
WALTER
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GASKELL
THE ORIGIN
OF VERTEBRATES

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The Origin of Vertebrates

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The discovery that the pineal body was originally an eye, or, rather, a pair of eyes, has perhaps more than anything else proved the impossibility of accepting this reversal of surfaces as an explanation of the genesis of the vertebrate from the annelid group. For whereas a pair of eyes close to the mid-dorsal line is not only likely enough, but is actually found to exist among large numbers of arthropods, both living and extinct, a pair of eyes situated close to the mid-ventral line near the mouth is not only unheard of in nature, but so improbable as to render impossible the theory which necessitates such a position.

Yet this very discovery gives the strongest possible additional support to the close identity in the plan of the central nervous system of vertebrate and appendiculate.

A truly paradoxical situation! The very discovery which may almost be said to prove the truth of the hypothesis, is the very one which has done most to discredit it, because in the minds of its authors the only possible solution of the transition from the one group to the other was by means of the reversal of surfaces.

Still, as already said, even if the theory advanced to explain the facts be discredited, the facts remain the same; and still to this day an explanation is required as to why such extraordinary resemblances should exist between the two nervous systems, unless there is a genetic connection between the two groups of animals. An explanation may still be found, and must be diligently sought for, which shall take into account the strong evidence of this relationship between the two groups, and yet not necessitate any reversal of surfaces. It is the object of this book to consider the possibility of such an explanation.

What are the lines of investigation most likely to meet with success? Is it possible to lay down any laws of evolution? It is instructive to consider the nature of the investigations which have led to the two theories just mentioned, for the fundamental starting-point is remarkably different in the two cases. The one theory is based upon the study of the vertebrate itself, and especially of its central nervous system, and its supporters and upholders have been and are essentially anatomists, whose chief study is that of vertebrate and human anatomy. The other theory is based upon the study of the invertebrate, and consists especially of an attempt to find in the invertebrate some structure resembling a notochord, such organ being considered by them as the great characteristic of the vertebrate; indeed, so much is this the case, that a large number of zoologists speak now of Chordata rather than of Vertebrata, and in order to emphasize their position follow Bateson, and speak of the Tunicata as Uro-chordata, of Amphioxus as Cephalo-chordata, of the Enteropneusta as Hemi-chordata, and even of Actinotrocha (to use Masterman's term), as Diplo-chordata.

The upholders of this theory lay no stress on the nature of the central nervous system in vertebrates, they are essentially zoologists who have made a special study of the invertebrate rather than of the vertebrate.

Of these two methods of investigating the problem, it must be conceded that the former is more likely to give reliable results. By putting the vertebrate to the question in every possible way, by studying its anatomy and physiology, both gross and minute, by inquiring into its past history, we can reasonably hope to get a clue to its origin, but by no amount of investigation can we tell with any certainty what will be its future fate; we can only guess and prophesy in an

uncertain and hesitating manner. So it must be with any theory of the origin of vertebrates, based on the study of one or other invertebrate group. Such theory must partake rather of the nature of prophecy than of deduction, and can only be placed on a firm basis when it so happens that the investigation of the vertebrate points irresistibly to its origin from the same group; in fact, "never prophesy unless you know."

The first principle, then, I would lay down is this: In order to find out the origin of vertebrates, inquire, in the first place, of the vertebrate itself.

Importance of the Central Nervous System.

Does the history of evolution pick out any particular organ or group of organs as more necessary than another for upward progress? If so, it is upon that organ or group of organs that special stress must be laid.

Since Darwin wrote the "Origin of Species," and laid down that the law of the 'survival of the fittest' is the factor upon which evolution depends, it has gradually dawned upon the scientific mind that 'the fittest' may be produced in two diametrically opposite ways: either by progress upwards to a superior form, or by degeneration to a lower type of animal. The principle of degeneration as a factor in the formation of groups of animals, which are thereby enabled to survive, is nowadays universally admitted. The most striking example is to be found in the widely distributed group of Tunicata, which live, in numbers of instances, a sedentary life upon the rocks, have the appearance of very low forms of animal life, propagate by budding, have lost all

the characteristics of higher forms, and yet are considered to be derived from an original vertebrate stock. Such degenerate forms remain degenerate, and are never known to regenerate and again to reach the higher stage of evolution from which they arose. Such forms are of considerable interest, but cannot help, except negatively, to decide what factor is especially important for upward progress.

At the head of the animal race at the present day stands man, and in mankind itself some races are recognized as higher than others. Such recognition is given essentially on account of their greater brain-power, and without doubt the great characteristic which puts man at the head is the development of his central nervous system, especially of the region of the brain. Not only is this point most manifest in distinguishing man from the lower animals, but it applies to the latter as well. By the amount of convolution of the brain, the amount of grey matter in the cerebral hemispheres, the enlargement and increasing complexity of the higher parts of the central nervous system, the anthropoid apes are differentiated from the lower forms, and the higher mammals from the lower. In the recent work of Elliot Smith, and of Edinger, most conclusive proof is given that the upward progress in the vertebrate phylum is correlated with the increase of brain-power, and the latter writer shows how steady and remarkable is the increase in substance and in complexity of the brain-region as we pass from the fishes, through the amphibians and reptiles, to the birds and mammals.

The study of the forms which lived on the earth in past ages confirms and emphasizes this conclusion, for it is most striking to see how small is the cranium among the gigantic Dinosaurs; how in the great reptilian age the denizens of the

earth were far inferior in brain-power to the lords of creation in after-times.

What applies to the vertebrate phylum applies also to the invertebrate groups. Here also an upward progress is recognized as we pass from the sponges to the arthropods—a progress which is manifested, first by the concentration of nervous material to form a central nervous system, and then by the increase in substance and complexity of that nervous system to form a higher and a higher type, until the culmination is reached in the nervous system of the scorpions and spiders. No upward progress is possible with degeneration of the central nervous system, and in all those cases where a group owes its existence to degeneration, the central nervous system takes part in the degeneration.

