no identity between the main portions of the two continents, but around the Pole there is a region where the animals of either verge of the continents are identical.

As soon as we go farther South we find in the temperate zones of Asia and America the animals all become distinct from the arctic animals and differ among themselves, so much so that those of the temperate region of Europe are distinct from those in the same region of North America. Still there is a great likeness between them, so great that the first settlers of this country gave them the names of European animals. You have the fox, the bear, the deer and the marten, which are so many names of European animals. In fact all the vulgar European names are applied to your own animals. But notwithstanding this, the animals of the two continents are only analogous, and as specifically distinct as some allied species are distinct among themselves. For example, two species of foxes are found in Europe,—the common fox, and the jackall on the shores of the Mediterranean, differing in the same manner as American from European foxes, or as some in Central America differ from those in this region. Thus you see that as we recede from the cold climate of the North we find animals gradually becoming more and more distinct, and showing a certain analogy which is very striking among certain types, though less so in others. I may go so far as to say that the genera are the same, though species differ.

As soon as we reach the tropical regions we have not even an analogy between the genera. Animals of Tropical America and Tropical Africa and Southern Asia differ materially. We have no such genera as the hippopotamus, rhinoceros and elephant in Central America, nor do the tapir and llama exist in Africa. There is only the camel corresponding to the llama in Tropical America. All those in the tropical regions of that world have no analogous types in Central America.

As we recede to the temperate regions of the South, we return to a greater similarity of types. In the southern extremity of America we return, as it were, to the types in the Arctic regions. But the southern point of Africa is peculiar and distinct in its animals, and the Continent of New-Holland is so exceedingly different from everything else that there is a combination of animals having no analogy with any other groups in any other spot on the globe. And indeed what is still more curious, is that the didelphides found in all parts of New-Holland occur often in New-Guinea, in those warmest portions of New Holland, and also in the temperate regions, so that we have here a most striking evidence that these modifications of types are not owing to temperature, but that they are regulated by a higher design, one which escapes our observation, unless we refer it to the primitive Law of all existence.

I would not go beyond these few remarks, only to mention that even in the Pacific there are similar laws of distribution; and animals in the northern portion are identical with those on the Asiatic and American shores—while in the temperate and tropical portion there is no analogy at all.

Some marine groups of animals are circumscribed in narrow limits, though they are at liberty to swim in all directions. There is a group of fishes common in the Indian Ocean, very little known in this part of the world, and not represented either in America. Europe or Africa, but confined about the large islands between New-Holland and India Proper. In this little group of islands there is a family of fishes circumscribed and not extending into the Pacific, nor even all over the Indian Ocean.

This shows again how limited some types can be, notwithstanding the power they possess of traveling about in all directions. Far from considering this power of locomotion a reason for the spreading of animals, I think it is only a cause for their keeping within definite boundaries. Being at liberty to change their location they will keep within the most congenial boundaries, and not be scattered at random. That the eggs of fishes can be carried by currents is true, but we do not find that this influence causes the fishes to be so diffused; but, on the contrary, they remain within what appear to be their original boundaries. In fact, we can come to no other conclusion than that they have originated where they exist.

We have another fact connected with this which is highly interesting, and perhaps will throw some additional light upon the origin of Mankind. The different varieties of men are circumscribed in boundaries similar to those occupied by natural groups of animals. In other words, the different races of men cover the natural boundaries of the definite associations in the Animal Kingdom.

But, without going into details in this investigation, I will proceed to elucidate the subject of *the Order of Succession of Types in Geological epochs.*

It was necessary to show that all animals are limited to certain natural boundaries, which appear to have been their original location, in order to show the importance of a knowledge of the characteristics of fossil animals. If it was not the fact that all fossil animals of New-Holland are identical in type with those now living in the same locality, and that the fossil types of South America agree precisely in type, though not in species, with those now living in Brazil, I would long since have left the subject.

The subject of the order of succession of types in geological epochs, is one which has been considered by geologists in a different point of view from that in which I shall now consider it. Perhaps it is proper for me to make a few remarks upon

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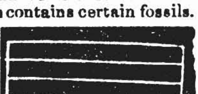
the value of investigations made under different views.

