MANCHESTER SCIENCE LECTURES FOR THE PEOPLE.

EIGHTH SERIES. WINTER SESSION, 1876.

THE SUCCESSION OF LIFE ON THE EARTH.

BY PROFESSOR W. C. WILLIAMSON, F.R.S.

LECTURE I.

WHEN this course of lectures was arranged, it was thought desirable that you should have brought before you, in a brief but connected series, a general idea of what may be called the Cosmos,—the universe; and accordingly, arrangements were made, that our friend Mr. Lockyer should tell you about the Heavens, that Dr. Roscoe should discourse to you of the Earth, and that I should follow suit, in giving you a sketch of the history of Life upon the Earth. This then is the task that has been imposed upon me.

If it be true, as many of our scientific friends believe, that man has had an ancient ancestry very different from that which we are now inclined to recognise, it becomes desirable that we should have some sort of idea, who and what those ancestors were. We are told that man was once not only a monkey, but that there was a time in which he existed as some yet more obscure form of the lower animal creation, and from which form he has developed to what he is now. This is the doctrine of the Evolutionists; a doctrine in which I need scarcely say there is a large amount of truth; a doctrine that unquestionably explains much that has never been explained by any other hypothesis; but I have come to the conclusion, that though it does undoubtedly explain the origin of many of the lower as well as of the higher forms of animal life, I have never been able so to reconcile it with my knowledge of the facts as they stand, as to believe that it accounts equally well for the origin of man.

The study of the succession of animal life as it has appeared upon the earth is the study of an enormous number of isolated facts. Now isolated facts are always comparatively uninteresting. It is just in proportion as we can associate some general idea with those facts, and show that there exist points of union, links connecting them together, that they assume a new aspect, and exhibit a measure of interest they did not possess when standing alone. It is when thus viewed relatively to the doctrine of evolution, that facts concerning the origin and history of life appear to me to assume their newest and most independent interest. And it is in reference to this doctrine that I shall endeavour to expound to you the leading truths of the science. The doctrine of evolution presupposes that external influences, acting through enormously long periods of time, have altered the character, the wants, and the organisation of living things. But such changes could not be produced quickly; our own experience of what has taken place during the historic age shows us that such changes must have been slow. The crocodiles, oxen, cats, ibisses, and various other creatures that were embalmed amongst the mummies of Egypt, were animals such as still live on the earth without having undergone any change; the species are still identically what they were in the age of the Pharaohs.

In like manner, when we glance at the Assyrian sculptures, we see that the negro at the time of the Assyrian kingdom was precisely what the negro of the valley of Sennaar is still.

Here then we have proof that, in the examples in question, external influences, acting through thousands of years, have failed to make any material impression upon objects that flourish around us. If this be true, and there is no question that it is so, it follows, that we can never hope to test the doctrine of evolution by experiment. Man's life is too short to enable him to obtain the necessary results. Where then must we look for evidence? I unhesitatingly say, that it can only be derived from the rocks of which the crust of the earth is composed. It is impossible for us to assign definite periods to the ages of these rocks; we cannot say how many thousands or millions of years slipped by whilst those rocks were accumulating; but we know that those periods must have been enormous. I doubt not, that we should be much safer in counting them by millions rather than by thousands; and it is in the rocks thus slowly accumulated, that we shall obtain satisfactory evidence of what time can do in permanently modifying organic forms of life.

But unfortunately the records which the rocks give us are imperfect, and they are so for many reasons. These rocks have accumulated, generally speaking, under the sea, just as sediments are accumulating now. Most of our dry land was under the ocean at a comparatively late period. At a period geologically recent the Alps and the Apennines, the Andes and the Indian Himalayas, were all beneath the sea. A map of Europe pointing out what was land and what was water at a very recent date, gives you altogether different outlines from those you have at the present time. Such changes in the sea-level have been going on perpetually, and the areas over which sediments, brought together by oceanic currents, were accumulating, have consequently undergone similar changes. Nor have they ceased to do so even at the present hour. At every period there were large areas of land separated by oceans, —and at each one of those periods both the sea and the land had, in all probability, their respective inhabitants; but many objects must have been living on the land that never reached the ocean; and even of the few terrestrial things that were entombed in the sea, remembering at how few spots the geologist has opened the bowels of the earth, you will see that many chances exist against the probability of such rare relics being stumbled upon by the fossil-hunter.

Let me give you an illustration of what I mean. We have for some time past been dredging the ocean in all directions; expedition after expedition has gone forth, culminating in that noble and successful one of the *Challenger*. Through these agencies the deepest parts of the sea have yielded many sub-marine treasures, but has there been any one solitary instance, in the whole of these dredgings, in which a human bone has been fished up from the depths of the ocean? Not one; and yet we know that thousands of unhappy mariners are immersed for ever in that ocean each year of our existence. If then we merely trusted to what the dredge has brought up, such results would tell us nothing of the life of man upon the earth. And so it must have been in all ages It can only have been by fortunate combinations of circumstances that any particular deposit could give us a fair conception of what the life was, that existed upon the earth when that deposit was found.