This law of the paramount importance of the growth of the central nervous system for all upward progress in the evolution of animals receives confirmation from the study of the development of individuals, especially in those cases where a large portion of the life of the animal is spent in a larval condition, and then, by a process of transformation, the larva changes into the adult form. Such cases are well known among Arthropoda, the familiar instance being the change from the larval caterpillar to the adult imago. Among Vertebrata, the change from the tadpole to the frog, from the larval form of the lamprey (*Ammocœtes*) to the adult form (*Petromyzon*), are well-known instances. In all such cases the larva shows signs of having attained a certain stage in evolution, and then a remarkable transformation takes place, with the result that an adult animal emerges, whose organization reaches a higher stage of evolution than that of the larva.

This transformation process is characterized by a very great destruction of the larval tissues and a subsequent formation of new adult tissues. Most extensive is the destruction in the caterpillar and in the larval lamprey. But one organ never shares in this process of histolysis, and that is the central nervous system; amidst the ruins of the larva it remains, leading and directing the process of re-formation. In the Arthropoda, the larval alimentary canal may be entirely destroyed and eaten up by phagocytes, but the central nervous system not only remains intact but increases in size, and by the concentration and cephalization of its infra-œsophageal ganglia forms in the adult a central nervous system of a higher type than that of the larva.

So, too, in the transformation of the lamprey, there is not the slightest trace of any destruction in the central nervous system, but simply a development and increase in nervous material, which results in the formation of a brain region more like that of the higher vertebrates than exists in Ammocœtes.

In these cases the development is upward—the adult form is of a higher type than that of the larva. It is, however, possible for the reverse to occur, so that the individual development leads to degeneration, not to a higher type. Instances are seen in the Tunicata, and in various parasitic arthropod forms, such as Lernæa, etc. In these cases, the transformation from the larval to the adult form leads to degradation, and in this degradation the central nervous system is always involved.

It is perhaps a truism to state that upward progress is necessarily accompanied by increased development of the central nervous system; but it is necessary to lay special

stress upon the importance of the central nervous system in all problems of evolution, because there is, in my opinion, a tendency at the present time to ignore this factor to too great an extent.

The law of progress is this—The race is not to the swift, nor to the strong, but to the wise.

This law carries with it the necessary corollary that the immediate ancestor of the vertebrate must have had a central nervous system nearly approaching that of the lowest undegenerated vertebrate. Among all the animals living on the earth at the present time, the highest invertebrate group, the Arthropoda, possesses a central nervous system most closely resembling that of the vertebrate.

The law, then, of the paramount importance of a steady development of the central nervous system for the upward progress of the animal kingdom, points directly to the arthropod as the most probable ancestor of the vertebrate.

Evolution of Tissues.

In the whole scheme of evolution we can recognize, not only an upward progress in the organization of the animal as a whole, but also a distinct advance in the structure of the tissues composing an individual, which accompanies that upward progress. Thus it is possible to speak of an evolution of the supporting tissues from the simplest form of connective tissue up to cartilage and thence to bone; of the contractile tissues, from the simplest contractile protoplasm to unstriped muscle, and thence to the highest forms of

striated muscle; of the nervous connecting strands, from undifferentiated to fine strands, then to thicker, more separated ones, resembling non-medullated fibres, and finally to well-differentiated separate fibres, each enclosed in a medullated sheath.

In the connective tissue group, bone is confined to the vertebrates, cartilage is found among invertebrates, and the closest resemblance to vertebrate embryonic or parenchymatous cartilage is found in the cartilage of Limulus. Also, as Gegenbaur has pointed out, Limulus, more than any other invertebrate, possesses a fibrous connective tissue resembling that of vertebrates.

In the muscular group, Biedermann, who has made a special study of the physiology of striated muscle, says that among invertebrates the striated muscle of the arthropod group resembles most closely that of the vertebrate.

In the nervous group the resemblance between the nerve-fibres of Limulus and Ammocœtes, both of which are devoid of any marked medullary sheath, is very apparent, and Retzius points out that the only evidence of medullation, so characteristic of the vertebrates, is found in a species of prawn (*Palæmon*). In all these cases the nearest resemblance to the vertebrate tissues is to be found in the arthropod.

The Evidence of Palæontology.

Perhaps the most important of all the clues likely to help in the solution of the origin of vertebrates is that afforded by Geology, for although the geological record is admittedly so

imperfect that we can never hope by its means alone to link together the animals at present in existence, yet it does undoubtedly point to a sequence in the evolution of animal forms, and gives valuable information as to the nature of such sequence. In different groups of animals there are times when the group can be spoken of as having attained its most flourishing period. During these geological epochs the distribution of the group was universal, the numbers were very great, the number of species was at the maximum, and some of them had attained a maximal size. Such races were at that time dominant, and the struggle for existence was essentially among members of the same group. At the present time the dominant race is man, and the struggle for existence is essentially between the members of that race, and not between them and any inferior race.

The effect of such conditions is, as Darwin has pointed out, to cause great variation in that group; in consequence of that variation and that dominance the evolution of the next higher group is brought about from some member of the dominant group. Thus the present age is the outcome of the Tertiary period, a time when giant mammals roamed the earth and left as their successors the mammals of the present day; a time of dominance of quadruped mammals; a time of which the period of maximum development is long past, and we now see how the dominance of the biped mammal, man, is accompanied by the rapid diminution and approaching extermination of the larger mammals. No question can possibly arise as to the immediate ancestor of the biped mammal; he undoubtedly arose from one of the dominant quadrupedal mammals.

Passing along to the next evidence of the rocks, we find an age of reptiles in the Mesozoic period. Here, again, the

number and variety is most striking; here, again, the size is enormous in comparison with that of the present-day members of the group. This was the dominant race at the time when the birds and mammals first appeared on the earth, and anatomists recognize in these extinct reptilian forms two types; the one bird-like, the other more mammalian in character. From some members of the former group birds are supposed to have been evolved, and mammals from members of the other group. There is no question of their origin directly from lower fish-like forms; the time of their appearance on the earth, their structure, all point irresistibly to the same conclusion as we have arrived at from the consideration of the origin of the biped from the quadruped mammal, viz. that birds and mammals arose, in consequence of the struggle for existence, from some members of the reptilian race which at that time was the dominant one on earth.