Geologists have for a long time known that fossils in different strata are not the same. All the species that have been found have for the most part been fully described, figured, and well compared with living animals. It has been shown that strata of different ages contain no identical species.—Nevertheless all I have now to say has been mentioned in works in which these facts are related.—Geologists have considered fossils by themselves—as medals by which they can ascertain the ages of geological strata. They have, in fact, been enabled by these fossils to find out whether certain strata of rocks are older than others. What I have found on investigating the same subject, has been, that the order of that succession corresponds precisely with the gradation of types of animals when classified according to their structure. Zoölogists have done an extensive work, in connection with anatomists, in investigating the structure of animals, and from their external characters they have worked out a classification more or less natural, and a methodical distribution of them, forming a complete Zoölogical system. These series of investigations have been traced for half a century since the first researches of Cuvier, and his classification according to structure.

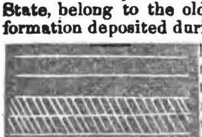
Here, then, we have two series of independent observations;—first, those of geologists, ascertaining that in different successive strata there are fossils of different kinds and species which do not occur in other series of strata above or below; and, second, the classification derived from the structure of animals.

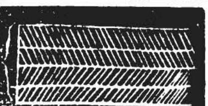
What I can add is this;—to show that these two series of phenomena cover each other:—that you may read the order of succession with a certain intelligence. and you will find that the classification according to *succession* agrees precisely with the classification made according to the *structure* of animals.

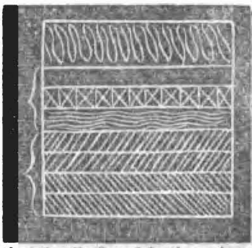
In order to make this evident, let me mention a few geological facts. The whole series of strata forming the crust of our globe, not to include those which contain no fossils, can be divided into a series of layers, each of which contains certain fossils.



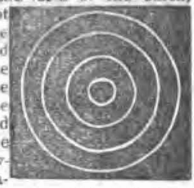
The lowest strata. for instance, the limestone, so extensive over the northern and western parts of this State, belong to the oldest formation deposited during the existence of animal life. There we discover the oldest animals. Above this we find another set of rocks which are allied to them, containing coal—strata so extensive in certain parts of the Middle States and in the West. The oldest strata of coal I would unite with the lowest series under the name of *primary rocks*. Then we have a series, not extensively developed in this part of the world, in which the new red sandstone of the Connecticut Valley forms a part, to which belongs the series of oolitic rocks so extensive in the South of England, and the bluish limestone of Somersetshire and Yorkshire, and above that the chalk. All these have a certain connection, and have been called *secondary strata*. In these the green sands of New-Jersey are included. Above that we have strata of a more recent date, which contain shells similar to those now in existence; these strata are called *tertiary beds*. The primary, secondary and tertiary beds are not to be mistaken for those rocks which have no stratification and contain no fossils.







Let me mention that fossils found in the primary beds, and even in the different layers of the primary beds, are different from one another, as well as from those found in the secondary beds. Geologists have known this for half a century. Again, the tertiary contain fossils entirely different from the secondary. I will represent these layers by concentric circles, which will be in accordance with the form of the earth, only the proportions will not be true. Let this be the most ancient strata formed on the primitive rock; the next, the secondary; and the upper, the tertiary. These strata have been distributed in an irregular manner, some being inclined by the upheaving of the Plutonic or volcanic masses, which have modified their primitive horizontal position. But all these details belong to Geology, and have no connection with the order of succession.



Now there has been an opinion prevailing among geologists and naturalists, that the animals succeed in these different strata in an order corresponding to their zoölogical gradation. The view has been widely entertained, and it is still the opinion of many philosophers, that the higher types were gradually introduced, until at last Man was formed.

This view, thus expressed, is entirely false; investigations of geologists having shown, to the contrary, that in the most ancient strata there are polyps, echinoderms, and in the Trenton limestone even higher types of the most ancient echinoderms. There are also bivalve shells, cephalopoda and crustacea, found in the most ancient rocks; and there are also fishes. We have, therefore, not the lowest types in the oldest strata, but we have representatives of all the types. After this fact had been ascertained, geologists were led to believe that there was no regular order of succession in the appearance of fossils. We have gasteropoda—all classes of molluscs, acephala and cephalopoda, we have trilobites belonging to the order of crustacea; and we have some shells similar to those of worms, which have induced geologists to consider the class of worms as belonging to the oldest strata; and we have fishes. Therefore the notion of succession in constant, regular order was denied, and it is this view which generally prevails among modern geologists and naturalists. After they had been under the impression that types in the order of succession correspond to the gradation of the Animal Kingdom, beginning with polypi and ending with the class of fishes, having found fossils of all the different classes in the lowest beds, they actually denied all order and every evidence of plan in the succession of types.