If we examine the rocks composing what we call the crust of the globe, we discover a succession of layers arranged one upon another. The section on the screen may be taken to represent roughly a wide area, ranging from the central mountains of some continent to the sea, and such a section may approximately represent the structure of the outer portions of the earth's crust along a line hundreds, or even thousands, of miles in length. We here see that the lowest are the most ancient beds, and as we ascend from the lower to the upper strata, we arrive successively at those that are of more recent date. Of course if we merely dig into the earth at some few points, various parts of this series will be wanting; uplifted by volcanic and other causes, the rocks have frequently been tilted up on their edges, and since many of these uplifted portions have been swept away for thousands of vertical fathoms of thickness, by what we call denudation, it follows that many of the more modern rocks, though once existing at such spots, may have disappeared. We also find from observation that some of the more ancient rocks—as for instance those that form the mountain peaks of Snowdon and parts of Westmoreland—have not probably been entirely immersed under the sea for thousands, if not millions of years. And hence, while more recent deposits were accumulating in other parts even of the area now occupied by our own island, those particular parts may possibly never have been in such a position in relation to the sea as to enable them to receive a covering of the newer deposits. Thus you see, that, at many spots, we may fail to find the more modern strata, partly because they never accumulated at those spots, or after having accumulated they may have been swept away again by those vast denuding influences which have done so much to alter the physical structure of the surface of the globe. Nevertheless, if we begin on the south-eastern coast of England, and travel towards Snowdon, we shall cross the uplifted vertical sections or "outcrops" of most of the known rocks, beginning with the modern ones at the mouth of the Thames, passing successively the Chalk-hills of Hertfordshire, the Oolitic limestones of Northampton, the Red sandstones and Coal bearing strata of Stafford, until we finally reach the ancient slates of Snowdon and the Welsh borderland. Now you know very well that if a bricklayer begins to build a wall, he does not commence by hanging his top layer in mid air, and then building downwards; he puts his first layer of bricks on the solid ground, where he can obtain a good foundation, and then proceeds to build upwards upon this foundation.

And as a general rule we may safely affirm that this has been the case with the rocks of the section before you, as well as of this other one which shows the approximate relative thicknesses of the various layers that form the crust of the globe. At its base we have a series of strata only found in America—the Laurentian rocks, named from the river St. Laurence—near whose shores they are at least 30,000 feet in thickness. Above these is another series of American rocks, which possibly are also to be found in the Hebrides—these are the Huronian beds, probably 18,000 feet thick.

Then we come to some of our own Welsh and Westmore land mountains, where we find the Cambrian strata, which add 15,000 feet more. Yet higher we have the Silurian and other Welsh and Westmoreland rocks, 32,000 feet thick. Others, known as the Devonian beds, still higher, are from 10,000 to 14,000 feet. It is unnecessary to follow the section to its top. Enough has been said to show what an enormous mass of rock we have to account for; and yet every particle of that mass has been slowly accumulated by agencies which, depositing atom after atom, continued their action through incalculable periods. When you observe how slowly such accumulations progress at the present time—and we have no other standard whereby we can judge of their rate of progress in past ages—we are driven to the conclusion that this pile of strata represents periods which the human mind can scarcely conceive of. During these periods, forces, which we call Forces of Nature, but which are merely the instruments of the Divine Architect of the world, have been in incessant operation, and it is to some of the results of that unceasing action, in connection with once living things, that we have to look to-night.

If it be true, as the doctrine of evolution requires us to believe, that animal and vegetable life began with some obscure germs, out of which, as ages rolled on, other and more complex objects were developed, and that in this way plants and animals gradually increased in the complexity of their organisation as the world grew older, then, we should expect to find something corresponding with this order of development in the order in which plants and animals appear in the rocks. In the lecture of to-night, I hope to guide you in this direction, through what is called the Palæozoic age, the age in which many of the forms of life were very different from those now existing, but throughout much of which period certain types of organisation are found to prevail. Near the very bottom of the Laurentian series there has been found in Canada a very extraordinary object, a small magnified portion of a section of which is represented in Fig. 1. This is declared to be the oldest known fossil. There is some dispute as to whether it is a fossil, or a mere mineral

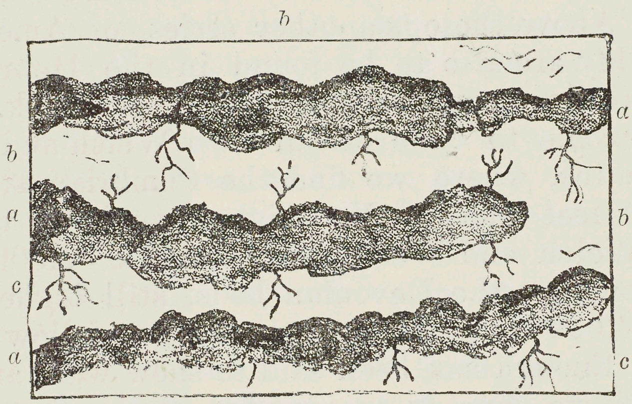

FIG. 1.—Portion of a section of Eozoon canadense. (*a*) Cavities occupied by the living animal. (*b*) Calcareous layers secreted by the animal. (*c*) Branching canals in the calcareous layers.