Passing down the geological record, we find that when the reptiles first appear in the Carboniferous age there is abundant evidence of the existence of numbers of amphibian forms. At this time the giant Labyrinthodonts flourished. Here among the swamps and marshes of the coal-period the prevalent vertebrate was amphibian in structure. Their variety and number were very great, and at that period they attained their greatest size. Here, again, from the geological record we draw the same conclusion as before, that the reptiles arose from the race which was then predominant on the earth—the Amphibia.

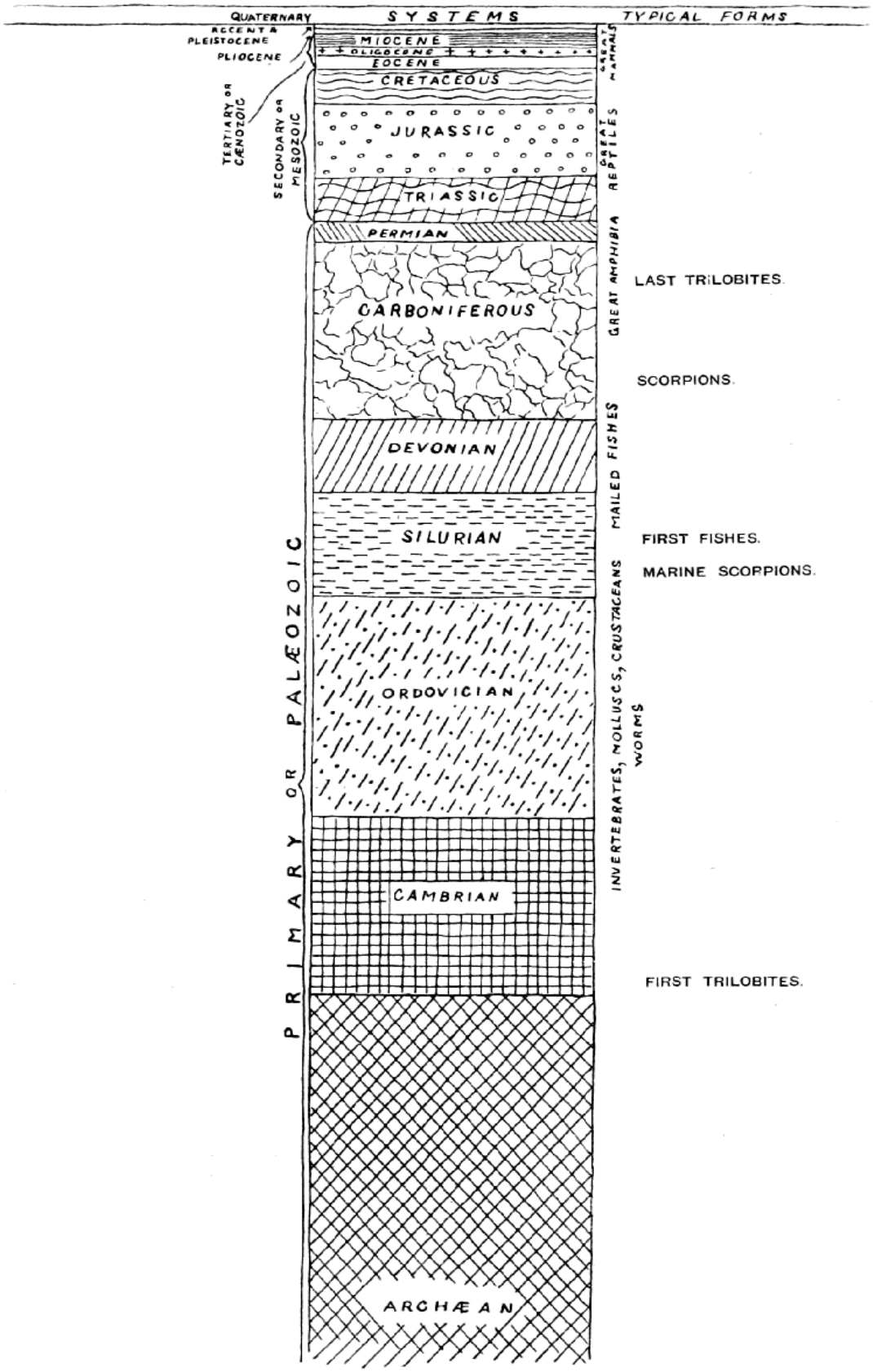

QUATERNARY
RECENT & PLEISTOCENE
PLIOCENE
TERTIARY OR CÆNOZOIC
SECONDARY OR MESOZOIC
PRIMARY OR PALÆOZOIC
SYSTEMS
TYPICAL FORMS
MIOCENE
OLIGOCENE
EOCENE
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
ARCHÆAN
GREAT MAMMALS
GREAT REPTILES
GREAT AMPHIBIA
MAILED FISHES
INVERTEBRATES, MOLLUSCS, CRUSTACEANS WORMS
LAST TRILOBITES.
SCORPIONS.
FIRST FISHES.
MARINE SCORPIONS.
FIRST TRILOBITES.

FIG. 4.—PLAN OF GEOLOGICAL STRATA. (From LANKESTER.)

Again, another point of great interest is seen here, and that is that these Labyrinthodonts, as Huxley has pointed out, possess characters which bring them more closely than the amphibians of the present day into connection with the fishes; and further, the fish-like characters they possessed are those of the Ganoids, the Marsipobranchs, the Dipnoans, and the Elasmobranchs, rather than of the Teleosteans.