Now let us investigate and ascertain what occurs in the oldest strata. What animals do we there find? That is the question for examination.

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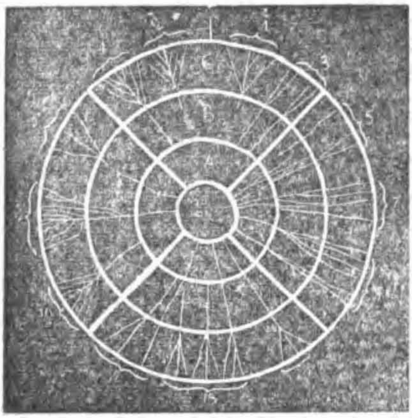
In this diagram I have divided the circle by draw-

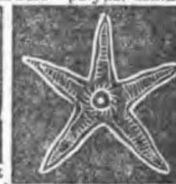


A..Primary.	B..Secondary.	C..Tertiary.
No. 1.Mammals.	No. 5.Cephalopoda	No.10.Worms.
.. 2.Birds.	.. 6.Crustacea.	.. 11.Polypi.
.. 3.Fishes.	.. 7.Gasteropoda.	.. 12.Echinoderms.
.. 4.Reptiles.	.. 8.Insects.	.. 13.Medusæ.
	.. 9.Acephala.	

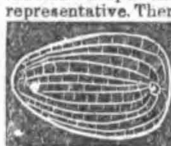
ing four heavy lines from the centre, making four sections. In these sections I have drawn lighter lines radiating from the centre, to indicate the order of introduction of the different classes. We have in the primary strata vertebrated animals, as is indicated by the light lines extending into the primary strata. In the most ancient strata we find fishes, but no reptiles. The type of reptiles is not found till after the coal era. The section on the right side contains the class of molluscs. You remember I divided this type into three classes: acephala, gasteropoda and cephalopoda. These three classes occur at once in the beginning. We have bivalves under the form of spirifers and terebratula; we have gasteropoda in the form of univalve shells, and we have cephalopoda. So we have three classes of molluscs, but only one of vertebrated animals—the fishes. In the left section I have figured articulated animals. We have crustacea from the beginning. We have insects in the coal, which belongs to the primary beds; and we have worms in the most ancient strata. So we have in the primary epoch the three classes of Articulata. In the bottom section I have figured the classes of Radiata. Now we have the polypi from the beginning, and also the echinoderms. The soft animals, the medusæ, are not found in ancient strata, but in the oolitic series; also in the lithographic limestone of Germany impressions of jelly-fishes have been seen. There is no doubt, then, that if this class existed in the oolitic epoch, they existed earlier; only on account of their softness they have not been preserved. So it is likely that three classes of radiated animals existed, and we know that two—the corals and echinoderms—were numerous.

So we have the nine classes of invertebrated animals beginning in the lowest stata, but only one class of vertebrated animals—the fishes—in that epoch. From the beginning, therefore, animals of all classes, except the three higher classes of vertebrated animals, were at the same time called into existence—even all classes of invertebrated animals, and fishes among vertebrated.

But now let us examine what we have in these different classes in the geological epochs. I will take a few examples in order to give an idea of the order of succession. Having made Echinoderms a particular study, I can give more precise examples from them. All the ancient types are crinoids. You remember that the class of echinoderms is divided into three orders—polyps, echini,



and holothurida. The first is divided into groups, comprising those which rest on a stem and those that are free. The echini are divided into three families—the circular ones, the heart shaped and the oblong, of which this is a representative. There are no such echinoderms in the



primary strata;—all are starfish like, with the stem fixed upon the soil by a root, in a way similar to the polyps.—All that have stems belong to the lowest family, and to that