organisation. It is called the *Eozoon*, which means the "dawn of life." Now that this is a fossil I have no doubt whatever; if so, it is the earliest trace we have yet met with of any animal form. We know that there are certain little objects now living in the sea called Foraminifera; objects that possess microscopic shells made out of lime which they extract from the sea-water; and as the animals perish, their dead shells sink through the ocean and accumulate in its depths, where they form vast deposits of calcareous mud. The valley of the Atlantic is largely filled with these deposits. Each of these microscopic objects lives an independent life; they are very minute—the largest recent Foraminifer I have seen scarcely equalling the size of half-a-crown; and living forms of this magnitude are very rare; generally speaking they are like the dust that we see blowing about the roads on a dry summer's day. And yet, put them under the microscope, and you discover that they are really organic atoms which often display exquisite beauty. Now the probability is that the Eozoon was a creature allied to these Foraminifera, but instead of existing as a multitude of minute and separate protoplasms, as is the case with our living forms, in the Eozoon these protoplasms blended to form thin extended layers of jelly superimposed upon each other. As myriads of minute polype animals combine, at the present day, to form coral-reefs many miles in length, so the united protoplasms of the Eozoon constructed vast reefs of foraminiferous shell. Assuming these opinions to be correct, what position does this primitive creature occupy in the scale of organisation? It is as near the bottom of that scale as it well can be. The only objects with which we are acquainted that are lower, are certain microscopic, infusorial creatures, little specks of jelly-like protoplasm, that are found in both fresh and salt water, and of which it is absolutely impossible that any trace could be preserved in a fossil state. Thus far then the earliest known fossil creature presents itself in a form consistent with the idea of evolution. The rocks reveal no further indication of organic life until we ascend to the series called Cambrian, found amongst the mountains of Wales, Westmoreland, and elsewhere. This group of rocks was chiefly investigated by that noble-minded man, the late Professor Adam Sedgwick of Cambridge, whose ceaseless energy, bright intelligence, and manly character, long will cause his name to retain a foremost place in the annals of English science. At a comparatively low horizon of this Cambrian series there have been found at one or two localities, but especially at a place called Bray-Head near Dublin, the remarkable objects to which the name of Oldhamia has been given. These objects are found in such quantities that layer after layer of the rock is composed of them. That they are organic, and not mere mineralised forms, the result of crystallisation, is indisputable. We are not absolutely certain what they were, but we have every reason for supposing that they were Corallines, allied to those found so abundantly on our sea-coasts.

This second fossil naturally suggests the question, What is the position of the Corallines in the scale of nature? We have ascended to a considerable height in the series of rocks, and we should expect, according to the theory of evolution, to have made some advance in the organisation of any fossils which those rocks may contain. There is no doubt that the Corrallines come next to the Protozoa, to which group the Eozoon belonged; they occupy a higher position, but it is still low compared with what is to follow. Thus far objects continue to be arranged in their right order. When we ascend still higher in this series we come upon an extraordinary set of forms of wonderful diversity. The oldest shell that we have found is a minute creature, differing from the ordinary shells with which you are familiar. It belongs to a group well known to the conchologist and geologist as Brachiopoda, and of which the best-known are called Terebratulæ and Lingulæ. These creatures occupy a position in the scale of organisation a little lower than such shell-fish as oysters, cockles, and mussels. It is to this somewhat lower group that the Obolella—the first form of shell-fish that has been found amongst the Welsh mountains—belongs. I do not mean to say that this is the oldest shell that ever lived; I merely say that it is the oldest of which we have found any trace. A little higher up we come upon a remarkable outburst of life; we arrive at a part of the Cambrian series in which we find a number of extraordinary creatures, called Trilobites. They are "crustaceous" creatures, allied to crabs and lobsters, but occupying a lower position in the crustacean series than crabs and lobsters do. Associated with these, we find fossil sponges, somewhat similar to those you are familiar with at the present day. These well-known objects began to make their appearance upon the earth even at this early period. Associated with these sponges and curious crustaceans, we also come upon objects known as Encrinites, representatives of which are still living in our seas. These are animals very closely allied to star-fishes, but which, instead of being free and able to wander hither and thither, are planted upon a fixed stalk. The stem does not afford nourishment to the star-fish at its top, but the star-fish affords nourishment to the stem; and although it has certain root-like organs, these do nothing for the creature beyond fastening it in the sand, in which it chiefly resides. They do not draw any nourishment from that sand as the roots of a tree would do; they merely fix the creature there. The mouth, which is in the middle of a terminal series of branching arms, receives the food that those arms entangle; and it is this part of the creature—the star-fish part—that nourishes the stem and roots, and not the stem and roots that nourish the fish. These Encrinites now begin to be comparatively abundant; we shall find them still more as we ascend higher. Thus we see that we have already made a somewhat important advance in the development of animal life. Ascending still higher, we reach the Silurian group of rocks, for the investigation of which we are chiefly indebted to the labours of Sir Roderick Murchison. We were long

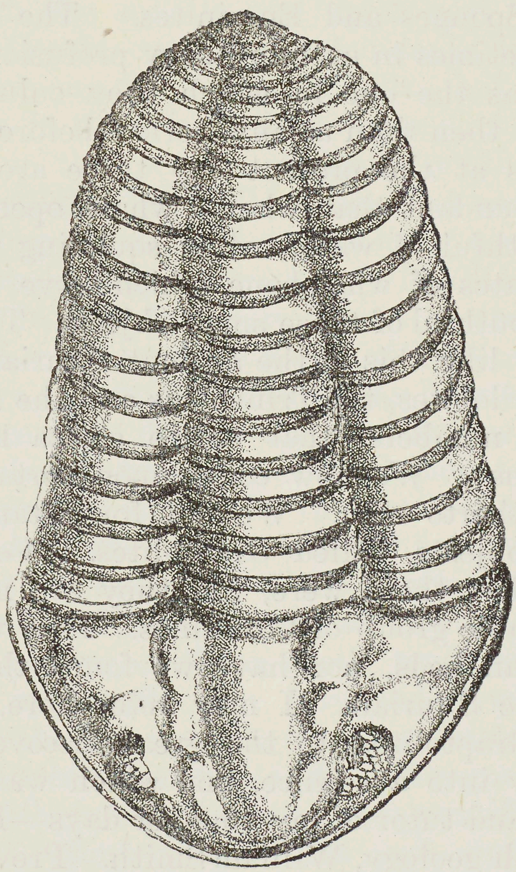

FIG. 2.—Upper surface of a Trilobite from the Silurian rocks.