Now, it is a striking fact that the ancient fishes at the time when the amphibians appeared had not reached the teleostean stage. The ganoids and elasmobranchs swarmed in the waters of the Devonian and Carboniferous times. Dipnoans and marsipobranchs were there, too, in all probability, but teleosteans do not appear until the Mesozoic period. The very kinds of fish, then, which swarmed in the seas at that time, and were the predominant race before the Carboniferous epoch, are those to which the amphibians at their first appearance show the closest affinity. Here, again, the same law appears; from the predominant race at the time, the next higher race arose, and arose by a most striking modification, which was the consequence of altering the medium in which it lived. By coming out of the water and living on the land, or, rather, being able to live partly on land and partly in the water, by the acquisition of air-breathing respiratory organs or lungs in addition to, and instead of, water-breathing organs or gills, the amphibian not only arose from the fish, but made an entirely new departure in the sequence of progressive forms.

This was a most momentous step in the history of evolution —one fraught with mighty consequences and full of most important suggestions.

From this time onwards the struggle for existence by which upward progress ensued took place on the land, not in the sea, and, as has been pointed out, led to the evolution of reptiles from amphibians, birds and quadrupedal mammals from reptiles, and man from quadrupeds. In the sea the fishes were left to multiply and struggle among themselves, their only opponents being the giant cephalopods, which themselves had been evolved from a continual succession of the Mollusca. For this reason the struggle for existence between the fishes and the higher race evolved from them did not take place until some members of that higher race took again to the water, and so competed with the fish-tribe in their own element.

Another most important conclusion to be derived from the uprising of the Amphibia is that at that time there was no race of animals living on the land which had a chance against them. No race of land-living animals had been evolved whose organization enabled them to compete with and overcome these intruders from the sea in the struggle for existence. For this reason that the whole land was their own, and no serious competition could arise from their congeners, the fish, they took possession of it, and increased mightily in size; losing more and more the habit of going into the water, becoming more and more truly terrestrial animals. Henceforth, then, in trying to find out the sequence of evolution, we must leave the land and examine the nature of the animals living in the sea; the air-breathing animals which lived on the land in the Upper Silurian and Devonian times cannot have reached a stage of organization comparable with that of the fishes, seeing how easily the amphibians became dominant.

We arrive, then, at the conclusion that the ancestors of the fishes must have lived in the sea, and applying still the

same principles that have held good up to this time, the ancestors of the fishes must have arisen from some member of the race predominant at the time when they first appeared, and also the earliest fishes must have much more closely resembled the ancestral form than those found in later times or at the present day.

What, then, is the record of the rocks at the time of the first appearance of fish-like forms? What kind of fishes were they, and what was the predominant race at the time?

We have now reached the Upper Silurian and Lower Devonian times, and most instructive and suggestive is the revelation of the rocks. Here, when the first vertebrates appeared, the sea was peopled with corals, brachiopods, early forms of cephalopods, and other invertebrates; but, above all, with the great tribe of trilobites (Fig. 6) and their successors. From the trilobites arose, as evidenced by their larval form, the king-crab group, called the Xiphosura (Fig. 5). Closely connected with them, and forming intermediate stages between trilobites and king-crabs, numerous forms have been discovered, known as Belinurus, Prestwichia, Hemiaspis, Bunodes, etc. (Fig. 5 and Fig. 12). From them also arose the most striking group of animals which existed at this period—the giant sea-scorpions, or Gigantostraca. This group was closely associated with the king-crabs, and the two groups together are classified under the title Merostomata.

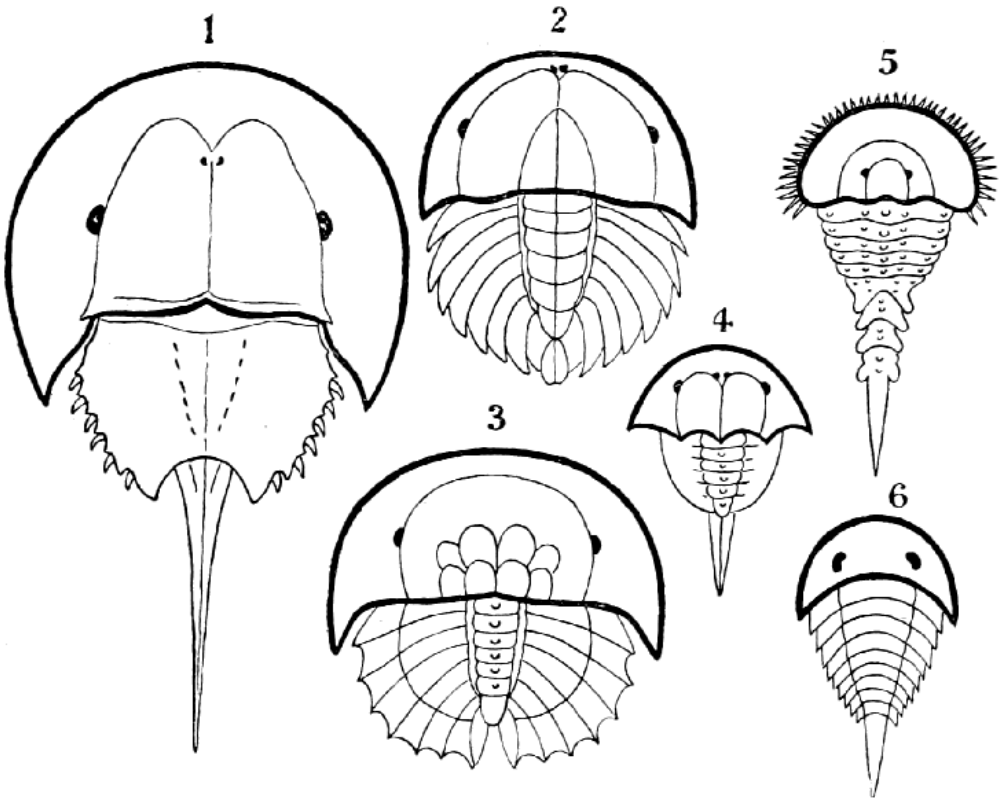


FIG. 5 (from H. WOODWARD).—1. *Limulus polyphemus* (dorsal aspect). 2. *Limulus,* young, in trilobite stage. 3. *Prestwichia rotundata.* 4. *Prestwichia Birtwelli.* 5. *Hemiaspis limuloides.* 6. *Pseudoniscus aculeatus.*

The appearance of these sea-scorpions is given in Figs. 7 and 8, representing Stylonurus, Slimonia, Pterygotus, Eurypterus. They must have been in those days the tyrants of the deep, for specimens of Pterygotus have been found over six feet in length.