family which in zoological classification is considered as the lowest. No zoölogist will claim a higher rank for the crinoids than the lowest. They have been sometimes placed among polyps, before they were known to belong to echinoderms. Now it is not enough that they belong to the lowest;—we can show that we have the free star-fish from the Mediterranean, the *comatula*, found fixed upon the sea-weed. When they escape from the egg they have a long articulated stem like all those crinoids of ancient times. They have radii extend

ing in all directions, and when these little animals grow larger the stem is cast, the centre is free and we have the star-fish. Now you see we have two relations

between these ancient types and the living ones. The ancient types of echinoderms are the lowest order, belonging to those which have a stem, and in that resemble the young of the free star-fish But of those which have stems there is only one species now existing—the pentacrinites, and what is singular is that our free star-fish, at least the family of comatula, have such a stem in their young state, and the young bear a strong resemblance to these ancient types. The next family which succeeds these is the free-star-

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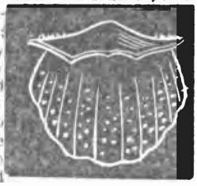
fish. Thus we see that class branching into different families. and these divisions also correspond to the types which begin to exist in different epochs.

I said we have no free echinoderms before the secondary strata. Now free star-fish of a higher order begin to exist in the tertiary formation, and the multiplication of types is accompanied with a gradual extinction of the primitive fixed star-fish with articulated stems. As the forms become more free and more different among themselves. the primitive stock is less numerous, until at the present time only one species remains.

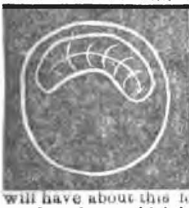
Of the polypi I cannot explain the order of succession, though the living ones have been beautifully illustrated. The forms of the fossils have not been compared to show any relation to the living species. There is yet a wide field for investigation in reference to the gradation of structure in living ones and the order of succession of ancient types.

Among the molluscs I could point to very similar facts. The class of bivalve shells, to which I have already alluded, is represented in the oldest strata only by such irregular bivalves as the brachiopoda. There are no regular bivalves in the primary strata; it is only in the secondary that we find them, and only in the tertiary do we find that variety of shells existing now. But we have seen that the gradation in the class of acephala is such that the brachiopoda should be considered the lowest.



The Monomyaria next succeed; then those which have two muscles. In that class we have an agreement between the order of succession of types with geological times, and the order when classified by their structure. The same fact can be seen in the cepholopoda. Those allied to the nautilus—the gonoidæ—are the lowest, while the naked types are found in secondary strata.

Among Crustacea, the lowest are the trilobites. Who would consider them as higher than the lobster or crab?—They are similar to the larvæ of crabs. Any one who has investigated the first formation in the egg of the young crab will remember one form within the egg which shows only such transverse divisions, and even at the beginning we see a kind of depression from which the successive rings will send forth respiratory organs or external appendages.—But seen from above they will have about this form, with perhaps some appendage here which is wanting among trilobites. There is such a close resemblance between young crabs and those ancient trilobites—the only crustacea found in the primary beds—that it is quite extraordinary that the old agree with the first form of young crustacea in the egg.



Next we have the lobster tribe—which occur in the secondary strata. We know that crabs stand higher than the lobster, and there are less of these external appendages in the tail of crabs—which appendages are by no means indicative of superiority; therefore we consider the crab as higher than the lobster. But the crabs begin to appear in the chalk just after the existence of the long-tailed crustacea.

So we have given the order of succession of these types agreeing with the gradation of form now in existence, when we consider only their organization. I could mention the first appearance of the wingless insects, with a form allied to that of the spider and the scorpion tribes.—the only ones are found in the coal deposition; those with wings, analogous to the more perfect insects, beginning and occurring in the secondary strata, in the beds of chalk and the oolitic series.

So we have in all classes the lowest existing first, and of invertebrated animals all classes in existence at once, because worms have been found from the beginning. So there can be no doubt that if all classes began to exist simultaneously, their lowest types occurred first, and their higher types appearing in succession—a great variety being established only during the existence of Man.