familiar with the fact that, running down the border-land between England and Wales, there was a long line of fossiliferous limestones, of which little was known; they were only recognised by the vague name of Transition limestones. We merely knew that they were thought to be somewhat more modern than the older slate rocks, and somewhat older than the coal-beds of the neighbourhood of Manchester. But Murchison found that these rocks were as capable of being studied and arranged in chronological order as any other rocks with which we are acquainted, and the publication of his great book, entitled *The Silurian System*, gave us the clue wanted to the understanding of the entire series. It turned out that this Silurian series of strata, which had been so long neglected, was not only richly fossiliferous, but was quite as much so as any rocks seen in other portions of the fossiliferous series. On entering this new region we still find that most of the types met with in the Cambrian beds lived into the Silurian age, though the species were different; we still have the Sponges and Encrinites. The Trilobites still occur, and sometimes in extraordinary profusion; in fact this Silurian age was the one in which they culminated; being more abundant then than at any period before or after. In the Arctic seas at the present day there are certain small creatures so abundant that when a whale opens its jaws and takes in a mouthful of water, after squirting the water out between the plates of whalebone, which serve as teeth, it retains a huge mouthful of these small objects. There must have been something like this in the ancient Silurian seas, because two of these Trilobites, the Trinucleus and the *Asaphus Buchii*, occur in such numbers, that entire strata largely consist of their remains. We now come upon certain things that we have not hitherto seen. We find, for instance, a group of extraordinary objects, called Graptolites. For a long time we doubted what these were, but they are now understood to be a remarkable group of Corallines. They were not found in the Cambrian beds, nor have we found them at a later period than the Silurian. I may refer here, whilst speaking of these Graptolites, to the great discovery which first erected geology into a science, and which was made by the veteran friend and tutor of my younger days—I mean the late father of English geology, William Smith. Previous to Smith's day the rocks were unclassified, because we had no means of estimating accurately their relative ages. Smith however discovered that in all this pile of strata—at all events in such portions of it as he was familiar with—each stratum or group of rocks possessed organic remains that were characteristic of that group, and that were not to be found in any other. Consequently, just as when you disinter some accumulation of buried antiquities, you see by the stamp upon the coins whether they belonged to Greek, Roman, or mediæval times, so the geologist, taught by Smith, learned to recognise, not, it is true, the actual age, but the relative age of the rock which he happened to be inspecting, by means of what my old friend

Dr. Mantell termed the "medals of creation." By this he meant the peculiar fossils which that rock enclosed within its stony matrix.

In strict accordance with Smith's theory, when we find these Graptolites we have every reason to believe we are dealing with Silurian rocks. In these rocks we also come across star-fishes. Thus you see we are steadily advancing into the midst of things with which we are still familiar in a living state. When we reach the middle and upper part of this class of rocks we find Corals extremely abundant; we find remains of Corals even among the Cambrian beds; but when we reach certain deposits in the middle and upper part of the Silurian system, we have the clearest evidence of the existence of tropical seas, because Corals like those that now flourish only within thirty degrees of the equator, have been as abundant as they now are in tropical regions. The limestone beds of Dudley, in the iron district, are almost entirely made up, in some places, of vast accumulations of tropical Corals. But besides these, we also find that there has been a rapid development in molluscan life during the Silurian age; and not only so, but we find here a remarkable development of that highest type of molluscan life known by the name of cuttle-fishes. I do not mean to say that we have actually found the cuttle-fishes themselves, but we have found shells which we know must have been embedded in the soft tissues of cuttle-fishes. When I tell you that some of these shells must have been seven or eight feet in length, you may judge what must have been the size of the living cuttle-fishes to which they belonged. Now mark what this means. Recollect how comparatively low our position still is in the scale of stratified rocks, and remember that these cuttle-fishes not only occupy the highest position in the scale of molluscan life—that is, the life of shell-fish—but that in many instances they approximate so near, in some parts of their organisation, to the vertebrate section of the animal kingdom, as almost to constitute a connecting link between the one and the other. For instance, the cuttle-fish has a brain enclosed in a cartilaginous cranium, a brain-pan made of gristle. Now here we clearly have an approach to the skull of the vertebrate type of animals. Still further; the cuttle-fish has special ganglia, or masses of brain, set apart for the exclusive purpose of giving origin to the nerves of sight. This is precisely what occurs in our own bodies. The nerves of sight in the human body arise from two special nervous ganglia, the "optic ganglia"; and we find two perfectly distinct ganglia, one on each side of the brain of the cuttle-fish, from which its nerves of vision proceed. Thus we see that, in more respects than one, these cuttle-fishes and their innumerable allies, not only occupy a high position in the scale of molluscan life, but they almost form a stepping-stone across the boundary which connects the molluscs with the vertebrate animals. In the Silurian age not only were these cuttle-fishes represented by the Orthoceras, but we find other external chambered shells of the same general type corresponding to the living Nautilus.