At this time, then, by every criterion hitherto used, by the multitude of species, by the size of individual species, which at this period reached the maximum, by their subsequent decay and final extinction, we must conclude that these forms were in their zenith, that the predominant race at this time was to be found in this group of arthropods. Just previously, the sea swarmed with trilobites, and right into

the period when the Gigantostraca flourished, the trilobites are still found of countless forms, of great difference in size. The whole period may be spoken of as the great trilobite age, just as the Tertiary times form the mammalian age, the Mesozoic times the reptilian age, etc. From the trilobites the Gigantostraca and Xiphosura arose, as evidenced by the embryology of Limulus, and, therefore, in the term trilobite age would be included the whole of those peculiar forms which are classified by the names Trilobita, Gigantostraca, Xiphosura, etc. Of all these the only member alive at the present time is Limulus, or the King-Crab.

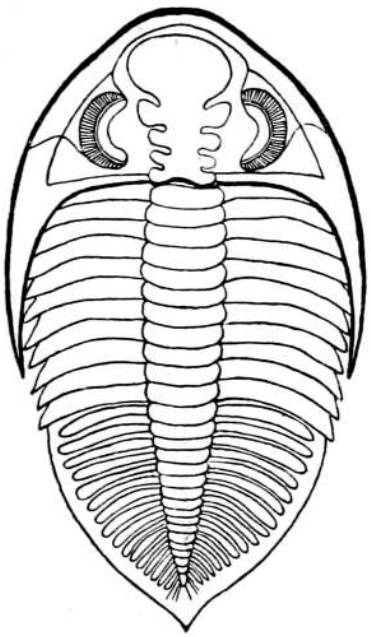


FIG. 6.—A TRILOBITE (*Dalmanites*) (after PICTET). Dorsal view.

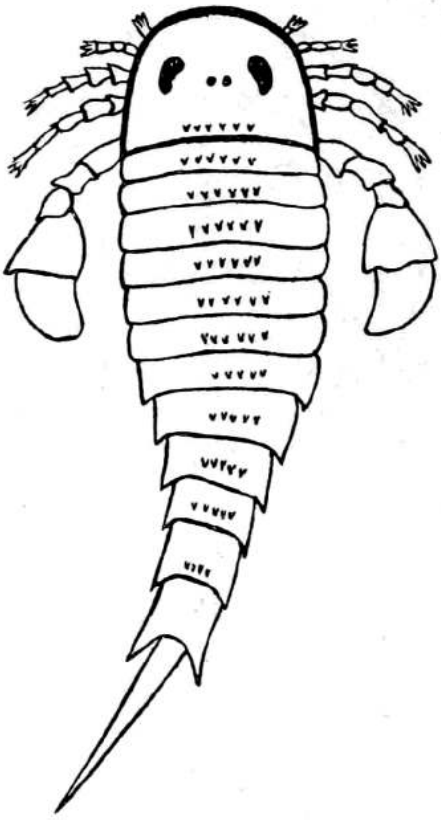


FIG. 7.—*Eurypterus remipes* (after NIESKOWSKI). Dorsal view.

As, however, the term 'trilobite' does not include the members of the king-crab or sea-scorpion groups, it is

advisable to use some other term to represent the whole group. They cannot be called crustaceans or arachnids, for in all probability they gave origin to both; the nearest approach to the Trilobite stage of development at the present time is to be found perhaps in Branchipus (Fig. 10) and Apus (Fig. 9), just as the nearest approach to the Eurypterid form is Limulus. Crustaceans such as crabs and lobsters are of much later origin, and do not occur in any quantity until the late Mesozoic period. The earliest found, a kind of prawn, occurs in the Carboniferous age.