What are the facts with vertebrated animals? We find fishes only in the older strata. In the secondary strata reptiles prevail considerably, with some indication of birds, and at very late epochs another indication of mammalia. But in the tertiary beds we find reptiles, birds, mammalia and fishes, animals which illustrate all the types of former epochs. But do we find the first fish called into existence to be the lowest? By no means.—The types of those first created must be considered the highest in their class. The first class that existed are the ganoids—those covered with enameled scales, in which we see some likeness to reptiles, and in fact indicative of higher orders which were not existing at that time.

Then again at another epoch—when reptiles began to exist in the secondary strata—we do not find batrachians first, but reptiles allied to the crocodile—the Rhizodonts—which indicate, by their character and form, a likeness to Mammalia, which were called into existence later. There is a great resemblance between these and cetacians—so great that in some respects it is difficult to distinguish their bones from cetacians.

Again, we find *pterodactyles*, as allied to birds, which were called into existence later.

So we see that the first types of the oldest vertebrated classes which are introduced are the highest among themselves. They are prophetic types, indicating the future existence of other types at a later epoch, and if we trace all these series we can go so far as to see that the order of succession is such that there is only one chain in the whole series of vertebrated animals, indicating from the beginning an intention to introduce at last Man, the highest type, at the head of Creation.

And this point of view allows us to consider the vertebrated animals as the only one in which there is a progression of this peculiar kind, in which the first step is already indicative of another higher step, till the complete series is accomplished.

It would take me much beyond the limits of my time if I were to enter into the details of all these types. Let me only show that these types succeeded each other in such a manner that they cannot be considered as derived from each other. They may be considered as entirely independent of each other, and only connected, in the idea of the Creator, in the same manner as these facts, of which we showed a succession, are connected, not materially, but in our minds only. All these fishes, though they have analogy to reptiles, are nevertheless by their characters true fishes: they have fins, gills, a vertebral column, and articulated fingers in the form of singularly modified fins with numerous rays. Even in different strata of the primary rocks we find fishes of different genera and species. We find in the

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secondary strata again other fishes—and, what is singular, the moment the class of reptiles begin to exist, these fishes no longer show so strong a likeness to reptiles, but begin to resemble more the fishes of our own day. In the cretaceous series we have all the types now in existence, though the genera with bony spine, dentated scales and multiplied fins on the back, show no indication of existence in the ancient strata.

But reptiles which first exist, assume all the characters we find in the beginning among fishes. But can they be considered as derived from those fishes? No more than any of our living species can be derived from another. There has never been a species derived from another. We have always seen the order of reproduction remain within the natural limits of the species, and it never passes from one to another. It must be maintained as a natural law that one species will not produce another, for what does not take place now cannot be admitted to have taken place in other epochs. If it had been so, we should find intermediate forms, and in such a manner that they could be shown to have been derived from different species existing previously. In fact, the anatomical characters in reptiles are such that there must have been a change in structure. and such change is never assumed except in varieties which can be found in tribes of domesticated animals when the races are mixed. These effects are entirely different from those of a succession of different species in geological epochs. So we would consider this analogy between the ancient fishes and the reptiles of a later period—this change of character in fishes when the reptiles begin to exist, and then the renewed changes in the successive epochs as indicating merely that at such epochs the plan contemplated at the beginning has actually been effected, and these modifications, which were intended to carry on the progress up to the appearance of Man, have been gradually accomplished by the Creator.

There is, therefore, in this view a gradation in all vertebrated animals. There is no such in the invertebrated:—they were intended to be companions of the vertebrated throughout the geological epochs, improving till they acquired that great variety which now accompanies Man—which type of vertebrated animals was intended to be the stock from which the highest type should spring forth at the latest epoch, then to find all that variety in the lowest animals. Therefore we conclude that Man is not only the highest group in Creation, but is the last intended type. We can even go farther, and say that this having been the intention of the Creator from the beginning, we can expect no higher progress or new development. The creation of Man is the highest possible development in the progress of Creation.

In this view we are borne out by other facts. For though the different geological types have been introduced upon different points of the surface of our globe—and though, as I have stated, animals in different parts of the globe are constantly circumscribed—Man at last began to be diffused, and to acquire a power over Nature which no other species ever had. At no epoch has any species ever had such a marked superiority over another as Man has now over the lower creation.