But we must advance yet a step higher. There have been found in the uppermost parts of this Silurian series of deposits the remains of fishes which are met with here for the first time. One of these fishes, the Cephalaspis, so much resembles a large Trilobite in form that, when first found, we need not be surprised at its having been mistaken for one. Further investigation, however, showed very clearly that it was a true fish. It might readily have been supposed that the Cephalaspis was a crustacean in course of development into a fish; but the peculiar shape which suggests this idea is only one of those outward resemblances, devoid of real identities, that are apt to mislead imaginative minds. When we examine the organisation of this object, we find that it had genuine bones like other fishes, and that its hard structures were altogether distinct from the peculiar integument that constituted the protecting covering of the crustaceans.

But associated with this Cephalaspis there also existed in the later Silurian days another fish. And now comes one of the perplexing facts which geological investigation has brought to light, and which appear unfavourable to the doctrines of development and evolution. Murchison first showed that in the upper Silurian beds there existed the remains of species of shark, and other observers have verified the statement. When we inquire what position the sharks occupy in the scale of fish-organisation, we learn that they occupy its summit. They possess at the present day a brain organisation which brings them extremely near to the reptiles. There is every reason to suppose that the particular fossil found in these Silurian beds is not only a shark, but that he belonged to one of the highest types of the sharks. We have here a seriously awkward fact. Nature has apparently taken a step forwards, in advance of her time. Between these sharks and the lowest forms of fishes there exists a vast series of fishes such as we see in our markets, but which have apparently no representatives in this ancient epoch. In the first place, if you take a salmon or a cod-fish you will see that its vertical tail divides into two nearly equal lobes; and if you trace its long vertebral column or backbone, you will see that it terminates midway between the upper and the lower lobes of the tail; but no such fish is to be found in any of these more ancient rocks. Before we can find fish like the recent ones, so far as the tail is concerned, we must reach the Oolitic period. Up to this point of time all the fishes that we find are either sharks, or belong to another great group, the Ganoids, of which I shall have to say a word or two presently. Here, then, I repeat, we have a difficulty. We cannot bridge over the gap which connects these sharks with the lower forms of animal life which I have been endeavouring to describe. What future research may do to remove this stumbling-block we cannot tell—but at present it does stand as a serious hindrance to our unreserved acceptance of the evolutionary theory.

But we must now pass another of the boundary lines dividing separate groups of strata, when we shall reach the Devonian beds; these are a very remarkable series of rocks, the relations of which have only become intelligible to us of late years; but they will have a special interest for some of you, if, as is probable, I have some Scotchmen amongst my audience. It was from amongst this series of Devonian beds that one of the brightest intellects of Scotland fought his way up from wielding a stonemason's hammer to becoming editor of one of the ablest of the Scotch newspapers, and the author of some of the most eloquent descriptive books ever written by mortal pen—I mean the late Hugh Miller. Now Miller, and others who followed in his footsteps, brought to light from this Devonian series of rocks a very remarkable set of fossils. I won't dwell upon the shells and other curious objects found in these rocks, for time is short, but I will call your attention to some of the fishes with which he first made us acquainted. One of these is the Pterichthys, an extraordinary-looking fellow, with two wing-like appendages hanging by his side, and covered with an armour of large angular plates that remind us more of a tortoise than a fish. The Coccosteus is another, and if possible still more curious fish, with a tadpole-like head, resembling in shape those black and slimy froglets and newtlets that dabble at the margins of our ponds in early spring. But besides these examples we have other modifications of the Ganoid fishes, in which rhomboidal scales overlap each other like the slates of a house, and in which the vertebræ of the tail run very conspicuously into the upper lobe.

The group to which all these fishes belong is not yet quite extinct. It continues to be represented by the bony pike of North America, and a similar fish, called the Polypterus,

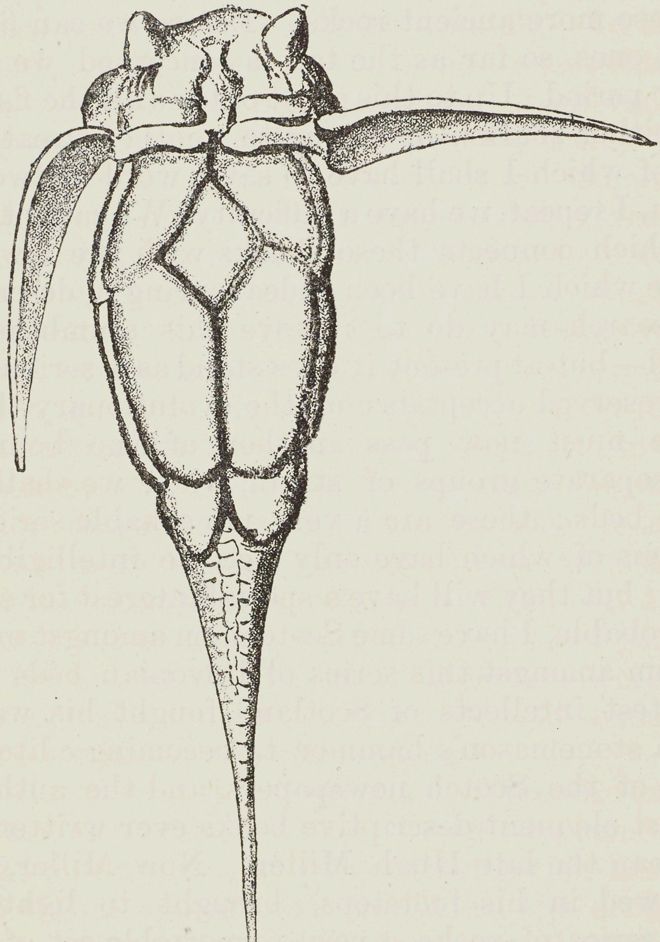

FIG. 3.—Under surface of a Pterichthys from the Devonian rocks.

is found in the Nile and in other rivers of Africa. In addition to the scales of these fishes differing from those of the cod and salmon in outward form, they are also much more bony in their internal structure. Ascending through the whole of this pile of ancient rocks, we discover no kind of fish excepting members of the shark tribe, including their relatives the skates, and these Ganoid fishes, until we reach the Chalk strata.