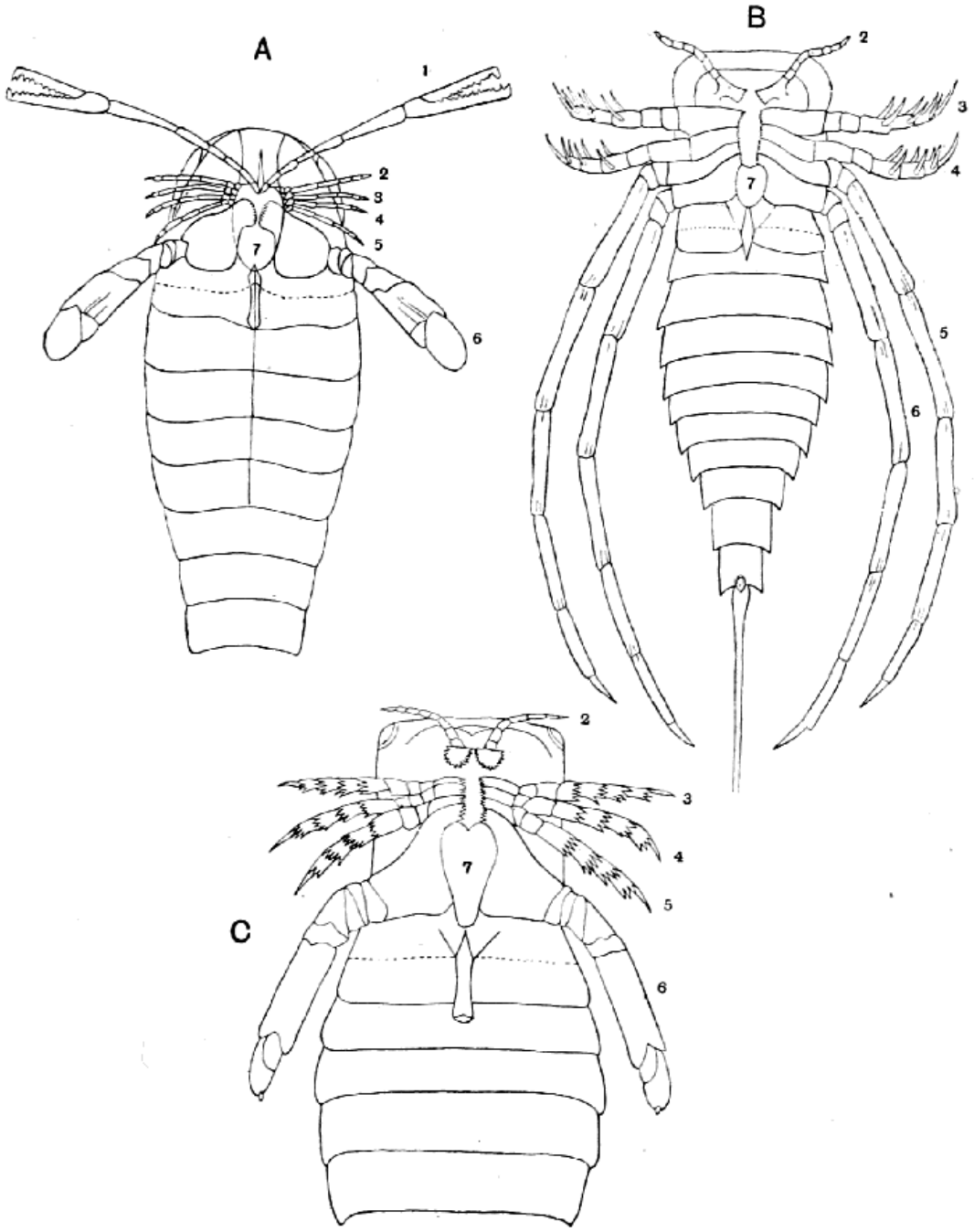


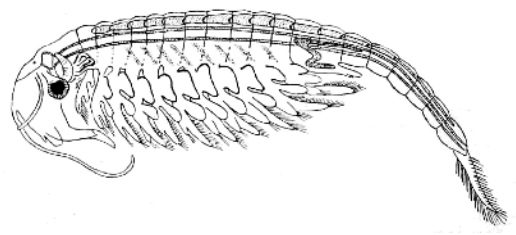
FIG. 8.—A, *Pterygotus Osiliensis* (from SCHMIDT). B, *Stylonurus Logani* (from WOODWARD). C, *Slimonia acuminata* (from WOODWARD).

Korschelt and Heider have accordingly suggested the name *Palæostraca* for this whole group, and *Protostraca* for the still earlier arthropod-like animals which gave origin to the

trilobites themselves. This name I shall adopt, and speak, therefore, of the *Palæostraca* as the dominant race at the time when vertebrates first appeared.

If, then, there is no break in the law of evolution here, the race which was predominant at the time when the vertebrate first appeared must have been that from which the first fishes arose, and these fishes must have resembled, not the crustacean proper, or the arachnid proper, but a member of the palæostracan group. Moreover, just as the Labyrinthodonts show special affinities to the fishes which were then living, so we should expect that the forms of the earliest fish would resemble the arthropodan type dominant at the time more closely than the fish of a later era.

At first sight it seems too great an absurdity even to imagine the possibility of any genetic connection between a fish and an arthropod, for to the mind's eye there arises immediately the picture of a salmon or a shark and a lobster or a spider. So different in appearance are the two groups of animals, so different their methods of locomotion, that it is apparently only an inmate of a lunatic asylum who could possibly suggest such a connection. Much more likely is it that a fish-like form should have been developed out of a smooth, wriggling, worm-like animal, and it is therefore to the annelids that the upholders of the theory of the reversal of surfaces look for the ancestor of the vertebrate.



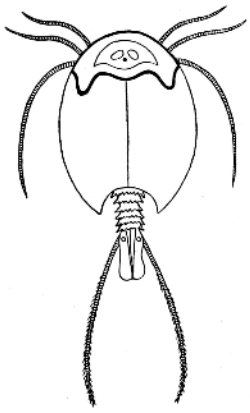


FIG. 9.—*Apus* (from the Royal Natural History). Dorsal view.

FIG. 10.—*Branchipus stagnalis.* (From CLAUS.)

We must endeavour to dismiss from our imagination such forms as the salmon and shark as representatives of the fish-tribe, and the lobster and spider of the arthropods, and try to picture the kind of animals living in the seas in the early Devonian and Upper Silurian times, and then we find, to our surprise, that instead of the contrast between fishes and arthropods being so striking as to make any comparison between the two seem an absurdity, the difficulty in the last century, and even now, is to decide in many cases whether a fossil is an arthropod or a fish.

I have shown what kind of animal the palæostracan was like. What information is there of the nature of the earliest vertebrate?

The most ancient fishes hitherto discovered have been classified by Lankester and Smith Woodward into the three orders, Heterostraci, Osteostraci, and Antiarcha. Of these the Heterostraci contain the genera Pteraspis and Cyathaspis, and are the very earliest vertebrates yet discovered, being found in the Lower Silurian. The Osteostraci are divided into the Cephalaspidæ, Trematapidæ, etc., and are found in the Upper Silurian and

Devonian beds. The Antiarcha, comprising Pterichthys and Bothriolepis, belong to the Devonian and are not found in Silurian deposits. This, then, is the order of their appearance —Pteraspis, Cephalaspis, and Pterichthys.

In none of these families is there any resemblance to an ordinary fish. In no case is there any sign of vertebræ or of jaws. They, like the lampreys, were all agnathostomatous. Strange indeed is their appearance, and it is no wonder that there should have been a difficulty in deciding whether they were fish or arthropod. Their great characteristic is their buckler-plated cephalic shield, especially conspicuous on the dorsal side of the head. Figs. 11, 14, 15, 16, give the dorsal shields of Pteraspis, Auchenaspis, Pterichthys, and Bothriolepis.

In 1904, Drevermann discovered a mass of *Pteraspis Dunensis* embedded in a single stone, showing the same kind of head-shield as *P. rostrata*, but the rostrum was longer and the spine at the extremity of the head-shield much longer and more conspicuous. The whole shape of the animal as seen in this photograph recalls the shape of a Hemiaspid rather than of a fish. It is, then, natural enough for the earlier observers to have looked upon such a fossil as related to an arthropod rather than a fish.