Again, when in any point of view we compare the structure of Man, we can see that he was the last object intended. You remember that fishes have a brain very little larger than the spinal marrow and it is placed horizontally with the vertebral column: the class of reptiles begins to raise its head: in the class of birds the head rises still higher: but in Man a position is assumed to which there is no superior. He stands erect—with a large brain and a head of such a spherical form that there is no improvement possible—but the highest degree of perfection is realized on that plan. Then if we take in connection with this the fact that, in the succession of types, the different species of animals are confined to particular localities, and that Man is spread all over the surface of the earth, we have an unmistakable indication that Man was not only the last creation up to the present time, but was intended to be the last—and that no material progress is possible on that plan, but all progress to be expected within the limits of Mankind is improvement in intelligence and morals. [Great applause.]

Professor Agassiz here reached the conclusion of his Course, amid the general applause of a highly attentive and intelligent assembly—who, during the whole series of the Lectures, had evinced an intense interest in the multiplied subjects so ably yet succinctly treated. Professor A. retired from our midst accompanied by the warmest congratulations and sincere hopes for future success of a multitude of our most distinguished and talented citizens.

THE NEW-YORK TRIBUNE.

We are on the eve of another Presidential Election.—Let none fancy that, since it is approached so calmly, it will be conducted sluggishly and terminated without excitement. Whoever cherishes such an illusion mistakes the character of the American People and the impulses which sway them. Equally idle is the imagination that Party lines are to be effaced and broken down in this contest—that the prestige of some heroic achievement or the glitter of an epaulette is to chase from the popular mind all memory of the radical differences of sentiment which have so often arrayed one-half our countrymen in fierce conflict with the other. Idle chimeras these! offspring of an empty heart or a sickly brain! With the progress of events a particular measure may become more or less important, the emphatic assertion of a certain principle more or less essential, but the question of questions remains and will remain. At one time, the establishment or maintenance of a Sound and Uniform Currency; at another, the upbuilding and cherishing of new or feeble branches of Home Industry; at another, the proper disposition of the Proceeds of the Public Lands; at a fourth, Peace or War, Spoliation or Justice; but underneath all these, mightier than any, more enduring than all, lives ever the elemental difference in which parties have their origin—on one side the idea that Government should be CREATIVE, CONSTRUCTIVE, BENEFICENT; on the other, the negative, skeptical, do-nothing element, whose axioms are 'The best Government is that which governs least,' 'The People are inclined to expect too much from Government,' &c.—which sees in a Canal, a Railroad, a Harbor, a Protective Duty, only a means of enriching a few individuals at the expense of the community, and which cannot conceive how any can be benefited by a public work without inflicting injury in at least equal measure upon others. The fundamental axioms of this negative philosophy are really hostile to Common Roads and Common Schools required and sustained by Law, as well as to those elements of National well-being against which it now directs the energies of a great party. The antagonism of sentiment growing out of these conflicting views of the nature and true ends of Government cannot, in the nature of things, be lastingly compromised; it cannot be terminated by the result of any one election. It must be potentially felt in the party contests and popular agitations of many years to come.

On this and all the great questions growing out of it, THE TRIBUNE maintains emphatically the doctrines of the Whig Party. It advocates PROTECTION TO HOME INDUSTRY, wherever such Protection may be needed, and to the extent of the necessity; a NATIONAL CURRENCY, sound and of uniform value, composed of Coin and Paper in such proportions as public interest and general convenience shall dictate; INTERNAL IMPROVEMENT, by the General and State Governments, each in its own sphere, and by Associations, liberally incited thereto by such facilities as Legislation may safely and justly afford; and such disposition of the PUBLIC LAND PROCEEDS as shall secure the benefit thereof to the People of all the States throughout all future time. Above all, this paper will 'study the things that make for PEACE,' and strenuously oppose the fell spirit of War, the lust of Conquest and the passion for Military Glory, so mortally adverse to all the ideas of Social and Political Economy to which it is devoted, as a mildew to genuine Democracy, as utterly at variance with Christianity, and as a scandal to the Nineteenth Century. These views will be faithfully and fearlessly commended to public favor; while our opposition to the Extension of Human Slavery over one foot of soil where it has not now a legal existence shall be unsparing, uncompromising and subject to no consideration of Party advantage or Presidential triumph. Far sooner will we sink with our principles than succeed without them, however desirable success or however mortifying defeat.

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