We still find in this Devonian bed the Cephalaspis, which continued to linger through the earlier parts of the Devonian age. But, before we leave this age I must introduce to you another acquaintance whom I have previously neglected but whose race began its career during the epoch of the upper Silurians which we have already considered. He is called the Eurypterus, and is a sort of half-developed lobster. He grew to the stature of an adult, whilst he retained some of the organisation of his earlier life. He seems as if his limbs had forgotten to grow along with his body. But when I tell you that he was often six or seven feet long, you will see that he would afford an excellent dinner to one of the lobster-loving sharks of that ancient date. He disappeared entirely at the close of the Devonian age, and there has been nothing like him since. I suppose the sharks of that period ate him up, and there was an end of him. "We shall not look upon his like again."

Thus far I have made no allusion to the vegetation existing on the earth. We find vague traces of plant-life in the Silurian and Cambrian beds, but, so far as we can ascertain, those plant-remains are merely fragments of seaweeds; we have no very definite evidence of anything higher than seaweeds existing in those older days. For a long time we were equally unaware that any higher flora lived in the Devonian age; but my friend Dr. Dawson, of Canada, has, within the last few years, revealed to us the existence of magnificent forests during this geological period. This flora corresponds very minutely in all its general features with that seen in the coal-beds surrounding Manchester.

For instance, we find in it extraordinary Calamites, huge plants allied to the horsetails of the present day. Then it contained Lepidodendra, gigantic representative of the dwarfed, living club-mosses, but instead of creeping along the ground, and barely lifting their heads twelve inches from the soil, these were magnificent trees, rising 100 feet into the air. Then we also had a rich array of ferns. We must not overlook the notable fact that in these Devonian beds this wonderful flora bursts upon us with almost the suddenness of a flash of lightning. Most of its plants are what botanists call cryptogamic; that is, plants that have no flowers, but merely develop what are termed spores, and not true seeds. But side by side with them we find a wonderful display of coniferous plants, allied to the tribe of pines and firs, and which we know to be flowering and seed-bearing plants; but they are flowering plants of a very peculiar type. Whether we may consider them as having a higher or lower organisation than oaks or elms, is a point on which opinions differ; but our best botanists incline to regard them as connecting the cryptogamic Lycopods on the one hand, with the flowering trees on the other. There exists no evidence showing that any of our ordinary forest trees grew on the earth in this Palæozoic age Up to the close of this vast period the flora was confined apparently to these cryptogamic plants and conifers. We must

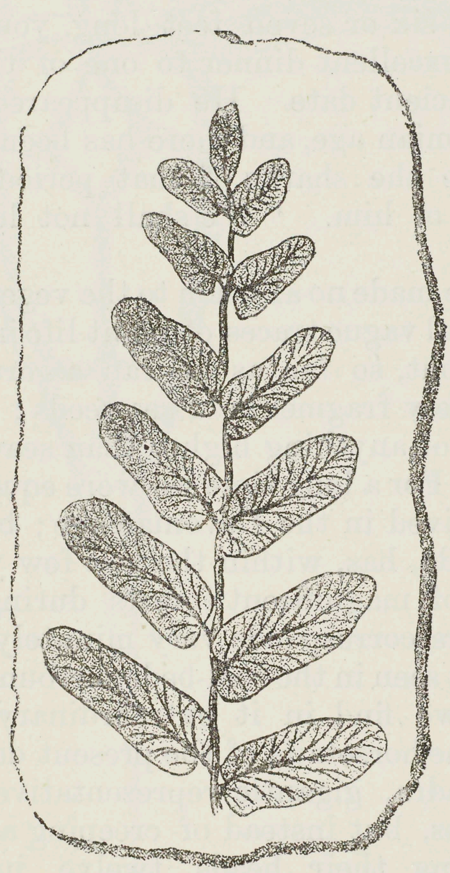

FIG. 4.—Pinnule of a Fern from the coal-measures.

not overlook the notable fact that this wonderful flora bursts suddenly upon us. We have yet found no indications of a previous and less highly-organised flora, out of which that under consideration might have been directly developed, at the same time it is possible that some such may have existed without any traces of it having been preserved in the older rocks.