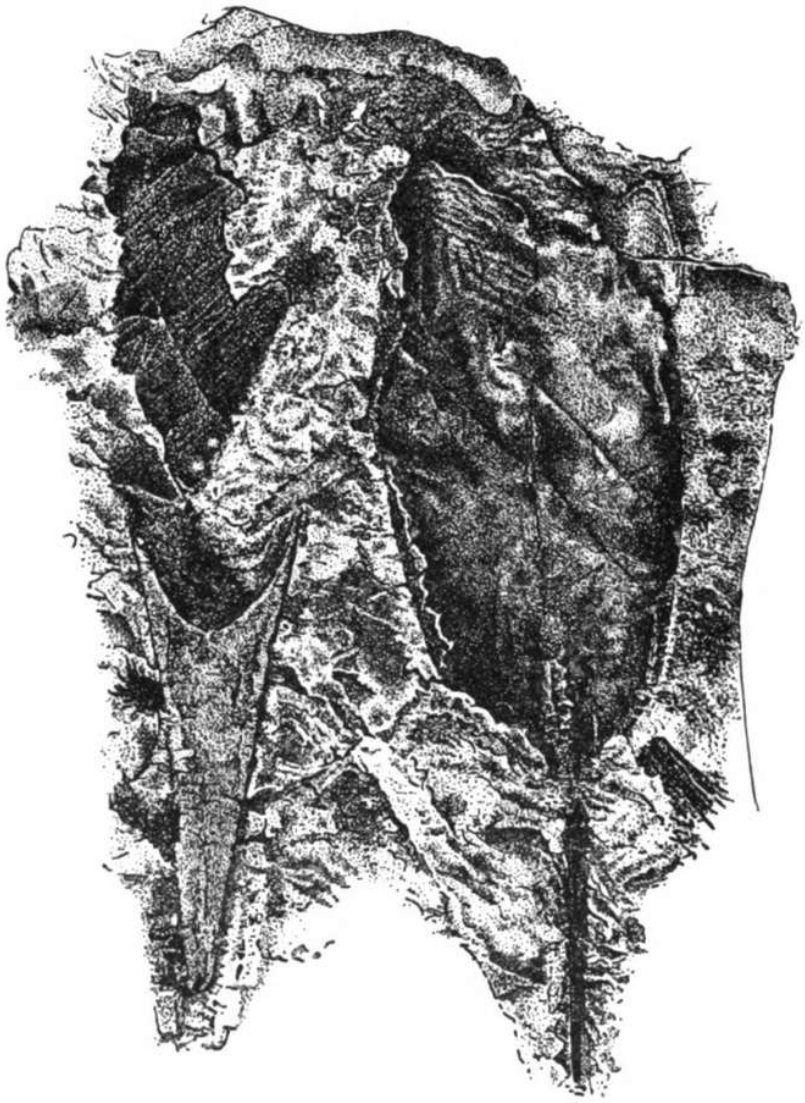


FIG. 11.—*Pteraspis dunensis* (from DREVERMANN). Dorsal view of body and spine on the right side. Head-end, showing long rostrum on the left side.

FIG. 12.—*Bunodes lunula.* (From SCHMIDT.)

FIG. 13.—*Auchenaspis (Thyestes) verrucosus*,

natural size. (From WOODWARD.)

In Figs. 12 and 13 I have placed side by side two Silurian fossils which are found in the same geological horizon. They are both life size and possess a general similarity of appearance, yet the one is a Cephalaspidian fish known by the name of *Auchenaspis* or *Thyestes verrucosa*, the other a Palæostracan called *Bunodes lunula*.

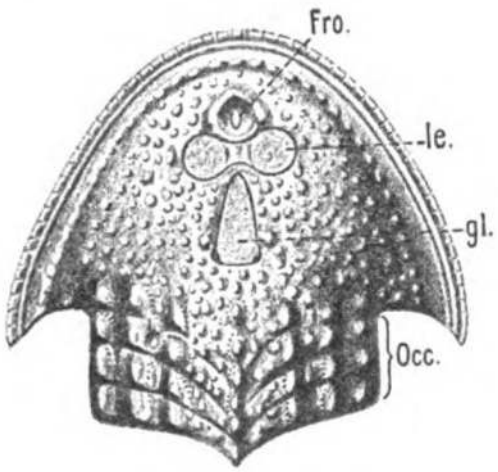


FIG. 14.—DORSAL HEAD-SHIELD OF *Thyestes (Auchenaspis) verrucosus*. (From ROHON.)

Fro., narial opening; *l.e.*, lateral eyes; *gl.*, glabellum or plate over brain; *Occ.*, occipital region.

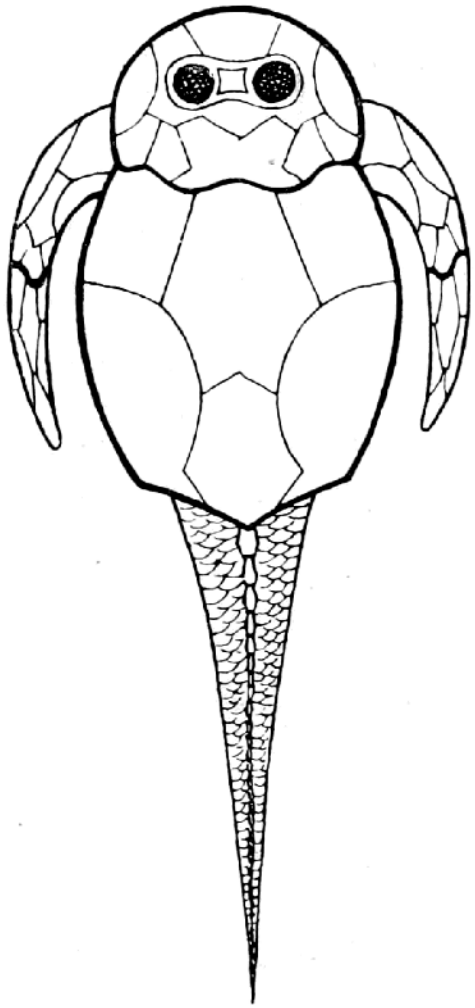


FIG. 15.—*Pterichthys.*

In a later chapter I propose to discuss the peculiarities and the nature of the head-shields of these earliest fishes, in connection with the question of the affinities of the animals which bore them. At this point of my argument I want simply to draw attention to the undoubted fact of the striking similarity in appearance between the earliest fishes and members of the Palæostraca, the dominant race of arthropods which swarmed in the sea at the time: a similarity which could never have been suspected by any amount of investigation among living forms, but is immediately revealed when the ages themselves are questioned.