We must now leave the Devonian age, and come to the

Carboniferous beds, that is, to the group of strata to which our British coal-measures belong. These, of course, are beds that interest us in every sense of the word, and were I to deal fully with them it would take an hour, even to clear the ground. I need scarcely say that the Carboniferous age has left rich blessings to mankind. Though it is not the only geological period which has supplied the world with that invaluable article of fuel which we call "coal," it is undoubtedly *the* period in which the finest and most widely diffused beds of coal were accumulated, and consequently our manufacturing interests owe more to this than to any other series of deposits. Not only is it our chief source of coal, but it is also that from which we draw our most valuable supplies of iron. So that here we get, side by side, the raw materials for the construction of our machinery, and the fuel by which that machinery is to be worked. At the time when the coal-measures began to accumulate our country exhibited very different outlines of land and sea from what it does now. If we go to the lowest of these Carboniferous strata in Western Yorkshire and Derbyshire, we there find the rocks in the shape of grey limestones—the Derbyshire limestone, with which most of you are familiar, and of which you make use in building your garden-rockeries; on visiting Derbyshire you see these limestones, rising on all sides, constituting the vertical cliffs that add such a charm to Derbyshire scenery. The fossils which they contain show that these limestones have been accumulated in a deep sea, which covered Derbyshire and the adjoining parts of Yorkshire. But when we cross over into Fifeshire and the neighbourhood of Edinburgh, we find that these thick strata of marine limestones are altogether absent. Whilst Derbyshire was deep under the ocean, there flourished in North Britain magnificent forests, analogous to those I have been describing as existing in the Devonian age. By and by, however, in our midland part of the country, the sea gradually became filled up with its accumulating organic sediments, in addition to which it is probable that the land itself slowly rose, and after passing through a transition period, in which sea seemed to struggle with land for the mastery, we arrive at what we call the Mountain coal mines. These are a series of very thin coals, which run along the hill-sides of Halifax and Oldham, and one of which, cuts horizontally through the top of Rivington Pike. Every bed of this coal represents the beginnings of an ancient forest. As yet the forests of this district evidently had not attained to any prolonged duration, as is indicated by the thinness of the coal seams; but when we rise a little higher we come to the rich coal-mines round Wigan, such as the Arley mine and others, with beds of coal from five to seven feet thick, and which have been entirely produced by the decay of the leaves, branches, and prostrated trunks of the forest-trees which accumulated on the ground where the coal-beds now exist.

We have now reached dry land and forest life. There is evidence amongst these beds that not only did plants grow, but that land-shells flourished under their shade; two land-shells having been found in coal-beds of this age in Canada. One is a true snail-shell, and the other is a Pupa—a genus of

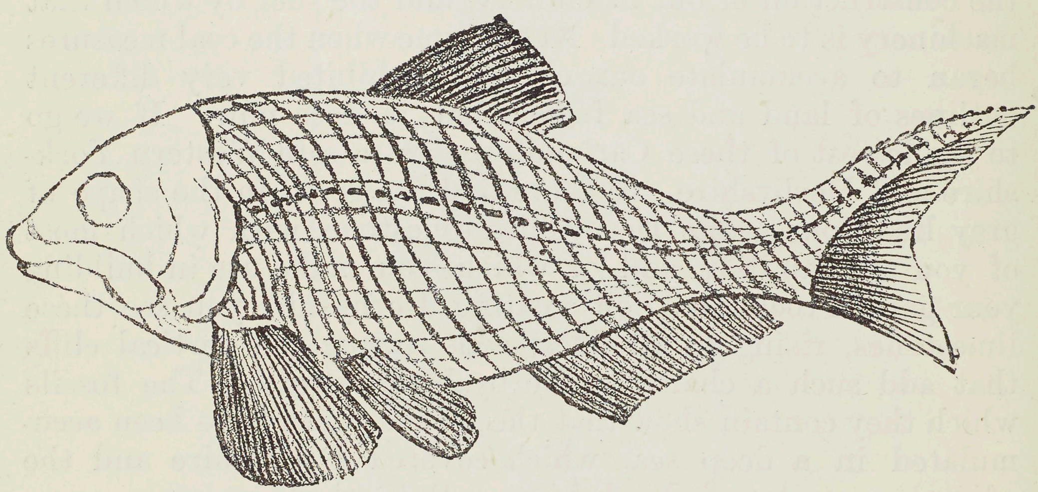

Fig. 5.—A Ganoid fish from the coal-measures with the "heterocercal" tail, *i.e.*, having the vertebral column prolonged into its upper lobe.

molluscs allied to the snails still found living in our own woods. If you were to examine the trees growing in the damper parts of Bowdon Woods I have no doubt whatever that you would find shells of the same kind adhering to their bark. We have also clear evidence that insects abounded at this period. Spiders, too, were not wanting, spiders of large size having been found in some of the ironstones of this Carboniferous age. Numerous shark-like fishes were associated with equally numerous Ganoid ones in the deeper waters, all these fishes having the "heterocercal" tail of Fig. 5, which represents a Ganoid from the coal-measures. In the marshes and estuaries there existed numerous Batrachians, or reptiles allied to the frog and newt; but some of which must have been almost as large as crocodiles. Combining all these facts, we find that so far as animal life is concerned we are steadily rising in the scale of organisation, and approaching nearer to living types; but so far as vegetable life is concerned, we are still in the same position as we occupied in the Devonian age. We find now that amongst the trees there still are gigantic horsetails, relatives of those which you see in our ditches and ponds at the present time; the latter plants are generally not more than a foot or eighteen inches high, though occasionally reaching to four or five feet: of which size I have found them in the damp parts of Derbyshire. But what size were these fossil "Calamites"? I have specimens of these ancient horsetails in my cabinet that must have been twenty or thirty feet high, and with stems nearly as thick as my waist. Then we have the plants already referred to as allied to our club-mosses. I mean the Lepidodendra and Sigillariæ, and we find that they often rose to 100 feet in height. We have in the Owens College museum a carefully-made cast of one of these huge stems, discovered at Dixon Fold, on the Manchester and Bolton Railway, and which measures twelve feet in circumference near its base. How very peculiar must have been the aspect of forests composed of such gigantic cryptogams!