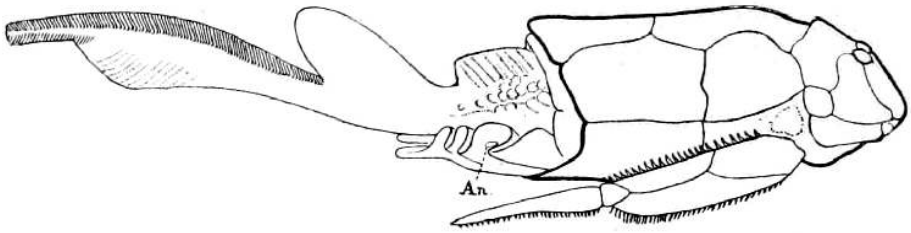


FIG. 16.—*Bothriolepis.* (After PATTEN.)

An., position of anus.

I have not reproduced any of the attempted restorations of these old forms, as usually given in the text-books, because all such restorations possess a large element of fancy, due to the personal bias of the observer. I have put in Rohon's idea of the general shape of Trematapis (Fig. 17) in order to draw attention to the lamprey-like appearance of the fish according to his researches (*cf.* Fig. 18).

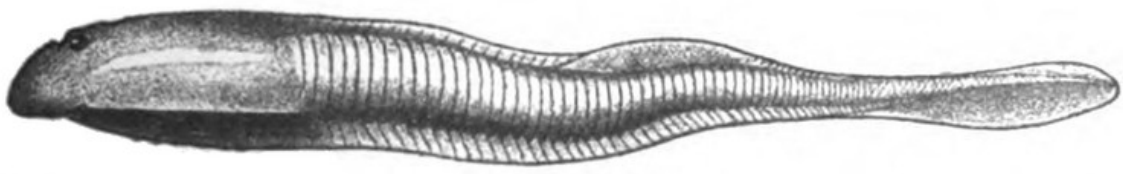


FIG. 17.—RESTORATION OF *Trematapsis*. (After ROHON, slightly modified.)

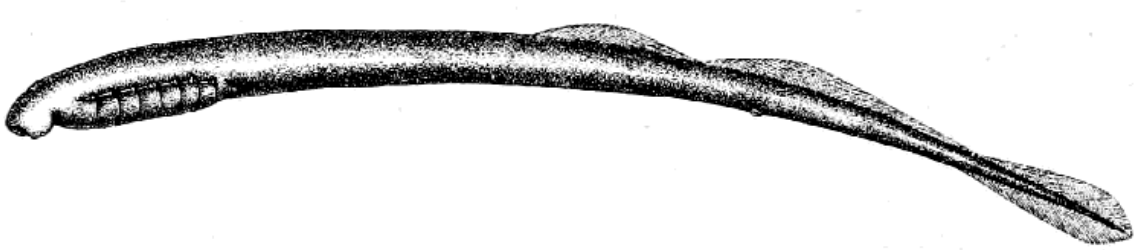


FIG. 18.—*Ammocœtes.*

The argument, then, from geology, like that from comparative anatomy and from the consideration of the importance of the central nervous system in the upward development of the animal race, not only points directly to the arthropod group as the ancestor of the vertebrate, but also to a distinct ancient type of arthropod, the Palæostracan, the only living example of which is the King-Crab or Limulus; while the nearest approach to the trilobite group among living arthropods are Branchipus and Apus. It follows, therefore, that for the following up of this clue, Limulus especially must be taken into consideration, while Branchipus and Apus are always to be kept in mind.

AMMOCŒTES RATHER THAN AMPHIOXUS IS THE BEST SUBJECT FOR INVESTIGATION.

It is not, however, Limulus that must be investigated in the first instance, but the vertebrate itself; for it can never be insisted on too often that in the vertebrate itself its past history will be found, but that Limulus cannot reveal the future of its race. What vertebrate must be chosen for investigation? Reasons have been given why our attention should be fixed upon the king-crab rather than on the lobster on the invertebrate side; what is the most likely animal on the vertebrate side?

From the evidence already given it is manifest that the earliest mammal belonged to the lowest group of mammals; that the birds on their first appearance presented reptilian characteristics, that the earliest reptiles belonged to a low type of reptile, that the amphibians at their first appearance were nearer in type to the fishes than were the later forms. As each of these groups advances in number and power, specialization takes place in it, and the latest developed members become further and further removed in type from the earliest. So also it must have been with the origin of fishes: here too, in the quest for information as to the structure and nature of the first-formed fishes, we must look to the lowest rather than to the highest living members of the group.

The lowest fish-like animal at present living is Amphioxus, and on this ground it is argued that the original vertebrate must have approached in organization to that of Amphioxus; it is upon the comparison between the structure of Amphioxus and that of Balanoglossus, that the theory of the origin of vertebrates from forms like the latter animal is based. For my own part, I think that in the first instance, at all events, Amphioxus should be put on one side, although of course its structure must always be kept in mind, for the following reasons:—

Amphioxus, like the tunicates, does not possess the characteristics of other vertebrates. In all vertebrates above these forms the great characteristic is a well-defined brain-region from which arise nerves to organs of special sense, the eyes and nose. In Amphioxus no eyes exist, for the pigmented spot at the anterior extremity of the brain-region is no eye but only a mass of pigment, and the so-called olfactory pit is a very rudimentary and inferior organ of smell. In connection with the nearly complete absence of