There was also an undergrowth of ferns and smaller horsetails, with here and there a few Tree-ferns vainly aspiring to rival the aristocratic Lycopods that towered above their heads, and on the drier uplands the pine-forests appear to have flourished apart from their cryptogamic neighbours. There is evidence that the climate of that Carboniferous age was not that of our temperate region. We have reason to suppose that it was a warm one, but we have no proof that it was tropical in its character. Whatever it was, it was the same in Greenland, in Central Europe, and in Australia, since in all these remote localities we discover similar fossil plants in the Carboniferous beds. There must have been a peculiarity in the physiognomy of these Carboniferous forests. No flowering plants gave local colour to the landscape. There were no grassy meadows covered with daisies and buttercups, or rich moorlands glowing with the purple and gold of heather and furze. The entire aspect of the vegetable world must at that time have been something like what Mr. Wallace tells us is so characteristic of tropical forests in the present day, where we see every shade of green. The earth is ladened with the luxuriant vegetation which it supports, but you have no masses of flowers giving distinctive colouring to the landscape. You have, it is true, individual trees that are rich in their gorgeous bloom, but they are isolated and lost in the verdant expanse. Such also must have been the hue of the woodlands which flourished in the Carboniferous age.

As we ascend through the Carboniferous rocks we find that marine objects become gradually fewer in number. In the older beds a great many of the types of shells that characterise the Silurian and Devonian ages still flourish. We find Corals and Encrinites; we also discover a few small Trilobites which still linger, but which now take their departure and we see them no more; but as they disappear we have evidence that their place is being taken by the living Crustaceans that may be regarded as the nearest relatives of these Trilobites—I mean the curious Limuli, or king-crabs, now found in the tropical parts of the world. The king-crab, which exists in the seas of many tropical regions, is very like the Trilobite in its structure and general appearance; and the advocates of evolution would contend that the king-crab was evolved from the Trilobite. Be this as it may, I can only say that we have the last descendants of the expiring Trilobites preserved in the Carboniferous rocks, and, side by side with them, we have the Limuli beginning their race of life. The former are the latest of all known Trilobites, whilst the latter are the earliest of all known king-crabs; but there is not the slightest indication of any transmutation of the one into the other of these two fossils. Of course it is not impossible that there may have been embryonic links establishing a transition from the Trilobite to the Limulus, but geology gives no evidence whatever of the existence of such links. The Limuli are very definite in their shapes, and cannot by any stretch of the imagination be made to merge into the little worn-out Trilobite that was evidently coming to the end of its days.

Above these Carboniferous rocks we have a group called the Permian beds, upon which I will not dwell long. If you go to the neighbourhood of Collyhurst, near Manchester, you will probably still find traces of an old quarry, called the Vauxhall quarry. That quarry was well known thirty years ago, because it was from it that the Manchester iron-founders of that period obtained sand for constructing moulds in which to make their iron castings. Now that sandstone rests upon the coal strata, and forms the base of this Permian series of rocks. Then there were found, not far from Vauxhall, a few thin layers of limestone ; and in the neighbourhood of Bedford, near Worsley, these limestones are a little more fully developed. These limestone rocks contained peculiar fossil shells characteristic of the Magnesian limestone, which is a member of the Permian series.

On going eastward across the Lancashire hills we come to a series of beds of yellow limestone, which you will see in cuttings in the neighbourhood of Wakefield and Normanton ; these again are the same Magnesian limestones as those thinner ones found in Lancashire. When we reach Durham we find this same limestone still further developed, attaining, in that district, a thickness of something like 500 feet. It is obvious that the sea in which these limestones were deposited was a shallow one in western Lancashire, and deepened as we approach the Durham coast. This Magnesian limestone—so called because it contains a small percentage of Magnesia mixed with calcareous matter—is rich in fossil remains. Many of these remains are peculiar. They are fossils that we have not found in the Carboniferous beds below, or in the Triassic beds above ; some of these Permian beds are often exceedingly rich in the remains of Ganoid fishes ; but though the species are distinct, the types are similar to some found in the Carboniferous strata. . . . The chief importance of these beds to us now is found in the circumstance, that in the neighbourhood of Bristol the remains of reptiles of a higher order than any we have hitherto met with have been found in them. These reptiles are partly allied to the lizards, and partly to the crocodiles.

Thus we see that so far as we have accomplished our ascent from the lowest to the highest strata, race has been supplanted by race, generation has followed generation ; occasionally we have seen evidence that seemed to indicate the existence of links connecting a departing race with another that succeeded it ; suggesting the possibility of a gradual transition having taken place from lower to higher forms as years rolled by. There are also broad general indications of an upward progress, shown by the introduction, from age to age, of animals having a higher organisation than those which preceded them. But nothwithstanding this we are obliged to admit, that when viewed in minute detail, the rocks which we have examined give but a very limited support to the doctrine of evolution.

I will not dwell upon this subject now, because I shall have to give you a slight *résumé* of the matter in the concluding lecture of the series. I have thus far guided you only through the Palæozoic series of rocks; and that but hastily and imperfectly, because of the limited time at our disposal. I have only been able to give you a bird's-eye view of the country over which we have been travelling; trusting that you will again go over the ground by yourselves, and in a more detailed and leisurely manner.